

**Government of  
Democratic Socialist Republic of Sri Lanka**

**Ministry of Power**

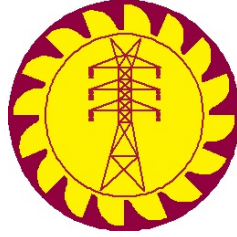
**CEYLON ELECTRICITY BOARD**

**Request for Proposals  
Development of 100 MW<sub>AC</sub> Solar PV Power Plant on Build,  
Own and Operate (BOO) Basis and Construction of 132 kV  
Transmission Facility on Turnkey Basis**

**REQUEST FOR PROPOSALS**

**(APPENDIX 5-B)**

**GENERAL TECHNICAL SPECIFICATION (GRID  
SUBSTATION)**



**CEYLON ELECTRICITY BOARD SRI LANKA**

**SIYAMBALANDUWA 100 MW SOLAR POWER  
PROJECT**

**CONSTRUCTION OF GRID SUBSTATIONS**

**GENERAL TECHNICAL SPECIFICATION**

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## CHAPTER 1 – GENERAL INFORMATION

### 1.1 EXTENT OF CONTRACT

#### (i) Definite Work

This Contract is on a turnkey basis & includes the site survey, design, manufacture, inspecting and testing, insurance, packing for export, shipment, clearing from port, delivery to site, unloading, complete erection, finishing, painting, site testing, training and commissioning of the Plant described herein.

The Contractor shall be responsible for making good for any defective material design or workmanship for a period of twelve months after taking over.

The Contractor is to co-operate with other contractors and CEB operating staff as may be necessary.

The Contractor is responsible for design, supplying and erecting all plant such that the complete function is guaranteed, without necessity for any additional works to be initiated by the Engineer, unless specifically excluded in these Bidding Documents or agreed upon in writing. That includes among others e.g.: protection and other studies, manufacture, type tests, testing at factory and at site, insurance, packing, transportation and delivery to site, erection and commissioning.

Works must fully interact with each other in every respect. Additionally, they must properly interact with any other Contractor's work as far as an interfacing is specified or mentioned herein.

In case the Contractor finds any parts of these Specifications incomplete, contradictory or defective, he shall be responsible to immediately bring this to the notice of the Employer and make a proposal for the Employer's approval, for making good such incompleteness or defect at the stage of bidding. No additional cost to the Employer shall arise out of such rectification.

If the contractor requires to obtain a third party opinion with regard to the content of this specification during the design or construction stage, the contractor shall obtain prior approval from the employer to seek the third party consultation.

Main design data given in these Specifications and general layouts of the substations are available in the Drawings.

### 1.2 ASSOCIATED PLANT DETAILS

The given particulars elsewhere in this document are those anticipated for plant being provided under other Contracts or already existing and should be used in the preparation of the Bid. They are, however, subject to confirmation and where they are considered to have an effect on the final design of equipment being provided under this Contract, the Contractor is to obtain figures from the Engineer before proceeding with designs.

### 1.3 ELECTRICAL DESIGN CRITERIA

#### 1.3.1 System Conditions

The networks are mainly of outdoor type. The basic parameters are set out below:

Nominal system voltage between phases	kV	220	132	33	11
Earthing of neutral at transformers		Solid	Solid	Solidly via earthing transformer	Resistor 4Ω, 2000A
System Earthing		Effective earthed	Effective earthed	Non Effective earthed	Non Effective earthed
System Frequency	Hz	50	50	50	50
System Highest Voltage	kV	245	145	36	12
Symmetrical short-circuit current at Rated Voltage RMS (ultimately)	kA	40	40	25	25
Impulse withstand voltage					
Main Transformer	kV	1050	650	170	75
Other equipments	kV	1050	650	170	75
Power frequency voltage (1 min)					
Main Transformer	kV	460	275	70	28
Other equipments	kV	460	275	70	28

#### Power supply for electrical operation

1.0 Control /alarm /emergency	DC Voltage	110/220 V
2.0 Supply voltage of auxiliary equipment	AC Voltage	400/230V
3.0 Supply voltage for auxiliary equipment	DC Voltage	110/220 V
4.0 Power Line Carrier	DC Voltage	48V

### 1.3.2 Minimum Substation Clearances

Air insulated outdoor and indoor busbars and connections shall have electrical clearances as listed in the following table: -

Highest system voltages between phases	kV	245	145	36	12
Minimum clearance between live metal and earth	mm	2200	1350	325	200
Minimum clearance between live metal of different phases	mm	2200	1350	325	250
Minimum safety clearance between the nearest point not at earth potential of an insulator to ground(Pedestrian Access)	mm	2300	2300	2300	2300
Minimum safety clearance between live metal and positions to which access is permissible with other conductive equipment	mm	4500	3650	2625	2590

### 1.3.3 Pollution levels of Insulators and Bushings

For Grid Substations 43.3 mm/kV (unified specific creepage distance)

(Note: If not specified in the scope, this value shall be applied)

### 1.3.4 Minimum Factors of Safety for Switchgear where Applicable

Busbar or other connections based on an elastic limit or 0.1 % proof stress	2.5
Complete insulator units based on mechanical test	2.5
Insulator metal fittings based on elastic limit	2.5
Steel structures based on elastic limit of tension members and on crippling loads of compression members	2.5
Foundations for structures against overturning or uprooting under maximum simultaneous working loads	2.5

## 1.4 ELECTRICITY SUPPLIES FOR AUXILIARY PLANT

The electricity supplies available for auxiliary plant shall be:

- (i) 400V 3 phase 50 Hz 4 wire for power.
- (ii) 230V single phase for lighting and indication.
- (iii) 110/220V DC for essential indication and circuit-breaker closing and tripping supplies.
- (iv) 110/220V DC for multi-window facia type alarm schemes.

The equipment provided under this Contract is to be capable of operating reliably within the following voltage ranges:

- (a) DC Equipment  
From 80% nominal voltage up to 120% nominal voltage.

(N.B. Circuit breakers are required to carry out tripping operation at 70% of nominal voltage).

(b) AC Equipment

Voltage	Single phase 230 V r.m.s.	a.c.+10%,-20%
	or	
	3-phase 400V r.m.s	a.c.+10%,-20%
Frequency	Nominal	50 Hz
	Maximum	51 Hz
	Minimum	48.5 Hz

### 1.5 MINIMUM REQUIREMENTS FOR MANUFACTURES OF MAIN EQUIPMENT (EXCLUDING POWER TRANSFORMERS)

The bidder shall ensure, that each main equipment (listed below) offered under this contract, is manufactured by a manufacturer with a minimum of fifteen (15) years successful experience in manufacturing comparable equipment, in rated voltage and capacity, to the equipment offered under the contract. In addition, minimum of ten years experience shall be in manufacturing for order from outside the country of the manufacturer.

In respect of each main equipment offered under this contract, the bidder shall ensure that equipment identical in design had been in service for a minimum period of five years. In addition minimum of three years of service shall be outside the country of the manufacturer.

If the offered equipment is manufactured under license, the manufacturing/service experience of equipment manufactured by the parent company would be counted only if clear documentary evidence is given to prove that the equipment is identical in the design to the original equipment manufactured by the parent company.

Bidder shall provide adequate evidence of compliance to above requirements to the satisfaction of the CAPC. Bids non-complying with above requirements or with incomplete evidence of compliance would be rejected.

Main equipment List: -

- Indoor switchgear
- Auxiliary transformers
- Power Cables, Terminations and Joints
- Circuit Breakers
- Capacitors banks
- Current transformers
- Voltage transformers
- Disconnecting Switchers
- Surge arrestors
- Earth Switches

Energy Meters  
Protection, Control  
Control cables  
Battery banks & chargers  
SCADA and Fibre Optic equipment

## 1.6 MINIMUM REQUIREMENTS FOR MANUFACTURES OF POWER TRANSFORMERS

### 1.6.1 Transformer - 31.5 MVA, 132/33 kV

- i. Manufacturer shall possess design, manufacturing and supply record of power transformers having more than 10 MVA rating, as per international industry standards IEC or IEEE, over last **twenty five (25) years** and supplying them to export market outside the country of manufacture essentially during last **ten (10) years or more**. Documentary evidence (reference list) shall be provided.
- ii. Manufacture shall possess experience in design and manufacturing three phase transformers for transmission applications of;
  - a. Voltage of the highest rated winding of at least 132 kV voltage higher,
  - b. Frequency 50/60 Hz,
  - c. Rated capacity of 31.5 MVA or higher,
  - d. With on load tap changer.

Documentary evidence shall be provided for a transformer similar to above that has been in continuous operation for **five (5) years or more outside the country of manufacture**. For this purpose at least two (2) certificates issued by two different overseas end users (power utilities) or relevant purchase order number and contact details of the person from the end user's company who might be contacted to inquire about the successful operation shall be submitted.

- iii. If manufacturing facility having the above experience belongs to a global manufacturer, license agreement with the parent manufacturer shall be furnished. If such license is shared with many factories of the same group and the licensee gets all the R & D results, instructions and IT tools by a structured implementation system, evidence shall be submitted to prove the availability of such facilities.
- iv. Manufacturer shall guarantee that they have the last 5 -10 years content of the failure investigation and R & D Reports to be inspected by the Employers personnel if required during a factory visit before awarding the contract. List of R & D reports published during the last two years together with a copy of the latest publication to IEEE, CIGRE, etc., by R & D section of the factory shall be submitted for reference.
- v. Brief description of the software tool used for the design work shall be submitted. List of sub suppliers of the material and quality control plan and standards for the material purchase and testing shall be supplied.

- vi. List of test equipment at the factory for Routine, Dielectric and special tests as per IEC60076 shall be submitted. If short circuit tests facility is available within the factory, description of such facility shall be submitted. Otherwise the name and address of the nearest short circuit test facility shall be given.

Bidder shall provide adequate evidence of compliance to above requirements to the satisfaction of the Procurement Committee. It is a mandatory requirement to submit completed schedule below with the bid.

Bids non-complying with above requirements or with incomplete evidence of compliance would be rejected.

Main equipment List: -

- 02 Nos. of outdoor Three phase 23/31.5 (ONAN/ONAF) MVA 132/33 kV YNd1 transformer with On Load Tap changers at 132 kV winding.

<b>Manufacturing of Power transformers</b>					
<b>Item</b>	<b>Information</b>				
Manufacturer	<i>[Insert manufacturer's name and address]</i>				
Country of manufacture	<i>[Insert name of country]</i>				
Brief specification, type of Manufacturer's auto transformer	<i>[Insert very brief specification, type of power-transformer]</i>				
Year of commencement of manufacturing of transformer	<i>[Insert the year of commencement of manufacturing of transformer]</i>				
Type & special test certificates	<i>[Insert manufacturer's design standard, type test certificate no. to be applicable]</i>				
Quantity (unit) of same size of transformer manufactured in last 5 years	2021	2020	2019	2018	2017
Document to certify Twenty five (25) years manufacturing and supply experiences	<i>[Yes/ No]</i> <i>[Attached the document of certification]</i>				
Document to certify Ten (10) years export record outside the country of manufacture	<i>[Yes/ No]</i> <i>[Attached the document of certification]</i>				
Document to certify five (5) years or more continuous operation record outside the country of manufacture	<i>[Yes/ No]</i> <i>[Attached the document of certification]</i>				
Manufacturer's quality assurance certificate	<i>[Insert details of QA certificate]</i>				



Whether manufacturer’s Letter of Authorization has been attached by the bidder to offer their auto transformer for this tender	<p>[Yes/No] [Attached the Letter of authorization]</p>
<p>Documents required as mentioned below are attached?</p> <p>(a). Catalogues, brochures and supply records verifying their quality, performance, life expectancy &amp; reliability.</p> <p>(b) Customer reference list.</p> <p>(c) Customers’ appraisal letters, if any.</p> <p>(d) ISO 9001 Certificate.</p> <p>(e) Total manufactured MVA for last three years with annual breakdown</p>	<p>[Yes/No] [Attached all relevant documents]</p>
Additional information/documents required in clause 1.6 of General Information are submitted?	<p>[Yes/No] [Attached all relevant documents]</p>

**1.6.2 Transformer - 63 MVA, 132/33 kV**

- i. Manufacturer shall possess design, manufacturing and supply record of power transformers having more than 10 MVA rating, as per international industry standards IEC or IEEE, over last **twenty five (25) years** and supplying them to export market outside the country of manufacture essentially during last **ten (10) years or more**. Documentary evidence (reference list) shall be provided.
- ii. Manufacture shall possess experience in design and manufacturing three phase transformers for transmission applications of;
  - a. Voltage of the highest rated winding of at least 132 kV voltage higher,
  - b. Frequency 50/60 Hz,
  - c. Rated capacity of 63 MVA or higher,
  - d. With on load tap changer.

Documentary evidence shall be provided for a transformer similar to above that has been in continuous operation for **five (5) years or more outside the country of manufacture**. For this purpose at least two (2) certificates issued by two different overseas end users (power utilities) or relevant purchase order number and contact details of the person from the end user’s company who might be contacted to inquire about the successful operation shall be submitted.

- iii. If manufacturing facility having the above experience belongs to a global manufacturer, license agreement with the parent manufacturer shall be furnished. If such license is shared with many factories of the same group and the licensee gets all the R & D results, instructions and IT

tools by a structured implementation system, evidence shall be submitted to prove the availability of such facilities.

- iv. Manufacturer shall guarantee that they have the last 5 -10 years content of the failure investigation and R & D Reports to be inspected by the Employers personnel if required during a factory visit before awarding the contract. List of R & D reports published during the last two years together with a copy of the latest publication to IEEE, CIGRE, etc., by R & D section of the factory shall be submitted for reference.
- v. Brief description of the software tool used for the design work shall be submitted. List of sub suppliers of the material and quality control plan and standards for the material purchase and testing shall be supplied.
- vi. List of test equipment at the factory for Routine, Dielectric and special tests as per IEC60076 shall be submitted. If short circuit tests facility is available within the factory, description of such facility shall be submitted. Otherwise the name and address of the nearest short circuit test facility shall be given.

Bidder shall provide adequate evidence of compliance to above requirements to the satisfaction of the Procurement Committee. It is a mandatory requirement to submit completed schedule below with the bid.

Bids non-complying with above requirements or with incomplete evidence of compliance would be rejected.

Main equipment List: -

- 02 Nos. of outdoor Three phase 46/63 (ONAN/ONAF) MVA 132/33 kV YNd1 transformer with On Load Tap changers at 132 kV winding.

<b>Manufacturing of Power transformers</b>					
<b>Item</b>	<b>Information</b>				
Manufacturer	<i>[Insert manufacturer's name and address]</i>				
Country of manufacture	<i>[Insert name of country]</i>				
Brief specification, type of Manufacturer's auto transformer	<i>[Insert very brief specification, type of power-transformer]</i>				
Year of commencement of manufacturing of transformer	<i>[Insert the year of commencement of manufacturing of transformer]</i>				
Type & special test certificates	<i>[Insert manufacturer's design standard, type test certificate no. to be applicable]</i>				
Quantity (unit) of same size of transformer manufactured in last 5 years	2021	2020	2019	2018	2017

Document to certify Twenty five (25) years manufacturing and supply experiences	[Yes/No] [Attached the document of certification]
Document to certify Ten (10) years export record outside the country of manufacture	[Yes/No] [Attached the document of certification]
Document to certify five (5) years or more continuous operation record outside the country of manufacture	[Yes/No] [Attached the document of certification]
Manufacturer’s quality assurance certificate	[Insert details of QA certificate]
Whether manufacturer’s Letter of Authorization has been attached by the bidder to offer their auto transformer for this tender	[Yes/No] [Attached the Letter of authorization]
Documents required as mentioned below are attached?  (a). Catalogues, brochures and supply records verifying their quality, performance, life expectancy & reliability. (b) Customer reference list. (c) Customers’ appraisal letters, if any. (d) ISO 9001 Certificate. (e) Total manufactured MVA for last three years with annual breakdown	[Yes/No] [Attached all relevant documents]
Additional information/documents required in clause 1.6 of General Information are submitted?	[Yes/No] [Attached all relevant documents]

**1.7 PROGRAM OF WORK**

Due to system requirements, existing transmission circuits and transformers cannot be released at the same time. Therefore, initially only one of the circuits or transformers would be released to the contractor for connecting to the system.

Taking into account the above fact, within one month of award of the contract, the Contractor is to forward to the Engineer four copies of the Chart detailing the Plant manufacture and delivery, civil work, transmission circuit outages, erection & commissioning program for the complete contract work for his approval.

**1.8 PROTECTION OF THE ENVIRONMENT**

**1.8.1 TRANSPOTATION**

Transport of heavy equipment and construction materials shall be minimised from 0700 hrs to 1800 hrs.

No transformer oil which contains PCB shall be used or discharged into surface water or to the ground

### **1.8.2 THE ENVIRONMENT AND ADHERENCE TO THE ENVIRONMENTAL ACTS, REGULATIONS AND / OR GUIDELINES**

The selected contractor is responsible for the full compliance with the following acts, regulations and/or guidelines with respect to the execution of this project.

National Environmental Act No. 47 of 1980 including all the amendments.

The bidders also shall take into consideration the relevant costs that will be incurred, for the strict adherence to the environmental safeguard measures stipulated in the environmental approvals and the relevant documents forming part of such approvals obtained under the above acts/regulations/guidelines with respect to this project.

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## CHAPTER 2 - SWITCHGEAR

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## CHAPTER 2 – SWITCHGEAR

### 2.1 OUTDOOR SWITCHGEAR

#### 2.1.1 SWITCHGEAR DESIGN AND PERFORMANCE

The contractor shall design the layout of the switchyards in such manner that good access to all equipment and installations is ensured, that all overhead transmission lines can be connected easily and the indicated future extensions will be possible. Drawings in these specifications are tentative only, and do not relieve the contractors from the responsibility of design by himself.

The switchgear shall be suitable for the specified location and capable of continuous operation under the climatic conditions existing at site and complete in every respect with all necessary ancillary plant installations whether specified in detail or not.

The Bidder shall present layout drawings showing the equipment he wants to use with the relevant dimensions. These drawings shall include all distances, clearances, service roads, etc. as necessary and as may be required by applicable standards.

The contractor shall take effective measure to manufacture and supply all equipment and services as required in this specification and agreed in the contract.

The clearances between all live and earthed parts and the working clearances shall be equal at least to Chapter 1 of this Specification in order to allow work and maintenance on one section of any equipment whilst the remaining sections of the equipment remains live.

All changes of equipment or services that do not comply with the specification shall be indicated in the schedule for deviations and shall be put in writing by Bidder during the bidding phase. The Engineer reserves the right to request variations in the layout and dimensions to suit site conditions.

All electrical equipment, such as circuit breakers, isolators, measuring transformers, lightning arrestors, supports etc., shall be mounted on solid hot-dip galvanised support structures. Hot-dip galvanising shall be performed as per Technical Specification - Grid Substation if not required differently.

The rigidity of the structures shall be such that the alignment of the equipment, which they carry, shall not be disturbed by the loads to which the structures are subjected. This applies to all operation conditions including short circuits, all climatic and other influences. Reference is made to 'Steel Structures' of Chapter 13 of Technical Specification – Grid Substation.

Equipment supplied shall be newly manufactured using latest applicable technology. There shall be no defect or mistake in design, material and workmanship. Technical documents and drawings shall be clear, consistent, correct in content and meet the requirements for installation, commissioning, operation and maintenance.

If any defect or damage is found during installation, commissioning or during defect liability period in any supplied equipment the contractor shall take the approval of the Engineer and replace the complete equipment/part at his own expense as soon as possible. Other than minor damages at site or in transport no other repairs shall be carried out at site.

The switchgear, busbar and electrical connections shall be made of approved materials and they shall be such construction that partial discharge is avoided, and



suitable measures shall be taken to avoid corona discharge, especially at edges and corners.

### 2.1.2 RATINGS

Every current-carrying part of the switchgear including current transformers, busbars, connections, contact and joints shall be capable of carrying its specified rated current at rated frequency continuously, and in no part shall its temperature rise exceed that specified in relevant standards.

Every part of the switchgear shall also withstand, without mechanical or thermal damage, the instantaneous peak currents and rated short time current pertaining to the rated breaking capacity of the circuit breaker.

The equipment shall withstand all arising voltages. This is applicable for operational and lightning voltages. The rated insulation level of all the equipment shall not be lower than the values indicated in the schedules of the Technical Specification and/or required by latest applicable IEC recommendations.

Equipment shall be designed so as to minimise corona or other electrical discharge and radio interference (RIV). The Contractor in the presence of Engineer in accordance with IEC 60437 shall carry out tests for corona and radio interference.

### 2.1.3 MEDIUM VOLTAGE 12 kV and 36 kV OUTDOOR

#### 2.1.3.1 Circuit Breakers

##### Type

Circuit breakers shall be of SF<sub>6</sub> or Vacuum types and shall be according to IEC 62271-100 with individual self-contained spring operated mechanisms. Pneumatic operating mechanisms and hydraulic operating mechanisms shall not be accepted.

Offered equipment will only be accepted if equipment identical in design has a minimum field experience as specified in Chapter 1.5.

##### (a) Sulphur Hexafluoride Circuit Breakers

Circuit breakers of the SF<sub>6</sub> type shall incorporate precautions to minimise the presence of moisture and SF<sub>6</sub> decomposition products. Static and moving gas seals shall be designed to prevent the leakage of gas or ingress of moisture throughout the service of the interrupting module.

The enclosure of the module shall be strong enough to withstand the internal pressures generated when switching and shall incorporate an over-pressure relief device proved to be capable of allowing the safe discharge of any excess pressure that may arise in service how ever caused.

Interrupters incorporating separate main and arcing contacts are not acceptable. Circuit breakers with single break per phase shall be provided.

Gas pressure monitoring devices shall be incorporated to provide an alarm first and further reduction in pressure shall cause to trip and lock-out the circuit breaker. If the manufacturer does not recommend to trip the breaker at the second stage, SF<sub>6</sub> pressure low lock-out shall initiate a breaker failure protection or similar tripping arrangement.

Adequate external clearances and surface creepage distances shall be provided to ensure satisfactory performance under service conditions.

Means for measurement of contact erosion without major dismantling shall be incorporated and an appropriate gauge shall be provided.

### **(b) Vacuum Circuit Breakers**

Circuit breakers of the vacuum type shall incorporate contacts designed to ensure a long contact life at all currents up to the rated making and breaking current switching conditions. Contact materials having low current chopping levels are preferred to minimise the occurrence of excessive over voltages when switching.

If additional devices are required to limit over voltages caused during switching to a safe level, these shall be supplied and the details given in the schedule of particulars.

Contact material properties shall be such that the specified dielectric strength across open contacts is obtained at all times.

Transmission of high mechanical stresses to the vacuum enclosure during operation shall be reduced to the minimum possible by the use of resilient mountings. Features to prevent the application of abnormal stresses to the flexible seals shall be incorporated.

Adequate external clearances and surface creepage distances shall be provided to ensure satisfactory performance under service conditions.

The details of any vacuum monitoring facilities shall be stated in the Schedule of Particulars.

### **Rate of rise of restriking voltage**

Where specifically stated in the test certificates submitted with the Bid, the bidder shall certify that the Transient Recovery Voltage (TRV) to which the circuit-breaker was subjected during the short-circuit tests was the most severe condition that could be imposed by the available test plant for a first phase-to-clear factor of 1.5.

Any device incorporated in a circuit breaker to limit or control the rate of rise of restriking voltage across the circuit-breaker contacts shall be to the Engineer's approval and full descriptions of any such device shall be given.

### **Reclosure duty**

Circuit-breakers may be subjected to several single shot auto-reclosing duty cycles within quick succession upon the occurrence of multiple faults coupled with short reclaim timer settings. Bidders shall state the minimum time interval permissible between each auto-reclose duty at rated short-circuit current and advise the number of reclosing operations allowable before lockout becomes necessary.

The contractor shall ensure the circuit-breaker requirements are embodied in the auto-reclose protection scheme as described in Chapter 5. The Circuit breaker shall have following operation duty cycle.

O - 0.3 sec-CO-3min-CO.

### **Interrupting duties**

In addition to the requirements of IEC 62271-100 for interrupting terminal faults, circuit-breakers shall be capable for coping with the interrupting duties produced by the switching of low inductive currents associated with reactors or transformer magnetising currents, or by the switching of capacitor currents associated with overhead line-charging, cable-charging or capacitor banks as may be applicable. It is preferred that circuit breakers for these duties shall be of the restrike-free type only.

Circuit breakers shall be capable of interrupting currents associated with short-line faults and the out-of-phase switching conditions that may occur in service.

Bidders should include a statement of the accumulative breaking capacity, which the circuit breakers are capable of, before maintenance is required.

Test certificates demonstrating the ability of the circuit breakers for these duties shall be submitted with the bid.

### **General Arrangement**

Circuit breakers shall be suitable for mounting directly on concrete foundations and shall include any necessary supporting steel works, which shall be galvanized.

All members of steel parts shall be hot dip galvanized as specified in Technical Specification – Grid Substation.

Anchor bolts with lockouts shall be provided. The arrangement of the switchgear at Site shall be such that adequate access for normal routine maintenance and the replacement of either a complete set or a part shall be available.

Where the distance from ground level to the bottom of the supporting insulators is less than the value specified in Chapter 1, screened enclosures shall be provided to the approval of the Engineer.

Evidence shall be provided that enclosure subject to pressures in excess of normal atmospheric pressure during service operation have withstood approved pressure tests without leakage, permanent distortion or any temporary distortion such as might cause mal-operation of the circuit-breaker.

Means shall be provided to allow easy access for the inspection and maintenance of fixed and moving contacts and other enclosed components.

### **Contacts, arcing chambers and insulation**

Designs shall permit removal of complete interrupting chambers of circuit breakers.

Static and moving seals shall be designed to prevent any leakage of gas, ingress of moisture while in service and without deterioration.

Pressure sensitive devices to prevent switching at SF<sub>6</sub> gas operating pressures outside the declared limits of operation shall be included.

Where single rods or tubes are utilised for operating the moving contacts of circuit breakers, they shall be securely pinned at each end to prevent rotation or displacement of the contacts. Tubes shall be plugged in an approved manner where contacts or other parts are fixed to the tubes.

Circuit breakers shall not comprise materials liable to deterioration or create undesirable chemical action when in contact with SF<sub>6</sub> and its by-products under service conditions. Precautions to minimise the presence of moisture and other by-products of arcing in SF<sub>6</sub> design shall be incorporated.

Noise made by the circuit breaker when operating under all specified conditions shall not be such as to cause a nuisance to residents beyond a radius of 100m.

### **Operating mechanisms**

Circuit-breaker mechanisms shall be “trip free” as defined in IEC Publication 62271-100. It is recognised that it may be necessary for contacts to close momentarily prior to opening to ensure satisfactory current interruptions.

The mechanism shall be independent, motor wound-spring charged.

Each part of the operating mechanisms shall be of substantial construction, utilising such materials as stainless steel, brass or gunmetal where necessary to prevent sticking due to rust or corrosion. The overall designs shall be such as to reduce mechanical shock to a minimum and shall prevent inadvertent operation due to fault current stresses, vibration or other causes.

An approved mechanically operated indicator shall be provided on each circuit-breaker operating mechanism to show whether the circuit breaker is open or closed.

Power closing mechanism shall be recharged automatically for further operations as soon as the circuit breaker has completed the closing operation. The design of the closing mechanisms shall be such that the circuit breaker cannot be operated inadvertently due to external shock forces resulting from short circuits, circuit-breaker operation or any other cause.

Circuit-breaker operating mechanisms shall be capable of storing energy for at least two complete closing and tripping operations, local to the equipment and without recharging

If a circuit-breaker operating mechanism is not fully recharged for further operation within a predetermined time after a closing cycle, the mechanism shall be locked out and an alarm initiated.

In the event of failure of the motor drive, charging of the operating mechanism shall be possible by external means, i.e. manually by a handle.

#### **2.1.3.2 Disconnecting Switches and Earthing Devices**

Disconnecting and earthing devices shall be designed to comply with IEC 62271-102. They shall be complete with supporting steelwork and installed to permit maintenance of any section of the substation plant when the remainder is live and shall be so located that the minimum safety clearances stated in Chapter 1 are always maintained.

In outdoor substations, disconnectors shall be of double rotating post type with single air break.

Circuit disconnecting switches shall be rated not less than associated circuit breaker except bus section and bus coupler disconnecting switches which shall be rated not less than that of the associated busbars.

Disconnecting switches shall be designed for live operation and will not be required to switch current other than the charging current of open busbars and connections or load current shunted by parallel circuits. Where specified for transformer banking, they shall be capable of switching transformer HV magnetising currents. Main contacts shall be of the high contact pressure line type and arcing contacts, if provided, shall be to the Engineer's approval.

Service conditions require that disconnecting switches shall remain live and in continuous service for periods of up to two years in the climatic conditions specified and without operation. The contacts shall carry their rated load and short-circuit currents without overheating or welding.

The earthing switch, when in the closed position, shall be capable of carrying the rated short-time current without the contacts burning or welding for one second for 12 kV and 36 kV equipment.

The earthing switches shall be of self closing / spring release type and shall be interlocked with 'live' feeders.

Disconnectors shall be motor operated, but approved means for manual operation shall be provided. Motor enclosure shall comply with protection class IP 54 (Weather proof).

Disconnector operating mechanisms shall be of robust construction, carefully fitted to ensure free action and shall be unaffected by the climatic conditions at Site. Mechanisms shall be as simple as possible and comprise a minimum of bearing and wearing parts. Approved grease lubricating devices shall be fitted to all principal bearings, which are not of the self-lubricating type. The mechanisms shall be housed in a weatherproofed enclosure with protection class IP 54 complete with auxiliary switches, terminal blocks and cable gland plates. All members of steel and malleable iron parts shall be hot dip galvanised as specified in Civil Specification.

For motor operated disconnectors, Local/Remote and Open/Close control switches shall be installed in the operating cubicles.

All feeder disconnectors and other disconnectors shall, where specified, be fitted with approved three phase line earthing devices, mechanically coupled or interlocked with main disconnector so that the earthing device and main disconnector cannot be closed at the same time.

Disconnecting devices shall be interlocked with circuit breakers and other disconnectors, as necessary, to prevent possibility of making or breaking load current. Except where electrical interlocking is provided, each mechanism shall be interlocked through key type key interlocks.

### **2.1.3.3 Voltage Transformers**

Voltage transformers for 12 kV and 36 kV shall be of the capacitor type. These shall comply with IEC 61869 and the requirements of this Specification. The voltage transformers shall supply measured values to protection equipment, measuring instruments, meters and voltage regulating devices.

Capacitor type voltage transformers may be of the single phase or three phase type and shall be hermetically sealed.

Primary clamps and connectors suitable for "hot-line" maintenance shall be fitted on voltage transformers.

The insulating body shall be of brown glazed porcelain with alternating or uniform sheds.

The voltage transformers shall be either of the oil immersed or SF<sub>6</sub> gas insulated, hermetically sealed post insulator type. The oil-immersed type shall be equipped with an oil level indicator and provided with oil filling and oil draining plugs. They shall be suitable for phase-to-ground connection.

An intermediate transformer (electromagnetic unit) shall give maximum insulation reliability under all operating and environmental conditions.

The voltage transformers must be designed such as to avoid ferro-resonance under all possible modes of operation.

Each circuit connected to the secondary shall be provided with a separate with the proper dimension to protect this circuit. These miniature circuit breakers shall be located as near to the transformer as possible and in a weatherproof metal clad box.

The secondary circuits of voltage transformers shall not be connected in parallel. The voltage transformer ground connection shall be earthed through a link, which can be removed for insulation testing.

The rated primary voltage of voltage transformers shall be equal to the nominal system voltage. The insulation rating of the voltage transformer shall allow, at site conditions, a 20% continuous overloading referred to nominal rating of the voltage transformer.

All the voltage transformers shall have an output rating adequate to cope with the burdens connected to them.

The voltage transformers shall have an accuracy of 0.2 percent. For all networks where over voltage caused by resonance effects between the network and inductance of the voltage transformers may occur, the manufacturer of the voltage transformers shall take all necessary measures to avoid this effect (providing resistors for open delta connections, etc.).

The voltage transformer shall be insulated to withstand over voltage including impulse voltage of a level equal to withstand value of the switchgear and the high voltage system.

For very high speed protection, transient oscillations should be minimised. In this respect, the supplier has to consider the data of the capacitive voltage transformers in order to guarantee proper performance of the protection.

The voltage transformers shall be provided with:

- weather-proof secondary terminal box
- earthing terminal
- mounting bolts
- oil-filling and drain valve if applicable
- earthing terminal using stranded copper of at least 120 mm<sup>2</sup> cross-section
- porcelain shall be made of high equality wet-process porcelain which shall be homogenous and not porous in order to withstand humidity.

The secondary insulation shall withstand a test voltage of 2 kV r.m.s. for 1 min.

#### **2.1.3.4 Current Transformers**

Current transformers shall comply with IEC 61869-2 and the requirements of this Specification.

Primary winding conductors shall be not less than 1.55 Amps/sq.mm (1000A/sq.inch) section and shall have a one second short time current rating not less than that of the associated switchgear. Secondary windings of each current transformer shall be earthed at one point only.

The thermal rating of the current transformer shall allow, at site conditions a 20% continuous overloading referred to nominal rating of the current transformer.

Magnetisation and core loss curves shall be provided for each type and rating of current transformer. Where the Contractor wishes to provide current transformer ratios differing from those specified he shall first obtain the approval in writing from the Engineer for each specific instance.

Current transformers for balanced protective schemes, including neutral current transformers where appropriate, shall have identical turns ratio and shall have magnetisation characteristics to the approval of the Engineer for each specific instance. Where an existing balanced protective scheme is being extended, the Contractor shall ensure that any additional current transformers are correctly matched to the existing equipment.

Current transformers provided for protective gear purposes shall have over current and saturation factors not less than those corresponding to the design short circuit level of the system. The contractor shall ensure that the capacity of the current transformers provided is adequate for operation of the associated protective devices and instruments. Where double ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformer indicating clearly the connection required for either ratio. These connections and the ratio in use shall be shown on the appropriate schematic and connection diagrams.

Where double ratios are specified and post Current transformers with multiple windings are tendered, it shall be possible to select either ratio for each winding without alteration to the number of primary turns.

Neutral current transformers are to be of the outdoor totally enclosed bushing type complete with suitable mounting steelwork as specified and complete with cable box for secondary connections.

CT burden shall be at least 20VA where CT cores are used in transformer differential and restricted earth fault protection.

The Contractor shall provide details of their method of calculating the outputs of the current transformers for each type of protection specified and shall submit calculations for all the current transformers for approval to the Engineer before starting manufacture. Removal of cover of any secondary circuit of current or voltage transformer shall not effect protection scheme.

### **2.1.3.5 Lightning Arresters**

Surge arresters shall be of the gap less metal oxide type. Except where approved the use of organic materials is not permitted.

Arresters shall be housed in porcelain containers sealed against the entry of moisture and oxygen. All internal components shall be designed to minimise internal corona and also to ensure minimal capacitive coupling with any conducting layer of pollutant on the outside of the porcelain housing.

Arresters shall comply in all respects with IEC 60099 shall be entirely suitable for operation under the system conditions specified including system voltage rises on unloading long transmission lines and shall have sufficient capacity to discharge system charging currents without damage.

Each surge arresters shall be fitted with a surge counter of an approved type.

Primary clamps and connectors suitable for “hot line” maintenance shall be fitted on surge arresters.

The surge arresters shall be capable of resealing against the maximum TOV.

The active elements shall be housed in suitable gas tight insulators of brown glazed porcelain with a creepage distance as specified in Chapter 1 based on the rated voltage of the switchgear, to cater for the site conditions of polluted air. The surge

arresters shall be equipped with a grading ring. If necessary, an internal grading system may control the voltage distribution along the metal oxide resistor stack.

A pressure relief device shall prevent damage by overpressure and discharge counters shall be provided to indicate the number of operations for each surge diverter.

Surge arresters shall be of the heavy-duty type. Connection to ground shall be by copper bars of adequate section connected to the substation general grounding grid.

The surge arresters shall be constructed and tested in accordance with IEC 60099.

#### **2.1.3.6 Breaker Switch Capacitor Banks**

Reactive power compensation equipment shall be installed at the substation as indicated in Scope of Works. Capacitor banks and associated switchgear and control equipment shall automatically control the parameters of the Medium Voltage busbar or windings of the power transformers as mentioned in Automatic Regulation and Control. In addition facilities for continuous manual operation shall be provided. The total reactive power compensation requirement to be distributed evenly on the all power transformers as indicated in the Scope of Works. The compensation shall be switched in steps in value specified in scope of work and the value specified in scope of works is the Mvar net value input to the system at the nominal voltage.

Capacitor banks shall be three phase banks in double “Y” connection of two equally rated star connected modules with ungrounded neutrals, which made up by connection of individual standard single phase capacitor units.

#### **Studies, Calculations and Reports to be submitted before manufacturing**

Contractor has to carry out detailed study and submit a comprehensive report with preliminary design and calculations, justifying the values chosen for the design for approval by Engineer.

In this study the contractor has to submit calculations justifying the MVAR rating selected for step sizes of capacitor banks to produce step size specified in scope of work to the system at 33kV. Further this study should include harmonics, inrush and transient studies.

Contractor also shall submit design proposal for the filter circuit according to the study and should submit how the capacitor system control and monitor the harmonic overload of the equipment. Further contractor shall prove that his design would prevent the equipment from additional resonances. Transformer impedance variation with tapping range and change of capacitance values due to aging of the capacitor bank for its life time shall be considered during the calculation of series and parallel resonance.

Contractor also have to prove that from his studies and calculations, all the over voltage levels including rated voltage and insulation level selected for designing the capacitors are suitable for the installation.

Further this should include calculations supported by the studies for selection of switchgear and justifying the switchgear ratings, proving that the switchgear is fully capable of handling all currents and surges that may occur under any switching operation of the capacitor bank installation. In addition the effect of operation of the switchgear for the capacitors should also study and report.



## Shunt Capacitor Banks

This part of the specification covers the design, manufacture, testing at the factory, delivery to site, erection, testing at site and commissioning of Medium Voltage (33 kV) shunt capacitor banks with associated switchgear and protection including all material and equipment required for a complete installation and for safe and reliable operation. This includes foundation, supporting structure and fencing as well as current limiting and discharging devices, voltage and current transformers and all electrical connections of these and to the substation earthing network. Also included are the power cables from the switchgear to the capacitor banks, control cables between the substation and the capacitor banks, and the protection relays. Any other equipment or devices necessary for safe and reliable operation shall be provided even if not particularly mentioned here.

The shunt capacitor banks will be used for reactive power correction. Both Capacitor banks and capacitor units shall be designed, tested and installed in accordance with IEC 60871 if not otherwise mentioned in this specification. The rated Mvar output of the capacitor bank shall be available after considering the worse case imposed by the individual capacitor and reactor manufacturing tolerances.

The capacitor banks shall be suitable for outdoor installation under the environmental and service conditions as laid down in the respective Chapters of these Specifications, and the capacitors must be fully capable to operate and be switched under these conditions. Forced air cooling is not acceptable in order to reduce maintenance requirements.

Capacitor banks shall be three phase banks in Double-Y-connection of two equally rated star connected modules with isolated neutrals, which are made up by connection of individual standard single phase capacitor units.

### Capacitor Units

Capacitor units may consist of one or several capacitor elements in the single container and insulated there from. Capacitor units shall be of the single phase type with both terminals being brought out through bushings.

The capacitor units shall have a dielectric to be formed of suitable materials having well proven record and should meet the requirements of IEC 60871.

Capacitor impregnant should have a well proven record. Detailed characteristics of the impregnant must be furnished, and the impregnant may not have any PCB compound. Low toxicity is required. The impregnant shall be a class 111 B (OSHA classification) combustible fluid and shall be easily disposable by burning without generating poisonous gases, or shall be biodegradable.

Sufficiently high insulation level must be provided between capacitor element and the container.

Internal fuses shall be provided according to the IEC 60871 and for disconnection of any faulty capacitor element in order to prevent total failure of capacitor unit or bank. Any fuse operation shall not affect adjacent elements or fuses.

Each capacitor unit shall be equipped with an internal discharge device, which reduces the residual voltage from crest value of rated voltage  $U_n$  down to 50 Volts or less within 5 minutes after disconnection.

## Unit Containers

Capacitor units shall have housing of stainless steel. These shall be given a suitable number of coats of weather proof paint for resistance to corrosive atmospheres. The outer paint shall be high gloss in order to reduce dust deposition. Both capacitor connections shall be brought out through bushings with a minimum creepage distance of 25 mm/kV and terminals to ISO standard (metric), with the container insulated. The container shall have stud for earthing.

Lifting eye shall be provided on each side of tank for simplified installation of individual units.

The rupturing strength of the case when fitted with bushings etc. and sealed as when in service for both steady pressures and shock pressures shall be tested at the manufacturers works to demonstrate the ability of the case to withstand distortion due to internal pressure (e.g. pressure arising from dielectric, etc.).

## Racks

Capacitor units are to be mounted on standard racks made of hot dip galvanised steel sections. These racks are also to be provided. The minimum substation clearances specified in section 1.3.2 of this specification have to be maintained. These racks are also to be provided. The mounting structures shall be suitable for bolting onto anchoring bolts of suitably designed foundations. Calculations on loading shall include an allowance for the weight of maintenance staff with tools (2 times 150 kg) and wind loads etc. The safe removal and safe replacement of capacitor units shall not require the dismantling of any structural member, or support including insulators and main connections. Where necessary, approved means shall be provided on the capacitor equipment for the fixing and bonding of external connections to secure efficient earthing. Steel work and all items of the capacitor equipment shall be provided to temporarily earth the connections and apparatus during maintenance.

## Power Losses

The loss of the capacitor banks shall not exceed 0.2 W/kVAR. This shall include the losses due to the internal discharge resistors.

## Capacitor Tolerances

Capacitor Tolerances shall be according to the IEC60871-1. Difference in capacitance between units or group of units when connected in series shall be selected to give minimum value to avoid over voltages due to such differences.

Capacitance values shall be maintained equally for 3 phases to avoid unbalance.

## Standard Temperature Category

All Capacitors shall be design for standard temperature category of -5/C or higher in accordance with IEC 60871. Further the Capacitors shall be able to expose to direct ray of the sun through out the day.

## Maximum Permissible Overloads

- 1 Capacitor units must be suitable for long duration operation under the maximum ambient temperature (Standard temperature category -5/C) at admissible voltage levels in service between terminals according to the IEC 60871-1 clause 19.1. Selection of admissible voltage level is the responsibility of the contractor. contractor has to prove from his studies and calculations the levels selected is suitable for the installation.

2. Capacitor units must be suitable for continuous operation at an r.m.s. sine current up to 1.3 times the current which occurs at rated sinusoidal voltage and rated frequency excluding transients.

### **Name Plate**

Following information shall be given on the name plate of each capacitor unit according to IEC 60871-1:

1. Manufacturer
2. Identification number and Manufacturing year.
3. Rated output in kVAR for three phase units total out put shall be given.
4. Rated voltage  $U_n$  in kV
5. Rated frequency in Hz
6. Temperature category
7. Connection symbol
8. Insulation level in kV
9. Discharge device indicated by words and rated ohmic value
10. Indication for Internal fuse by wording
11. Chemical or trade name of impregnant.
12. Reference standard (IEC no) and year of issue.
13. Measured capacitance in absolute values.

Following information shall be given on the name plate of the completed capacitor bank: according to IEC 60871-1

1. Manufacturer
2. Rated output in MVAR. Total output to be given.
3. Rated voltage  $U_n$  in kV
4. Insulation level, both the rated power frequency short duration and peak value of the rated lightning impulse voltage in kV
5. Rated frequency in Hz
6. Connection symbol
7. Minimum time required between disconnection and reclosure of the bank.
8. Time to discharge to 75V.
9. Any special instruction for safety

### **Tests**

#### Type tests:

Following type tests are required as per IEC 60871:

- Thermal stability test.
- Measurement of the tangent of the loss angle of the Capacitor at elevated temperature.

- AC voltage test between terminals and container, dry test.
- AC voltage test between terminals and container, wet test.
- lightning Impulse voltage test between terminals and container for capacitors intended for exposed installation.
- Short circuit Discharge test.
- Test of an external fuse in combination with a capacitor.
- Ionisation test on internal fuses.

Test certificates are to be submitted for the approval of the Employer/Engineer. Should no satisfactory type test certificate be submitted, then type tests shall be performed in the presence of the Employer/Engineer.

Routine tests on every capacitor bank:

Following routine tests must be carried out on every capacitor on completion in accordance with IEC 60871 and test certificates to be submitted:

- Capacitance measurement.
- Measurement of the tangent of the loss angle of the Capacitor
- Voltage test between terminals.
- AC voltage test between terminals and container.
- Test of internal discharge devices.
- Sealing Test.
- Discharge test on internal fuses.

Factory acceptance tests:

Factory acceptance tests are to be performed on each completed capacitor in the presence of the Employer/Engineer unless he waives the test. The factory acceptance tests shall be the same as mentioned above as routine tests.

**Insulation levels and Rated Voltage of a Capacitor.**

The r.m.s. value of the alternating voltage for which the capacitor bank is rated, and such voltage of the capacitor unit shall be decided by the contractor considering the influence of the capacitor itself. The rated voltage shall be higher than the maximum system voltage indicated below. Design calculations shall be submitted to the engineer justifying the selection of said voltages before manufacturing. Increase in the voltage due to the connection of shunt capacitors and voltage increase due to light load conditions shall be considered for the design.

The insulation levels shall be in accordance to the IEC 60871 and shall be not less than the values listed below. Further correct insulation requirements and insulation paths shall be selected from table 7 of IEC 60871-1 justifying the reasons and suitability. Other factors such as altitude of the installation site shall also consider when selecting the insulation levels.

Highest system voltage (line to line)	Power Frequency AC test voltage (r.m.s value)	Impulse Test crest value
Um		

36 kV r.m.s

70 kV

170 kV.

### Surge Limiting Coils

Surge limiting coils shall be installed in each feeding phase of a capacitor bank. The inductivity shall be designed such that surges harmful to any equipment or to the substation operation are avoided. The coils shall be air insulated with bird barriers, and mounted rigidly on post insulators. The coils of the three phases may be mounted one above the other. The choice of inductivity shall be supported by a calculation to be submitted for approval.

### Switchgear

Each capacitor bank assembly shall individually be switched through an individual isolator and circuit breaker [rated to the same rating or higher of the capacitor bank rated voltage. Care should be taken to select switching devices which operate without causing excessive over voltage. If nevertheless restrike cannot be prevented, it may be necessary to use capacitors having higher insulation level and higher rated voltage.

The specification for medium voltage switchgear (refer to Chapter 2.3) shall apply, and additionally the Contractor must prove by calculations submitted for approval by the Employer/Engineer that the switchgear is fully capable of handling all currents and surges that may occur under any switching operation of the capacitor bank installation.

### Protection

For protection of the capacitor banks and their feeders, refer to Chapter 5.

### Automatic Power Factor Regulation and control

Automatic regulation units with all necessary devices e.g. VT and CT shall be provided, which shall continuously monitor the power factor and reactive power flow at the Medium voltage (33 kV or 11 kV) windings of the power transformers or busbar. Automatic on and off commands shall be given to the circuit breakers of the individual capacitor banks based on following or combination of following criteria

1. Voltage, power factor and reactive power
2. Time of day function: Which allow the capacitor bank to switch based on time of day or week
3. Control one of the selected features (i.e. voltage, power factor or reactive power), individually while the bus section is opened and as a single bus, while the bus section is closed.

The regulation criteria will be decided at the time of detail engineering stage. However, care shall be taken that a suitable hysteresis between the on and off commands is maintained in order to avoid too frequent switching.

The control shall include monitoring of the voltage to prevent excessive high voltages.

The automatic regulation devices shall be incorporated in control cubicles located in the control room, together with manual/automatic selector switches, control switches for operation of the circuit breakers including position indication of isolators and CBs, power factor meters, reactive power meters and alarm tableau. Suitable interlocking shall prevent any dangerous mal-operation.

### Alarm Indication

One alarm indication tableau for each group of capacitor banks and all associated equipment shall be mounted in the control cubicles. Any protection action, supply

voltage failure or MCB trip shall initiate an alarm tableau of the substation, along with initiation of the existing horn or buzzer.

### **Control Panels**

The control panels shall be of the self standing fully enclosed sheet metal type, refer also to the specifications in other sections for similar panels.

The front panels shall exhibit a single line diagram of the complete reactive power compensation installation with control and check back as described for control room panels.

Measuring instruments shall include:

Power factor meter for each busbar section

Voltmeter with selector for each busbar section

Ammeter with selector switch for each capacitor bank

Other controls shall include:

Local – remote switch (remote control facilities wired up to terminals in the panels)

Automatic – manual switch

Alarm indication with multifaceted annunciator panels

Lamp test pushbutton

The protection equipment shall be incorporated in the same cubicle. .

#### **2.1.3.7 Busbars, Conductors And Connectors**

Busbars and electrical connections in outdoor substations made of aluminium shall be in accordance with BS 215 Part 1 and Part 2, BS 159, BS2898 in respect of current rating and material analysis.

Aluminium busbars and connections of tubular shape shall be of alloy E91E to BS 2898 and stranded conductors to IEC 61089. The number and diameters of the individual wires forming the finished conductor and the thickness of the tubes shall be subject to approval.

Whenever copper busbars and connections are used they shall be in accordance with BS.7884, BS 159 or equivalent IEC standard.

In case of hollow stranded copper conductors they shall be supported against crushing at clamping positions by sweating solid or plugging.

Busbar bending or any other related works shall be originated from factory.

Overhead conductors carried by the switchyard structures shall be erected with such sag and tensions that when the conductors are subjected to the load combinations in Technical Specification – Grid Substation the factor of safety will not be less than 2.5.

Materials used for busbars and connections shall be stressed to not more than two-fifths of their elastic limit. Provision shall be made for expansion and contraction with variation in conductor temperature and busbars shall be arranged so they may be readily extended in length with a minimum of disturbance of existing equipment. The design of joints and connections shall be such as to permit ready dismantling. All necessary terminals and connectors shall be provided under this Contract and also between equipment provided on this Contract and on other Contracts.

Unless otherwise approved, busbars shall be of continuous lengths between supports. Connectors shall be of approved types, and, if necessary, type tested. Connections dependent upon site welding techniques will not be permitted. (Except for grounding grid)

Suspension and tension conductor clamps shall be of approved types and shall be as light as possible. Those for aluminium conductor shall preferably be compression type in accordance with BS.3288. Suspension and tension clamps shall be designed to avoid any possibility of deforming the stranded conductor and separating the individual strands.

Tension conductor clamps shall not permit slipping of, or damage to, or failure of the complete conductor or any part thereof at a load less than 95% of the ultimate strength of the conductor as stated in the Schedule of Particulars and Guarantees.

Clamps and fittings made of steel or malleable iron shall be galvanised. All bolts and nuts shall be locked in an approved manner.

Unless otherwise approved, busbars and connections shall be so arranged and supported that under no circumstances, including short circuit conditions, the clearances between live metal and earth of earthed metal work or between other conductors shall become less than the specified distances.

Where dissimilar metals are in contact, approved means shall be provided to prevent electro-chemical action and corrosion. Unless otherwise approved, joints and surfaces of copper or copper alloy fittings shall be tinned.

Cleaning down and preparation of contact surfaces of connectors and clamps shall be to the approval of the Engineer.

### **2.1.3.8 Insulators**

All post insulators shall be of brown glazed porcelain and shall satisfactorily withstand the specified climatic and service conditions. The strengths of insulators as given by the electro-mechanical test load shall be such that the factor of safety when supporting their maximum working loads shall not be less than stated in Chapter 1 of this specification.

Designs shall be such that stresses due to expansion and contraction in any part of the insulators and fittings do not lead to development of defects.

Damaged insulators may not be repaired without the written consent of the Engineer.

Arcing horns are not required on post type and string insulators.

Porcelain insulators shall be in accordance with IEC 60168 and 60273. Porcelain shall be sound, free from defects and thoroughly vitrified and the glaze shall not be depended upon for insulation. A zinc anti-corrosion protective sleeve is to be fitted on the pins of cap and pin insulators. The sleeve shall project by not less than as specified.

The minimum specific creepage distances of outdoor insulators shall be as stated in Chapter 1 of this Specification.

Glazing shall be smooth, hard, of a uniform shade of brown and shall completely cover all exposed parts of the insulators. Outdoor insulator fittings shall remain unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

Porcelain shall not engage directly with hard metal and, where necessary, approved water and oil resistant yielding material shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces shall be approved quality, applied in an approved manner and shall not be chemically active with the metal parts or cause fracture by expansion in service. Where cement is used as a fixing medium, the cement thickness shall be as small and as even as possible and care shall be taken to correctly centre and locate the individual parts during cementing.

Suspension and tension insulators shall comprise porcelain or glass units with ball and socket fittings. Each tension insulator shall consist of a single string of insulator units or long-rod insulator and the associated fittings shall be in accordance with IEC 60383-2 and IEC 60305.

Porcelain insulators shall be secured in an approved manner, preferably by means of bolts to metal clamping plates with suitable packing material interposed.

Retaining pins or locking devices for insulating units shall be of phosphor bronze or other approved material, and shall effectively prevent accidental separation of the units.

Unless otherwise approved, the individual units of both the suspension and tension insulator sets shall be identical and interchangeable.

Each insulator shall have marked on it the manufacturer's name or trademark. Tension and suspension insulators shall also be marked with the guaranteed electro-mechanical strength. Marks shall be visible after assembly of fittings and shall be imprinted and not impressed. For porcelain insulators, the marks shall be imprinted before firing and shall be clearly legible after firing and glazing.

When a batch of insulators bearing a certain identification mark has been rejected no further insulators bearing this mark shall be submitted. The Contractor shall satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there is no possibility of the insulators being subsequently resubmitted for tests or supplied for the Purchaser's use.

### **2.1.3.9 Auxiliary Switches And Contactors**

Circuit breakers, disconnectors and earthing devices shall be provided with suitably rated auxiliary switches and contactors, where permitted, to relay circuit information for the purpose of control, protection, indication and metering at the substation site as required by the relevant Chapters of Specification. In addition circuit-breakers and automatic switches shall be provided with auxiliary contacts for position indication to the system control centre via the remote supervisory system.

Auxiliary contactors shall be provided only where the auxiliary switch arrangements and multiple contactors cannot meet the circuit requirement and relays will not be accepted in lieu of the auxiliary switches except as specifically approved by the Engineer. Auxiliary switches and contactors shall comply with the requirement of this specification and in particular shall be capable of operation within the same voltage limits as specified for the associated circuit-breaker close and trip coils.

The connections of all auxiliary switches, including spares, and contactors as well as the associated coil connections and interconnections between auxiliary switches, shall be wired to a terminal board located in the operating cubicle or other approved position.



Auxiliary switches and contactors shall be mounted in an approved accessible position clear of the main operating mechanism but with a minimum of additional mechanical linkages and housed in a substantial weatherproof enclosure.

Auxiliary switch contacts shall be positively operated, make with a wiping action and where necessary, discharge resistors shall be provided to prevent arcing when breaking inductive circuits.

### For Circuit Breakers

In addition to the contacts employed for the control and interlocking of the circuit-breaker, the requirements for auxiliary switches in respect of numbers of contacts and timing shall be as follows:-

Numbers of contacts : 6 × N.O., 6 × N.C.

Timing : N.O. contacts, with exception of two sets of this type, shall close in about 10 milliseconds after the making of the main circuit-breaker contacts and shall open in about 10 milliseconds before the separation of the main circuit breaker contacts whilst the two remaining sets shall close in about 5 milliseconds before the making of the main circuit breaker contacts and open simultaneously with the main circuit breaker contacts.

N.C. contacts shall close 10 milliseconds after the opening of the main circuit breaker contacts and open at least 10 milliseconds before the making of the main contacts.

### For Busbar Disconnectors

Number of contacts : 10 × N.O.; 10 × N.C.

Timing : The operating sequence of any disconnector auxiliary switches used in C. T. circuit and in D. C. circuits for low impedance busbar zone protection shall be such that the auxiliary switches operate: -

- (a) Before reaching the pre-arcing distance on closing the disconnector.
- (b) After the pre-arcing distance has been exceeded on the opening of the disconnector.

### For Line Disconnectors

Number of contacts : 4 × N. O. ; 4 × N. C.

Timing : As for Busbar disconnector auxiliary switches.

### For Earthing Switches

Number of contacts : 4 × N. O. ; 4 × N. C.

Timing : As for Busbar disconnector auxiliary switches. Auxiliary switches shall be adjustable from normally open (N.O.) to normally closed (N.C.) or vice-versa.

Any deviation from above, if any, should be stated in Departures in Specification.

## 2.1.4 HIGH VOLTAGE 145 kV OUTDOOR

### 2.1.4.1 Circuit Breakers

#### General

The circuit breakers shall be of the SF<sub>6</sub> gas type and shall comply with IEC 62271-100.

They shall be able to carry the rated current, interrupting all current from zero to the symmetrical and asymmetrical fault currents as well as small capacitive and inductive currents and short line faults and also of operation against short-circuit under the stipulated site conditions. The circuit breakers shall be able to interrupt the fault currents with the associated inherent rate-of-rise of re-striking voltages and amplitude factors.

The circuit breakers shall be porcelain insulated, suitable for outdoor operation and mounted on hot-dip galvanised steel structures. All members of steel parts shall be hot dip galvanised as specified in Technical Specification – Grid Substation.

The arrangement of the breaker at Site shall be such that adequate access for normal routine maintenance and the replacement of any complete apparatus shall be available.

Evidence shall be provided that enclosure subject to pressures in excess of normal atmospheric pressure during service operation have withstood approved pressure tests without leakage, permanent distortion or any temporary distortion such as might cause undue operation of the circuit-breaker.

Mechanical indicating devices shall be provided which indicate whether the breaker is in the “open”, “closed”, position, and which show the state of the energy storage also.

Electrical and mechanical interlocking shall be provided as specified in Clause 2.1.8 and the Contractor shall design the details, which are subject to the approval of the Engineer.

Means shall be provided to prevent pumping while the closing circuit remains energised in case the circuit breaker either fails to latch or is tripped during closing.

A suitable energy storage system shall ensure uniform, positive closing and opening. Pneumatic systems operating on compressed air and hydraulic operating mechanisms are not accepted. If the energy storage system is not fully recharged within a predetermined time, further operation shall be blocked and suitably indicated. The capacity of the energy storing system shall be large enough to permit two operations (CO-CO) if the electrical supply fails. In the event of failure of the power for the energy storage drive it shall be possible to operate the breaker by external means. Closing mechanism shall be recharged automatically for further operations as soon as the circuit breaker has completed the closing operation.

The design of the circuit breaker mechanisms shall be such that the circuit-breaker cannot be operated inadvertently due to external shock forces resulting from short circuits, other circuit-breaker's operation, due to fault current stresses, vibration or any other cause.

Circuit breakers shall be able to perform three-phase auto-reclose protection scheme as described in Chapter 5: Control, Supervision and Protection.

The 145 kV Circuit breaker shall have an operation duty cycle of: O-0.3 sec-CO-3 min-CO.

The circuit breakers shall be of the SF<sub>6</sub> gas live-tank, trip free single-break type and shall not take more than 3 cycles for opening.

SF<sub>6</sub> Circuit breakers shall incorporate precautions to minimise the presence of moisture and SF<sub>6</sub> decomposition products. Static and moving gas seals shall be designed to prevent the leakage of gas or ingress of moisture throughout the service of the interrupting module. The enclosure of the module shall be strong enough to

withstand the internal pressures generated when switching and shall incorporate an over-pressure relief device proved to be capable of allowing the safe discharge of any excess pressure that may arise.

Gas pressure monitoring devices shall be incorporated to provide an alarm and to block operation. SF<sub>6</sub> pressure low lock out shall be used for control of breaker failure protection or similar tripping arrangements.

All circuit breakers shall be connected for remote control as described. This shall comprise “ON-OFF” control and “OPENED”, “CLOSED” and “DISCREPANCY” indication, locally and in the control room of the station. Local electrical opening and closing of the breaker shall be permitted only when the control selector switch is in the “LOCAL” position. The operating mechanism shall be provided with an operation counter. All supervision and control facilities shall be located in a central local operating cubicle.

The circuit breaker local operation shall depend also on the synchro check equipment specified under Chapter 5: synchronising of these specification.

All circuit breakers shall be supplied with a sufficient number of auxiliary contacts for remote indication and any control and interlocking scheme required. At least two normally open and two normally closed spare auxiliary contacts shall be easily convertible from normally open to normally closed.

Continuous trip circuit supervision shall be provided for each circuit breaker, with individual local and remote indication “trip circuit healthy”.

Thermostatically controlled heaters for continuous operation at the rated AC voltage shall be provided on all operating mechanism installed outdoors to prevent condensation.

A sufficient number of cable entry glands shall be foreseen on all operating mechanisms and terminal blocks shall be supplied and installed as appropriate.

Circuit Breakers shall be covered by type test certificates issued by a recognised short-circuit testing station certifying the operation of the circuit breaker at duties corresponding to the operation of the rated breaking capacities of the circuit-breakers. The test duties shall not be less than the requirements of IEC 62271-100. Test certificates shall be submitted with the Bid.

Bidders should include a statement of the accumulative breaking capacity, which the circuit breakers are capable of, before maintenance is required.

Test certificates demonstrating the ability of the circuit breakers for these duties shall be submitted with the bid.

### **Circuit Breakers for Controlled Switching Applications**

For switching of shunt capacitor banks and shunt reactor, circuit-breakers supplied may be required to perform controlled (point-on-wave) switching duties. However, the circuit-breaker shall be capable of switching without the use of a controlled switching system. The supplier shall provide all accessories and cabling required for the point-on-wave relay.

IEC 62271-302 provides guidance on the design, construction, specification and testing of circuit-breakers with intentional non-simultaneous pole operation which are excluded from the scope of IEC 62271-100. Circuit breakers with intentional non-

simultaneous pole operation are mainly used for the implementation of controlled switching.

Circuit breakers used for Controlled Switching shall be single pole operated and mechanical staggering is not accepted. For Capacitor Bank applications the circuit breaker shall be of Class C2 and M2.

The supplier shall provide type test reports as per IEC 62271-302 for the offered circuit breaker. The supplier shall indicate whether the circuit-breaker offered was tested independent from any particular controller or whether it was tested with a dedicated controller and the necessary sensors and auxiliary equipment which form part of the tested equipment.

The supplier shall provide details with the tender documentation regarding the mechanical characteristics of the circuit-breaker which affect the mechanical operating time, e.g. influence of ambient temperature, substation DC control voltage, standing time, operating pressure, contact wear. The cause of deviations in operating times shall be indicated in all cases, e.g. arising in the operating coil/latch assembly, energy storage device, etc.

The supplier shall provide details with the tender documentation of the circuit breaker dielectric characteristic as a function of time (closing) and as a function of SF6 gas filling pressure up to the maximum rated design pressure. The supplier shall also supply the upper and lower limits of the dielectric characteristic which can be expected over the service life of the circuit breaker. The critical arcing time window shall be indicated for re-ignition-free shunt-reactor switching. For controlled closing of shunt capacitor banks as well as for controlled opening of shunt reactors, a tolerance of less than  $\pm 1$ ms is required as a function of the above mentioned parameters. If special measures are required to maintain operating times within these limits, this shall be stated with the tender documentation.

#### **2.1.4.2 Disconnecting Switches and Earthing Switches**

Disconnecting and earthing devices shall be designed to comply with IEC 62271-102. They shall be complete with supporting steel work and installed to permit maintenance of any section of the substation plant when the remainder is alive and shall be so located that the minimum safety clearances stated in Chapter 1 of this Specification are always maintained.

In outdoor substations, disconnectors shall be of the double rotating post type with single air break.

Circuit disconnecting switches shall be rated not less than that of the associated circuit breaker except bus section and bus coupler disconnecting switches which shall be rated not less than that of the associated busbars.

Disconnecting switches will not be required to switch current other than the charging current of open busbars and connections or load current shunted by parallel circuits. Where specified for transformer banking at 145 kV and lower voltage they shall be capable of switching transformer magnetising currents. Main contacts shall be of the high contact pressure line type and arcing contacts, if provided, shall be to the approval of Engineer.

Service conditions require that disconnecting switches shall remain live and in continuous service for periods of up to two years in the climatic conditions specified and without operation. The contacts shall carry their rated load and short-circuit currents without overheating or welding.

The earthing switch, when in the closed position, shall be capable of carrying the rated short-time current without the contacts burning or welding.

The earthing switches shall be of self closing/ spring release type and shall be interlocked with 'live' feeder.

Disconnectors shall be motor operated, but approved means for manual operation shall be provided. Motor enclosure shall comply to protection class IP 54 (weatherproof).

The local control cubicle shall contain a LOCAL/REMOTE control switch as well as OPEN/CLOSE control switches. Necessary switches/contactors/contacts shall be provided for interlocking, alarming and remote operation from the Control room.

At least one normally closed spare auxiliary contact shall also be provided. All operating mechanisms shall be provided with locks to secure them in either the open or closed position of the disconnector/earthing switch. Locks shall fit to a master key system of the station.

Where specified disconnectors shall be fitted with approved three phase line earthing devices, mechanically coupled or interlocked with main disconnector so that the earthing device and main Disconnector cannot be closed at the same time.

Disconnecting devices shall be interlocked with circuit breakers and other disconnectors, as necessary, to prevent possibility of making or breaking load current. Further safety interlocking shall be provided as specified.

All Disconnectors shall be porcelain insulated and provided with safety platforms to protect operators from dangerous potentials. The safety platforms shall be installed at the place from which the operating mechanism has to be operated, they shall be secured to the support structures and be connected to the substation grounding grid.

For corrosion protection of all ferrous parts, hot dip galvanising shall be applied as well as other measures as specified in Technical Specification – Grid Substation.

#### **2.1.4.3 Capacitor Voltage Transformers**

Voltage transformers for 145 kV shall be of the capacitor type. Type shall comply with IEC 61869-5 and the requirements of this Specification. Voltage transformers shall be of the CVT type and equipped with power line carrier coupling devices wherever necessary where specified. The capacitive voltage transformers shall supply measured values to protection equipment, measuring instruments, meters and voltage regulating devices, and shall in addition be used for power line carrier coupling to the respective equipment.

Capacitor type voltage transformers shall be suitable for use as line couplers for the operation of carrier accelerated tripping and communication systems and where specified the top cap of voltage transformers shall be suitable for mounting wave traps.

Primary clamps and connectors suitable for "hot-line" maintenance shall be fitted on voltage transformers.

The insulating body shall be of brown glazed porcelain with alternating or uniform sheds.

The voltage transformers shall be either of the oil immersed or Gas insulated, hermetically sealed post insulator type. The oil-immersed type shall be equipped with an oil level indicator and provided with oil filling and oil draining plugs. They shall be suitable for phase-to-ground connection.

An intermediate transformer (electromagnetic unit) shall give maximum insulation reliability under all operating and environmental conditions.

The voltage transformers must be designed such as to avoid ferroresonance under all possible modes of operation.

The secondary windings shall be connected through protective switches having sufficient auxiliary contacts to provide for alarm indications and the necessary signalling to protection and synchrocheck equipment. Each circuit connected to the secondary shall be provided with a separate miniature circuit breaker with the proper dimension to protect this circuit.

The miniature circuit breaker, which protects the secondary winding, shall be located as near to the transformer as possible and in a weatherproof metal clad box.

The secondary circuits of voltage transformers shall not be connected in parallel. The voltage transformer ground connection shall be earthed through a link, which can be removed for insulation testing.

The rated primary voltage of voltage transformers shall be equal to the nominal system voltage. The insulation rating of the voltage transformer shall allow, at site conditions, a 20% continuous overloading referred to nominal rating of the voltage transformer.

All the voltage transformers shall have an output rating adequate to cope with the burdens connected to them.

The voltage transformers shall have an accuracy of 0.5 percent. For all networks where overvoltages caused by resonance effects between the network and inductance of the voltage transformers may occur, the manufacturer of the voltage transformers shall take all necessary measures to avoid this effect (providing resistors for open delta connections, etc.).

The voltage transformer shall be insulated to withstand overvoltages including impulse voltage of a level equal to withstand value of the switchgear and the high voltage system.

For very high-speed protection, transient oscillations should be minimised. In this respect, the supplier has to consider the data of the capacitive voltage transformers in order to guarantee proper performance of the protection.

The voltage transformers shall be provided with:

- weather-proof secondary terminal box
- earthing terminal
- mounting bolts
- oil-filling and drain valve if applicable
- earthing terminal using stranded copper of at least 120 mm<sup>2</sup> cross-section
- porcelain shall be made of high quality wet-process porcelain which shall be homogenous and not porous in order to withstand humidity.

The secondary insulation shall withstand a test voltage of 2 kV r.m.s. for 1 min.

#### 2.1.4.4 Current Transformers

Current transformers shall comply with IEC 61869-2 and the requirements of this Specification.

They shall have a short time primary current rating not less than that of the associated switchgear. The thermal rating of the current transformer shall allow, at site conditions, a 20% continuous overloading referred to nominal rating of the current transformer.

The terminal designation of the primary and secondary windings shall be in accordance with IEC recommendations. Where double ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformer indicating clearly the connection required for either ratio. These connections and the ratios shall be shown on the appropriate schematic and connection diagrams.

Current transformers provided for protection purposes shall have over current and saturation factors of not less than those corresponding to the design short circuit level of the system. The output of each current transformer shall be not less than that specified. Contractor shall ensure that the capacity of the current transformers provided is adequate for operation of the associated protective devices and instruments.

The windings shall be located in accordance with the requirements of the single-line diagrams or typical feeder drawings as per Drawings.

To guarantee the correct protection relay operation, a through-fault stability calculation shall be submitted showing the correctness of the chosen current transformer core, i.e. rated output, class of accuracy, rated accuracy limit factors, the rated primary current, turns ratio, knee-point e.m.f. and resistance of the secondary windings (corrected to the maximum service temperature). Magnetisation and core loss curves shall be provided for each type and rating of current transformer.

CT burden shall be at least 20VA where CT cores are used in transformer differential and restricted earth fault protection.

The current transformer supplier is bound to co-operate closely with the protection supplier, and to make all required data available for relay calculations at an early stage of the Contract period. Reference is made to the Article of Protection Relays below.

For outgoing feeders, the Contractor shall make sure that the current transformer characteristics match the data of the relevant opposite feeder, this requirement supersedes the figures as may be stipulated in the Bidding Documents.

Where an existing balanced protective scheme is being extended, the Contractor shall ensure that any additional current transformers are correctly matched to the existing equipment.

Current transformers shall be of the porcelain insulated, oil-immersed and hermetically sealed or SF<sub>6</sub> gas insulated post insulator type. They shall be equipped with oil level indicator and provided with oil filling and oil draining plugs. They shall be connected to other switchgear in such a way that undue mechanical stress cannot be exerted on the transformer winding.

Where neutral current transformers are specified the same technical requirements apply.

All the current transformers and auxiliary transformers shall be of the low reactance type and, unless other wise approved, shall be of the bar-primary design capable of

carrying the rated primary current for a period of one minute with the secondary winding open-circuited.

Secondary windings shall be rated for 1A.

If not specified otherwise, the test voltages on the secondary windings and between the winding and the tank shall be at least 3kV.

Secondary windings that are not loaded must be short-circuited before the transformer is energised. This applies to all cores of the transformers, however, not to unloaded parts of tapped windings, provided that the other section is loaded or short circuited.

Current transformers for indication or metering shall have their secondary winding earthed at the switchgear. The secondary windings of the current transformers for protection shall be earthed only once at the panel which accommodates the associated relay. The earth connection shall be made via a removable link and shall be wired through the test block.

#### **2.1.4.5 Lightning Arresters**

Arresters shall comply in all respects with IEC 60099 Part 1A, Part 3, Part 4 and shall be entirely suitable for operation under the system conditions specified including system voltage rises on unloading long transmission lines and shall have sufficient capacity to discharge system charging currents without damage.

The lightning arresters shall be of the gapless metal-oxide and heavy-duty type.

Arresters shall be housed in porcelain containers sealed against the entry of moisture and oxygen. All internal components shall be designed to minimise internal corona and also to ensure minimal capacitive coupling with any conducting layer of pollutant on the outside of the porcelain housing. Lightning arrester shall have the rated voltage, minimum spark over voltage and insulator creepage distance as specified in Chapter 1 of this specification.

The lightning arresters shall be equipped with a grading ring. If necessary, an internal grading system may control the voltage distribution along the metal oxide resistor stack. Rupture diaphragms shall prevent damage by overpressure.

Discharge counters shall be provided to indicate the number of operations for each surge diverter. The discharge counter shall be connected in the main earth lead from the arrester in such a manner that the direction of the earth lead is not changed or its surge impedance materially altered. Bolted links shall be provided so that the discharge counter may be short-circuited and removed without taking the arrester out of service.

Connection to ground shall be performed by copper bars or copper strands of adequate cross section connected to the substation/gantry general grounding grid.

Lightning arresters shall be constructed and tested in accordance with applicable IEC standards at the Contractor's premises.

The supporting structure shall be protected against corrosion as specified in Technical Specification – Grid Substation.

#### **2.1.4.6 Busbars, Conductors and Connectors**

Busbars and electrical connections shall be of aluminium and shall be in accordance with BS 215 Part 1, BS 215 Part 2, BS 159, BS 2898 in respect of current rating and material analysis.



Tubular conductors shall be of alloy E91E to BS 2898 and stranded conductors to IEC 61089. The thickness of the tubes shall be subjected to approval.

If copper busbars and connections are used they shall be in accordance with BS 7884, BS 159 or equivalent IEC standard.

Unless otherwise approved, busbars shall be of continuous lengths between supports. Connectors shall be of approved types, and if necessary, type tested. Connections dependent upon site welding techniques will not be permitted. (except for grounding grid)

The general construction of the connections and their insulator supports shall be of approved design, it shall be mechanically strong and shall withstand all the stresses which may be imposed on them during ordinary work due to fixing, vibrations, climatic conditions, short circuit or other causes.

All connections shall be kept as short and as straight as possible. Provisions shall be made to allow expansion and contraction of all the connections due to changes of temperature, and under load and short circuit conditions while keeping the whole system in perfect operating condition, also without application of stress to any part of the system or the supporting structure.

The Contractor shall supply all necessary terminals and fittings for the connection of all equipment and cables of the station to allow perfect operation.

All fittings used shall be marked durably with mechanical and electrical rating.

Bolts shall be made of steel having a minimum tensile strength of 600 N/mm<sup>2</sup> (grade 8.8). Bolts secured by split pins and flat washers only are not permitted. Split pins for securing nuts of fittings shall be of tinned copper or stainless steel, washers shall be of stainless steel.

Where dissimilar metals are in contact, approved means shall be provided to prevent electro-chemical action and corrosion. Unless otherwise approved, joints and surfaces of copper or copper alloy fittings shall be tinned. All fittings shall be designed to facilitate hot line maintenance with appropriate tools.

The design of all conductor/insulator hardware and accessories shall avoid sharp corners or projections, which would produce high electrical stress in nominal working conditions. The Contractor has to present for approval and justify the proposed layout with view to corona discharges, mechanical and thermal stability and clearances to earthed and live parts.

Overhead conductor carried by the switchyard structures shall be erected with such sags and tensions that when the conductors are subjected to the load combinations as specified in the Civil specification. The factor of safety will not be less than that specified in the Technical Specification – Grid Substation.

The material and fittings shall conform to the relevant IEC standards as applicable.

#### **2.1.4.7 Insulators**

All insulators shall be of porcelain and shall satisfactorily withstand the specified climatic and service conditions. The strengths of insulators as given by the electro-mechanical test load shall be such that the factor of safety when supporting their maximum working loads shall not be less than stated in Chapter 1 of this specification. The minimum specific creepage distances of outdoor insulators shall be as specified in Chapter 1 of this specification. Unless otherwise approved, individual insulator units or sets or strings shall be identical and interchangeable.

Designs shall be such that stresses due to expansion and contraction in any part of the insulators and fittings do not lead to development of defects. Outdoor insulator fittings shall remain unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

Porcelain insulators shall be in accordance with IEC 60168 and 60273. Porcelain shall be sound, free from defects and thoroughly vitrified and glazed. Glazing shall be smooth, hard, of a uniform shade of brown and shall completely cover all exposed parts of the insulators and follow the relevant IEC standards.

Each insulator shall have marked on it the manufacture's name or trademark. Tension and suspension insulators shall also be marked with the guaranteed electro-mechanical strength. Marks shall be visible after assembly of fittings and shall be imprinted and/or impressed. For porcelain insulators, the marks shall be imprinted before firing and shall be clearly legible after firing and glazing.

Porcelain shall not engage directly with hard metal and where necessary, approved water and oil resistant yielding material shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces shall be of approved quality and applied in an approved manner and shall not be chemically active with the metal parts or cause fracture by expansion in service. Where cement is used as a fixing medium, the cement thickness shall be as small and as even as possible and care shall be taken to correctly centre and locate the individual parts during cementing.

When a batch of insulators bearing a certain identification mark has been rejected no further insulators bearing this mark shall be submitted. Contractor shall take adequate steps to mark or segregate the insulators constituting the rejected batch in such a way that there is no possibility of the insulators being subsequently resubmitted for tests or supplied for the Purchaser's use.

Suspension and tension insulators shall comprise porcelain or glass units with ball and socket fittings. Each tension insulator shall consist of a single string of insulator units or long-rod insulator and the associated fittings shall be in accordance with IEC 60383-2 and IEC 60305.

Porcelain insulators shall be secured in an approved manner, preferably by means of bolts to metal clamping plates with suitable packing material interposed.

Retaining pins or locking devices for insulating units shall be of phosphor bronze or other approved material, and shall effectively prevent accidental separation of the units.

#### **2.1.4.8 Auxiliary Switches and Contactors**

Circuit-breakers, disconnectors and earthing devices and circuit selector disconnectors shall be provided with suitably rated auxiliary switches and contactors, where permitted, to relay circuit information for the purpose of control, protection, indication and metering at the substation site as required by the relevant Chapters of Specification and in addition circuit-breakers and automatic switches shall be provided with auxiliary contacts for position indication to the system control centre via the remote supervisory system.

Auxiliary contactors shall be provided only where the circuit requirement cannot be met by the auxiliary switch arrangements and multiple contactors and relays will not be accepted in lieu of the auxiliary switches except as specifically approved by the Engineer. Auxiliary switches and contactors shall comply with the requirement of this

specification and in particular shall be capable of operation within the same voltage limits as specified for the associated circuit-breaker close and trip coils.

The connections of all auxiliary switches, including spares, and contactors as well as the associated coil connections and interconnections between auxiliary switches, shall be wired to a terminal board located in the operating cubicle or other approved position.

Auxiliary switches and contactors shall be mounted in an approved accessible position clear of the main operating mechanism but with a minimum of additional mechanical linkages and housed in a substantial weatherproof enclosure.

Auxiliary switch contacts shall be positively operated, make with a wiping action and where necessary, discharge resistors shall be provided to prevent arcing when breaking inductive circuits.

### **For Circuit-Breakers**

In addition to the contacts employed for the control and interlocking of the circuit-breaker, the requirements for auxiliary switches in respect of numbers of contacts and timing shall be as follows-

Numbers of contacts : 6 × N.O., 6 × N.C.

Timing : N.O. contacts, with exception of two sets of this type, shall close in about 10 milliseconds after the making of the main circuit-breaker contacts and shall open in about 10 milliseconds before the separation of the main circuit breaker contacts whilst the two remaining sets shall close in about 5 milliseconds before the making of the main circuit breaker contacts and open simultaneously with the main circuit breaker contacts.

N.C. contacts shall close 10 milliseconds after the opening of the main circuit breaker contacts and open at least 10 milliseconds before the making of the main contacts.

### **For Busbar Disconnectors**

Number of contacts : 10 × N.O. ; 10 × N.C.

Timing : The operating sequence of any disconnector auxiliary switches used in C. T. circuit and in D. C. circuits for low impedance busbar zone protection shall be such that the auxiliary switches operate: -

- (a) before reaching the pre-arcing distance on closing the disconnector
- (b) after the pre-arcing distance has been exceeded on the opening of the disconnector.

### **For Line Disconnectors**

Number of contacts : 4 × N. O. ; 4 × N. C.

Timing : as for Busbar disconnector auxiliary switches.

### **For Earthing Switches**

Number of contacts : 4 × N. O. ; 4 × N. C.

Timing : as for Busbar disconnector auxiliary switches. Auxiliary switches shall be adjustable from normally-open to normally-closed or vice-versa.

Any deviation from above, if any, should be stated in Employer's Requirements – Departures from Specification.

#### **2.1.4.9 145kV Breaker Switched Capacitor Banks**

Reactive power compensation equipment shall be installed at the substation as indicated in Scope of Works. Capacitor banks and associated switchgear and control equipment shall automatically and manually control the power factor/voltage on the High Voltage (132kV) busbar or windings of the power transformers to maintain it closer to 1 p.u. The total reactive power compensation requirement to be distributed evenly on all power transformers as indicated in the Scope of Works. The compensation shall be switched in steps in value specified in scope of work at 132kV and the value specified in scope of works is the Mvar net value input to the system at the nominal voltage (132kV).

Capacitor banks shall be three phase banks in double "Y" connection of two equally rated star connected modules with ungrounded neutrals, which made up by connection of individual standard single phase capacitor units.

#### **Studies, Calculations and Reports to be submitted before manufacturing**

Contractor has to carry out detailed study and submit a comprehensive report with preliminary design and calculations, justifying the values chosen for the design for approval by Engineer.

In this study the contractor has to submit calculations justifying the Mvar rating selected for step sizes of capacitor banks to produce step size specified in scope of work to the system at 132kV. Further this study should include harmonics, inrush and transient studies.

Contractor also shall submit design proposal for the filter circuit according to the study and should submit how the capacitor system control and monitor the harmonic overload of the equipment. Further contractor shall prove that his design would prevent the equipment from additional resonances. Transformer impedance variation with tapping range and change of capacitance values due to aging of the capacitor bank for its life time shall be considered during the calculation of series and parallel resonance.

Contractor also have to prove that from his studies and calculations, all the over voltage levels including rated voltage and insulation level selected for designing the capacitors are suitable for the installation.

Further this should include calculations supported by the studies for selection of switchgear and justifying the switchgear ratings, proving that the switchgear is fully capable of handling all currents and surges that may occur under any switching operation of the capacitor bank installation. In addition the effect of operation of the switchgear for the capacitors should also study and report.

After energizing, the targeted harmonic reduction with proposed BSC banks shall be confirmed by real time monitoring for each scenario of each substation mentioned in the initial design study. Measurements shall be carried out as per IEC 61000-4-30.

#### **Shunt Capacitor Banks**

This part of the specification covers the design, manufacture, testing at the factory, delivery to site, erection, testing at site and commissioning of High Voltage (132kV) shunt capacitor banks with associated switchgear and protection including all material

and equipment required for a complete installation and for safe and reliable operation. This includes foundation, supporting structure and fencing as well as current limiting and discharging devices, voltage and current transformers and all electrical connections of these and to the substation earthing network. Also included are the power cables from the switchgear to the capacitor banks, control cables between the substation and the capacitor banks, and the protection relays. Any other equipment or devices necessary for safe and reliable operation shall be provided even if not particularly mentioned here.

Both Capacitor banks and capacitor units shall be designed, tested and installed in accordance with IEC 60871 if not otherwise mentioned in this Specification.

The capacitor banks shall be suitable for outdoor installation under the environmental and service conditions as laid down in the respective Chapters of these Specifications, and the capacitors must be fully capable to operate and be switched under these conditions. Forced air cooling is not acceptable in order to reduce maintenance requirements.

Capacitor banks shall be three phase banks in Double-Y-connection of two equally rated star connected modules with isolated neutrals, which are made up by connection of individual standard single phase capacitor units.

### **Capacitor Units**

Capacitor units may consist of one or several capacitor elements in the single container and insulated there from. Capacitor units shall be of the single phase type with both terminals being brought out through bushings.

The capacitor units shall have a dielectric to be formed of suitable materials having well proven record and should meet the requirements of IEC 60871.

Capacitor impregnant should have a well proven record. Detailed characteristics of the impregnant must be furnished, and the impregnant may not have any PCB compound. Low toxicity is required. The impregnant shall be a class 111 B (OSHA classification) combustible fluid and shall be easily disposable by burning without generating poisonous gases, or shall be biodegradable.

Sufficiently high insulation level must be provided between capacitor element and the container.

Internal fuses shall be provided according to the IEC 60871 and for disconnection of any faulty capacitor element in order to prevent total failure of capacitor unit or bank. Any fuse operation shall not affect adjacent elements or fuses.

Each capacitor unit shall be equipped with an internal discharge device, which reduces the residual voltage from crest value of rated voltage  $U_n$  down to 50 Volts or less within 5 minutes after disconnection.

### **Unit Containers**

Capacitor units shall have housing of stainless steel. These shall be given a suitable number of coats of weather proof paint for resistance to corrosive atmospheres. The outer paint shall be high gloss in order to reduce dust deposition. Both capacitor connections shall be brought out through bushings with a minimum creepage distance of 25 mm/kV and terminals to ISO standard (metric), with the container insulated. The container shall have stud for earthing.

Lifting eye shall be provided on each side of tank for simplified installation of individual units.

The rupturing strength of the case when fitted with bushings etc. and sealed as when in service for both steady pressures and shock pressures shall be tested at the manufacturers works to demonstrate the ability of the case to withstand distortion due to internal pressure (e.g. pressure arising from dielectric, etc.).

### **Racks**

Capacitor units shall be mounted on standard racks made of hot dip galvanised steel sections which shall be provided by the contractor. The minimum substation clearances specified in section 1.3.2 of this specification have to be maintained. These racks are also to be provided. The mounting structures shall be suitable for bolting onto anchoring bolts of suitably designed foundations. Calculations on loading shall include an allowance for the weight of maintenance staff with tools (2 times 150 kg) and wind loads etc. The safe removal and safe replacement of capacitor units shall not require the dismantling of any structural member, or support including insulators and main connections. Where necessary, approved means shall be provided on the capacitor equipment for the fixing and bonding of external connections to secure efficient earthing. Steel work and all items of the capacitor equipment shall be provided with facilities for temporary earthing during maintenance.

### **Power Losses**

The losses of the capacitor banks shall not exceed 0.2 W/kvar. This shall include the losses due to the internal discharge resistors.

### **Capacitor Tolerances**

Capacitor Tolerances shall be according to the IEC60871-1. Difference in capacitance between units or group of units when connected in series shall be selected to give minimum value to avoid over voltages due to such differences.

Capacitance values shall be maintained equally for 3 phases to avoid unbalance.

### **Standard Temperature Category**

All Capacitors shall be design for standard temperature category of +5/C or higher in accordance with IEC 60871. Further the Capacitors shall be able to expose to direct ray of the sun throughout the day.

### **Maximum Permissible Overloads**

1. Capacitor units must be suitable for long duration operation under the maximum ambient temperature (Standard temperature category +5/C) at admissible voltage levels in service between terminals according to the IEC 60871-1 clause 19.1. Selection of admissible voltage level is the responsibility of the contractor. Contractor has to prove from his studies and calculations the levels selected is suitable for the installation.
2. Capacitor units must be suitable for continuous operation at an r.m.s. sine current up to 1.3 times the current which occurs at rated sinusoidal voltage and rated frequency excluding transients.

### **Name Plate**

Following information shall be given on the name plate of each capacitor unit according to IEC 60871-1:

1. Manufacturer
2. Identification number and Manufacturing year.

3. Rated output in kvar for three phase units total output shall be given.
4. Rated voltage  $U_n$  in kV
5. Rated frequency in Hz
6. Temperature category
7. Connection symbol
8. Insulation level in kV
9. Discharge device indicated by words and rated ohmic value
10. Indication for Internal fuse by wording
11. Chemical or trade name of impregnant.
12. Reference standard (IEC no.) and year of issue.
13. Measured capacitance in absolute values.

Following information shall be given on the name plate of the completed capacitor bank: according to IEC 60871-1

1. Manufacturer
2. Rated output in Mvar. Total output to be given.
3. Rated voltage  $U_n$  in kV
4. Insulation level, both the rated power frequency short duration and peak value of the rated lightning impulse voltage in kV
5. Rated frequency in Hz
6. Connection symbol
7. Minimum time required between disconnection and reclosure of the bank.
8. Time to discharge to 75V.
9. Any special instruction for safety

## Tests

### Type tests:

Following type tests are required as per IEC 60871:

- Thermal stability test.
- Measurement of the tangent of the loss angle of the Capacitor at elevated temperature.
- AC voltage test between terminals and container, dry test.
- AC voltage test between terminals and container, wet test.
- lightning Impulse voltage test between terminals and container for capacitors intended for exposed installation.
- Short circuit Discharge test.
- Test of an external fuse in combination with a capacitor.
- Disconnecting Test on internal fuses.

Test certificates are to be submitted for the approval of the Employer/Engineer. Should no satisfactory type test certificate be submitted, then type tests shall be performed in the presence of the Employer/Engineer.

Routine tests on every capacitor bank:

Following routine tests must be carried out on every capacitor on completion in accordance with IEC 60871 and test certificates to be submitted:

- Capacitance measurement.
- Measurement of the tangent of the loss angle of the Capacitor
- Voltage test between terminals.
- AC voltage test between terminals and container.
- Test of internal discharge devises.
- Sealing Test.
- Discharge test on internal fuses.

Factory acceptance tests:

Factory acceptance tests are to be performed on each completed capacitor in the presence of the Employer/Engineer unless he waives the test. The factory acceptance tests shall be the same as mentioned above as routine tests.

**Insulation levels and Rated Voltage of a Capacitor.**

The r.m.s. value of the alternating voltage for which the capacitor bank is rated, and such voltage of the capacitor unit shall be decided by the contractor considering the influence of the capacitor itself. The rated voltage shall be higher than the maximum system voltage indicated below. Design calculations shall be submitted to the engineer justifying the selection of said voltages before manufacturing. Increase in the voltage due to the connection of shunt capacitors and voltage increase due to light load conditions shall be considered for the design.

The insulation levels shall be in accordance to the IEC 60871 and shall be not less than the values listed below. Further correct insulation requirements and insulation paths shall be selected from table 7 of IEC 60871-1 justifying the reasons and suitability. Other factors such as altitude of the installation site shall also consider when selecting the insulation levels.

Highest system voltage (line to line)	Power Frequency AC test voltage (r.m.s value)	Impulse Test crest value
Um		
145kV r.m.s	275kV	650kV.

**Surge Limiting Coils**

Surge limiting coils shall be installed in each feeding phase of a capacitor bank. The inductivity shall be designed such that surges harmful to any equipment or to the substation operation are avoided. The coils shall be air insulated with bird barriers, and mounted rigidly on post insulators. The coils of the three phases may be mounted one above the other. The choice of inductivity shall be supported by a calculation to be submitted for approval.



## Switchgear

Each capacitor bank assembly shall individually be switched through an individual isolator and circuit breaker [rated to the same rating or higher of the capacitor bank rated voltage. Care should be taken to select switching devices which operate without causing excessive over voltage. If nevertheless restrike cannot be prevented, it may be necessary to use capacitors having higher insulation level and higher rated voltage.

The specification for high voltage switchgear (refer to Chapter 2.1.4) shall apply, and additionally the Contractor must prove by calculations submitted for approval by the Employer/Engineer that the switchgear is fully capable of handling all currents and surges that may occur under any switching operation of the capacitor bank installation.

## Protection

Refer Chapter 5 for protection of the capacitor banks and their feeders.

## Automatic Regulation and Control

Automatic regulation units with all necessary devices e.g. VT and CT shall be provided, which shall continuously monitor the power factor, voltage and reactive power flow at the High voltage (145kV) windings of the power transformers or busbar. Automatic on and off commands shall be given to the circuit breakers of the individual capacitor banks based on following or combination of following criteria

1. Voltage, power factor and reactive power
2. Time of day function: Which allow the capacitor bank to switch based on time of day or week
3. Control one of the selected features (i.e. voltage, power factor or reactive power), individually while the bus section is opened and as a single bus, while the bus section is closed.

The regulation criteria will be decided at the time of detail engineering stage. However, care shall be taken that a suitable hysteresis between the on and off commands is maintained in order to avoid too frequent switching.

The control shall include monitoring of the voltage to prevent excessive high voltages.

The automatic regulation devices shall be incorporated in control cubicles located in the control room, together with manual/automatic selector switches, control switches for operation of the circuit breakers including position indication of isolators and CBs, power factor meters, reactive power meters and alarm tableau. Suitable interlocking shall prevent any dangerous mal-operation.

## Alarm Indication

One alarm indication tableau for each group of capacitor banks and all associated equipment shall be mounted in the control cubicles. Any protection action, supply voltage failure or MCB trip shall initiate an alarm tableau of the substation, along with initiation of the existing horn or buzzer.

## Control Panels

The control panels shall be of the self standing fully enclosed sheet metal type, refer also to the specifications in other sections for similar panels.

The front panels shall exhibit a single line diagram of the complete reactive power compensation installation with control and check back as described for control room panels.

Measuring instruments shall include:

Power factor meter for each busbar section

Voltmeter with selector for each busbar section

Ammeter with selector switch for each capacitor bank

Other controls shall include:

Local – remote switch (remote control facilities wired up to terminals in the panels)

Automatic – manual switch

Alarm indication with multifaceted annunciator panels

Lamp test pushbutton

The protection equipment shall be incorporated in the same cubicle. .

### **Controlled Switching (Point on Wave Switching)**

Controlled Switching System (CSS) provider is responsible for the compatibility of the various equipment making up the CSS and its overall compatibility with the existing power system. The CSS shall take input from, and shall be compatible with, the network in which it is to operate and shall provide appropriate outputs, which are again compatible, to achieve the desired result.

Performance check of functionality shall be carried out on controller, sensors and circuit breaker and the complete CSS. Performance verification tests, parameter definition tests and type tests for circuit breakers intended for controlled switching applications (intentional non-simultaneous pole operation through electrical staggering) shall be performed as per IEC 62271-302.

Full details of the controlled switching system offered, i.e. the manufacturer's technical specification/manual for the controller and necessary sensors and auxiliary equipment required to achieve controlled switching, shall be supplied with the tender documentation.

### **Controller for Controlled Switching**

The controller shall be of modular design and shall be mountable in the front side of the standard control panel. The control IEDs, based on microprocessor technology, shall use numerical techniques for the calculation and evaluation of externally input analogue signals.

Protection trip signals shall bypass the switching controller and the controller shall be integrated to the existing substation automation system. Apart from the protection bypass, a switch shall be provided to switch the controller to In Service condition or Bypass condition.

The supplier shall provide proof with the Tender documentation that the communication interface of the controlled switching device (point-on-wave) is compliant to IEC 61850.

The controller and its associated circuitry shall be located at a remote location in the control room associated with the particular circuit-breaker.

The controller shall have necessary facilities to perform adaptive control which shall be a microprocessor based feature adapting the device to program itself to correct circuit breaker switching times in the event of contact drift when supply DC changes, ambient temperature changes and or breaker SF6 pressure changes. The operating time of the

last operation must be compared to the actual operating time and the time shift discrepancy shall be limited to maximum 1ms from one operation to another.

### **Control Functionality**

The controller shall be able to limit the over voltages and reduce inrush currents during circuit breaker closing and eliminate possibility of restrike during circuit breaker opening. One of the following two methods shall be adopted for capacitor bank closing depending on the capacitor bank design studies.

- a. Phase A, Phase B and Phase C shall be closed at individual voltage zero points. Phase A can be used as the reference for the controller.
- b. Phase A and Phase C shall close simultaneously and Phase B later. Phase A shall close 1.667ms after reference voltage passed through a voltage zero. Phase C shall close at the same time as Phase A. Phase B shall close 6.667ms later after the reference voltage passed through voltage zero. The closing sequence shall be A/C-B.

Following parameters of the circuit breaker shall be considered for selecting the optimum target operating point.

1. Scatter of mechanical operation
2. Rate of Decrease of the Dielectric Strength of the contact gap (RDDS)
3. Rate of Rise of the Dielectric Strength of the contact gap (RRDS)

## **2.1.5 HIGH VOLTAGE 245 kV OUTDOOR SWITCHGEAR**

### **2.1.5.1 Circuit Breakers 245kV**

The three phase circuit breakers shall be of the SF<sub>6</sub> gas type and shall comply with IEC 62271-100. An independent type test certificate has to be submitted with the Bid. The circuit breakers shall be able to carry the rated current, interrupting all currents from zero to the symmetrical and asymmetrical fault currents, as well as inductive currents. Restrike free switching must be guaranteed for line charging currents up to at least 145 Amps.

The circuit breakers shall be suitable for trip free independent operation. Single break per phase and rapid single short auto reclosing for three phases or single phase switching has to be provided. A phase discordance timer relay shall trip all phases in case of prolonged phase discordance, and an anti pumping device shall be equipped. In case of low gas pressure not permitting safe interruption of the full rated breaking current, the operation shall automatically be blocked through a pressure sensitive temperature compensated device. The arc extinguishing devices, especially the fixed and moving contacts, shall be easily accessible for inspection and maintenance.

The circuit breaker shall be capable of coping with the interrupting duties produced by out of synchronism conditions associated with auto reclosure.

The high voltage terminal bolts of circuit breakers shall allow connection on either side of the circuit breaker and be convertible and suitable for clamp type connectors.

The circuit breaker shall be equipped with brown-coloured porcelain insulating columns provided with shed.

Two M 12 screws have to be provided and installed for earthing the equipment.

The operating mechanism shall, as far as practicable, be located with respect to the circuit breaker to allow inspection and maintenance work during normal service. Each switching chamber shall be equipped with an absorber for moisture and for detrimental composition products of the SF<sub>6</sub> gas produced during arcing.

Thermostatically controlled heaters with a setting range of at least 15 °C to 45 °C for continuous operation at the rated AC voltage as well as suitable ventilation shall be provided on all operating mechanisms and control cubicles installed outdoor to prevent ingress of moisture, e.g. by entering cables through cable glands.

A suitable energy storage system shall ensure uniform and positive closing and opening. Pneumatic systems operating on compressed air and hydraulic operating mechanisms are not accepted. If the energy storage system is not fully recharged within a predetermined time, further operation shall be locked and suitably indicated. The capacity of the energy storage system must ensure a complete CO-CO cycle (Under auxiliary supply failure).

The operating mechanism shall be self-contained for each circuit breaker. Auxiliary power for control circuits shall be supplied by the DC network, while power for motors or pumps shall be supplied from the AC network. The activation of switching operations shall be through electric coils, one for closing and two independent ones for opening.

Mechanical indicating devices shall be provided showing whether the breaker is in the “open” or “closed” position. The state of the energy storage shall be indicated by a mechanical device or by pressure gauge.

The auxiliary switch for remote switch position indication shall be connected with the moving contact member by means of mechanical linkage only.

A sufficient number of cable entry glands shall be foreseen on all operating mechanisms and terminal blocks shall be supplied and installed as appropriate.

The mechanism of each circuit breaker shall be designed so that it can be operated from the control room and control and terminal cabinet (as the case may be) and locally at the circuit breaker. The operating mechanism shall be furnished with a local-remote selector switch and local push buttons or a standard control switch, mounted in the mechanism and wired in the control circuits. Local electrical opening and closing of the breaker shall be permitted only when the selector switch is in the “local” position. If it is in “local” position, this must be indicated in the control room.

All circuit breakers shall be connected for remote control as described. This shall be comprised “on-off” control and “open”, “closed” and “discrepancy” indication on the switchboards and in the control room of the station. Electrical opening and closing of the breaker locally shall be permitted only when the selector switch is in the “local” position. The operating mechanism shall be provided with an operating counter.

The operation voltage of the CBs shall be as specified in Technical Particulars and Guarantees.

### **2.1.5.2 Disconnecting Switches and Earthing Switches**

Disconnecting and earthing devices shall be designed to comply with IEC 62271-102. They shall be complete with supporting steel work and installed to permit maintenance of any section of the substation plant when the remainder is alive and shall be so

located that the minimum safety clearances stated in Chapter 1 of this Specification are always maintained.

In outdoor substations, disconnectors shall be of the double rotating post type with single air break.

Circuit disconnecting switches shall be rated not less than that of the associated circuit breaker except bus section and bus coupler disconnecting switches which shall be rated not less than that of the associated busbars.

Disconnecting switches will not be required to switch current other than the charging current of open busbars and connections or load current shunted by parallel circuits. Where specified for transformer banking at 245 kV and lower voltage they shall be capable of switching transformer magnetising currents. Main contacts shall be of the high contact pressure line type and arcing contacts, if provided, shall be to the approval of Engineer.

Service conditions require that disconnecting switches shall remain live and in continuous service for periods of up to two years in the climatic conditions specified and without operation. The contacts shall carry their rated load and short-circuit currents without overheating or welding.

The earthing switch, when in the closed position, shall be capable of carrying the rated short-time current without the contacts burning or welding.

The earthing switches shall be of self closing/ spring release type and shall be interlocked with 'live' feeder.

Disconnectors shall be motor operated, but approved means for manual operation shall be provided. Motor enclosure shall comply to protection class IP 54 (weatherproof).

The local control cubicle shall contain a LOCAL/REMOTE control switch as well as OPEN/CLOSE control switches or push buttons. Necessary switches/contactors/contacts shall be provided for interlocking, alarming and remote operation from the Control room.

At least one normally closed and one normally open spare auxiliary contact shall also be provided. All operating mechanisms shall be provided with locks to secure them in either the open or closed position of the disconnector/earthing switch.

Where specified disconnectors shall be fitted with approved three phase line earthing devices, mechanically coupled or interlocked with main disconnector so that the earthing device and main Disconnector cannot be closed at the same time.

Disconnecting devices shall be electrically interlocked with circuit breakers and other disconnectors, as necessary, to prevent possibility of making or breaking load current. Further safety interlocking shall be provided as specified.

All isolators shall be porcelain insulated and provided with safety platforms to protect operators from dangerous potentials. The safety platforms shall be installed at the place from which the operating mechanism has to be operated, they shall be secured to the support structures and be connected to the substation grounding grid.

For corrosion protection of all ferrous parts, hot dip galvanising shall be applied as well as other measures as specified in Technical Specification – Grid Substation.

### 2.1.5.3 Capacitor Voltage Transformers

Voltage transformers for 245 kV shall be of the capacitor type. Type shall comply with IEC 61869-5 and the requirements of this Specification. Voltage transformers shall be of the CVT type and equipped with power line carrier coupling devices wherever necessary. The capacitive voltage transformers shall supply measured values to protection equipment, measuring instruments, meters and voltage regulating devices, and shall in addition be used for power line carrier coupling to the respective equipment.

Capacitor type voltage transformers shall be suitable for use as line couplers for the operation of carrier accelerated tripping and communication systems and where specified the top cap of voltage transformers shall be suitable for mounting wave traps.

Primary clamps and connectors shall be fitted on voltage transformers, suitable to connect earthing devices.

The insulating body shall be of brown glazed porcelain with alternating or uniform sheds.

The voltage transformers shall be either of the oil immersed or Gas insulated, hermetically sealed post insulator type. The oil-immersed type shall be equipped with an oil level indicator and provided with oil filling and oil draining plugs. They shall be suitable for phase-to-ground connection.

An intermediate transformer (electromagnetic unit) shall give maximum insulation reliability under all operating and environmental conditions.

The voltage transformers must be designed such as to avoid ferroresonance under all possible modes of operation.

The secondary windings shall be connected through protective switches having sufficient auxiliary contacts to provide for alarm indications and the necessary signalling to protection and synchrocheck equipment. Each circuit connected to the secondary shall be provided with a separate miniature circuit breaker with the proper dimension to protect this circuit.

The miniature circuit breaker, which protects the secondary winding, shall be located as near to the transformer as possible and in a weatherproof metal clad box.

The secondary circuits of voltage transformers shall not be connected in parallel. The voltage transformer ground connection shall be earthed through a link, which can be removed for insulation testing.

The rated primary voltage of voltage transformers shall be equal to the nominal system voltage. The insulation rating of the voltage transformer shall allow, at site conditions, a 20% continuous overloading referred to nominal rating of the voltage transformer.

All the voltage transformers shall have an output rating adequate to cope with the burdens connected to them.

The voltage transformers shall have an accuracy of 0.5 percent. For all networks where overvoltages caused by resonance effects between the network and inductance of the voltage transformers may occur, the manufacturer of the voltage transformers shall take all necessary measures to avoid this effect (providing resistors for open delta connections, etc.).

The voltage transformer shall be insulated to withstand overvoltages including impulse voltage of a level equal to withstand value of the switchgear and the high voltage system.

For very high-speed protection, transient oscillations should be minimised. In this respect, the supplier has to consider the data of the capacitive voltage transformers in order to guarantee proper performance of the protection.

The voltage transformers shall be provided with:

- weather-proof secondary terminal box
- earthing terminal
- mounting bolts
- oil-filling and drain valve if applicable
- earthing terminal using stranded copper of at least 120 mm<sup>2</sup> cross-section
- porcelain shall be made of high quality wet-process porcelain which shall be homogenous and not porous in order to withstand humidity.

The secondary insulation shall withstand a test voltage of 2 kV r.m.s. for 1 min.

#### **2.1.5.4 Current Transformers**

Current transformers shall comply with IEC 61869-2 and the requirements of this Specification.

They shall have a short time primary current rating not less than that of the associated switchgear. The thermal rating of the current transformer shall allow, at site conditions, a 20% continuous overloading referred to nominal rating of the current transformer.

The terminal designation of the primary and secondary windings shall be in accordance with IEC recommendations. Where double ratio secondary windings are specified, a label shall be provided at the secondary terminals of the current transformer indicating clearly the connection required for either ratio. These connections and the ratios shall be shown on the appropriate schematic and connection diagrams.

Current transformers provided for protection purposes shall have over current and saturation factors of not less than those corresponding to the design short circuit level of the system. The output of each current transformer shall be not less than that specified and the Contractor shall ensure that the capacity of the current transformers provided is adequate for operation of the associated protective devices and instruments.

The windings shall be located in accordance with the requirements of the single-line diagrams or typical feeder drawings as per Drawings.

To guarantee the correct protection relay operation, a through-fault stability calculation shall be submitted showing the correctness of the chosen current transformer core, i.e. rated output, class of accuracy, rated accuracy limit factors, the rated primary current, turns ratio, knee-point e.m.f. and resistance of the secondary windings (corrected to the maximum service temperature). The contractor has to increase the rating at no additional cost to the purchaser, if necessary to achieve linear protection relay operation. Magnetisation and core loss curves shall be provided for each type and rating of current transformer.

The current transformer supplier is bound to co-operate closely with the protection supplier, and to make all required data available for relay calculations at an early stage of the Contract period. Reference is made to the Article of Protection Relays below.

For outgoing feeders, the Contractor shall make sure that the current transformer characteristics match the data of the relevant opposite feeder, this requirement supersedes the figures as may be stipulated in the Bidding Documents.

Where an existing balanced protective scheme is being extended, the Contractor shall ensure that any additional current transformers are correctly matched to the existing equipment.

Current transformers shall be of the porcelain insulated, oil-immersed and hermetically sealed or SF<sub>6</sub> gas insulated post insulator type. In the case of oil immersed current transformers, they shall be equipped with oil level indicator and provided with oil filling and oil draining plugs. They shall be connected to other switchgear in such a way that undue mechanical stress cannot be exerted on the transformer winding.

Where neutral current transformers are specified they shall be of the ring core design.

All the current transformers and auxiliary transformers shall be of the low reactance type and, unless other wise approved, shall be of the bar-primary design capable of carrying the rated primary current for a period of one minute with the secondary winding open-circuited.

Secondary windings shall be rated for 1A.

If not specified otherwise, the test voltages on the secondary windings against earth shall be at least 3 kV.

Secondary windings that are not loaded must be short-circuited before the transformer is energised. This applies to all cores of the transformers, however, not to unloaded parts of tapped windings, provided that the other section is loaded or short circuited.

Current transformers for indication or metering shall have their secondary winding earthed directly at the current transformer. The secondary windings of the current transformers for protection shall be earthed only once at the panel which accommodates the associated relay. The earth connection shall be made via a removable link and shall be wired through the test block.

#### **2.1.5.5 Surge Arresters**

Arresters shall comply in all respects with IEC 60099 and shall be entirely suitable for operation under the system conditions specified including system voltage rises on unloading long transmission lines and shall have sufficient capacity to discharge system charging currents without damage.

The surge arresters shall be of the gapless metal-oxide and heavy-duty type.

Arresters shall be housed in porcelain or composite insulation containers sealed against the entry of moisture and oxygen. All internal components shall be designed to minimise internal corona and also to ensure minimal capacitive coupling with any conducting layer of pollutant on the outside of the porcelain housing. Surge arrester shall have the rated voltage, minimum spark over voltage and insulator creepage distance as specified in Chapter 1 of this specification.

The surge arresters shall be equipped with a grading ring. If necessary, an internal grading system may control the voltage distribution along the metal oxide resistor stack. Rupture diaphragms shall prevent damage by overpressure.



Discharge counters shall be provided to indicate the number of operations for each surge arrester. The discharge counter shall be connected in the main earth lead from the arrester in such a manner that the direction of the earth lead is not changed or its surge impedance materially altered. Bolted links shall be provided so that the discharge counter may be short-circuited and removed without taking the arrester out of service.

Connection to ground shall be performed by copper bars or copper strands of adequate cross section connected to the substation/gantry general grounding grid.

Surge arresters shall be constructed and tested in accordance with applicable IEC standards at the Supplier's premises.

The supporting structure shall be protected against corrosion as specified Technical Specification – Grid Substation.

#### **2.1.5.6 Busbar system 245kV and Interconnections between HV equipment**

The busbar system shall be constructed in such manner that future extension on both ends is possible without necessity to shut down both busbars at the same time.

The 245kV strung busbar shall be of minimum of 2 x 500 mm<sup>2</sup> double bundled conductor of electrolytic copper, tensioned with 2 kg/mm<sup>2</sup>, or appropriate aluminium alloy conductor. The conductor bundles shall be strung between double dead end strings of long rod insulators or cap and pin type insulator strings, fitted with arcing horns.

The Bidder may also quote adequately dimensioned aluminium conductor steel reinforced (ACSR), respectively.

Where necessary, round solid or tube conductors shall be used, in which case post type insulators shall be used as support.

The conductor types shall comply with the corresponding recommendations of IEC 61089. The general construction of the connections and their insulator supports shall be approved design, shall be mechanically strong and shall withstand all the stresses which may be imposed on them during ordinary work due to fixing, vibrations, climatic conditions, short circuit or other causes. The dimensioning for mechanical and thermal short circuit strength shall be made to fulfil the requirements of IEC 60865.

All connections shall be kept as short and as straight as possible. Provisions shall be made to allow expansion and contraction of all the connections due to changes of temperature, and under load and short circuit conditions while keeping the whole system in perfect operating conditions, also without application of excessive stress to any part of the system or the supporting structure.

The Contractor shall supply all necessary terminals and fittings for the connection of all equipment and cables of the station to allow perfect operation. Where necessary, bimetallic clamps, terminals and fittings shall be used to prevent corrosion. Clamps and fittings shall fulfil the requirements of BS 3288 and shall be of the compression type designed to avoid deformation of stranded conductors. They shall be able to bear the load implied by the conductor at the chosen arrangement, plus a wind load of 970 N/m<sup>2</sup> on the projected conductor area, with a safety factor of 2. Suspension clamps shall be free to pivot in the vertical plane of the conductor.

The Contractor has to present for approval and justify the proposed layout with view to corona discharge, mechanical and thermal stability and clearances to earthed and live parts.

### 2.1.5.7 Insulators

All insulators shall be of porcelain and shall satisfactorily withstand the specified climatic and service conditions. The strengths of insulators as given by the electro-mechanical test load shall be such that the factor of safety when supporting their maximum working loads shall not be less than stated in Chapter 1 of this specification. The minimum specific creepage distances of outdoor insulators shall be as specified in Chapter 1 of this specification. Unless otherwise approved, individual insulator units or sets or strings shall be identical and interchangeable.

Designs shall be such that stresses due to expansion and contraction in any part of the insulators and fittings do not lead to development of defects. Outdoor insulator fittings shall remain unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

Porcelain insulators shall be in accordance with IEC 60168 and 60273. Porcelain shall be sound, free from defects and thoroughly vitrified and glazed. Glazing shall be smooth, hard, of a uniform shade of brown and shall completely cover all exposed parts of the insulators and follow the relevant IEC standards.

Each insulator shall have marked on it the manufacture's name or trademark. Tension and suspension insulators shall also be marked with the guaranteed electro-mechanical strength. Marks shall be visible after assembly of fittings and shall be imprinted and/or impressed. For porcelain insulators, the marks shall be imprinted before firing and shall be clearly legible after firing and glazing.

Porcelain shall not engage directly with hard metal and where necessary, approved water and oil resistant yielding material shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces shall be of approved quality and applied in an approved manner and shall not be chemically active with the metal parts or cause fracture by expansion in service. Where cement is used as a fixing medium, the cement thickness shall be as small and as even as possible and care shall be taken to correctly centre and locate the individual parts during cementing.

When a batch of insulators bearing a certain identification mark has been rejected no further insulators bearing this mark shall be submitted, and the Contractor shall satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there is no possibility of the insulators being subsequently resubmitted for tests or supplied for the Purchaser's use.

Suspension and tension insulators shall comprise porcelain or glass units with ball and socket fittings. Each tension insulator shall consist of a single string of insulator units or long-rod insulator and the associated fittings shall be in accordance with IEC 60383-2 and IEC 60305.

Porcelain insulators shall be secured in an approved manner, preferably by means of bolts to metal clamping plates with suitable packing material interposed.

Retaining pins or locking devices for insulating units shall be of phosphor bronze or other approved material, and shall effectively prevent accidental separation of the units.

### 2.1.6 TEMPORARY EARTHING FACILITIES

The facilities shall include an insulated rod of sufficient length with handles and a mechanism on one end which allows establishment of firm contact of the attached

flexible earthing conductor to connection points at selected locations in the HV switchyard or at transformers. The flexible conductor shall have sufficient length and be designed for the rated short circuit current of the installation. Suitable earthing points shall be located conveniently near all locations of connection points.

### 2.1.7 OPERATING CUBICLES

Equipment operating mechanisms, auxiliary switches and associated relays, control switches, control cables terminations, and other ancillary equipment shall be accommodated in sheet steel or Aluminium alloy vermin-proof and weatherproof cubicles. Where appropriate, the cubicles may be free standing with front and rear access.

Cubicles shall be of rigid construction; either folded or formed on a framework and shall include any supporting work necessary for mounting on the circuit breaker or on concrete foundations. The cubicle shall be anodised aluminium or galvanised steel. If they are made of steel, the galvanising should be in accordance with BS EN ISO 1461:1999 (i.e. at any place density of Zinc should be more than 610 mg/m<sup>2</sup> and thickness should not be less than 0.086 mm). Bolts or carriage keys shall not be used to secure the panels or doors. All fastenings shall be integral with the panel or door and provision made for locking. Doors and panels shall be rigid and fitted with weatherproof sealing material suitable for the climatic specified. The cubicle shall comply protection class IP 54.

Cubicles shall be well ventilated through vermin-proof louvers comprising a brass gauze screen attached to a frame and secured to the inside of the cubicle. Divisions between compartments within the cubicle shall be perforated to assist air circulation. In addition, an anti-condensation heater of an approved type shall be provided and thermostatically controlled switch mounted within the cubicle.

Access doors or panels shall be glazed where necessary to enable instruments to be viewed without opening the cubicles. The arrangement of equipment within the kiosk shall be such that access for maintenance or removal of any item shall be possible with the minimum disturbance to neighbouring apparatus.

Equipment control position selector and equipment operating control switches shall be installed in the cubicle. Equipment control from this position will be used under maintenance and emergency conditions only. Remote operation to be blocked when in 'local' mode.

An approved schematic diagram of the part of the control system local to the circuit-breaker, identifying the various components within the cubicle and on the circuit-breaker and referring to the appropriate drawings and maintenance instructions, shall be affixed to the inside of the cubicle access door. The diagram shall be marked on durable non-fading material suitable for the specified site conditions.

All incoming auxiliary supply cables shall be terminated on heavy-duty terminals, where the terminals shall be of required size to accommodate for looping these supplies into similar cubicles on the same substation site.

The circuit title and Purchaser's operational code shall be prominently displayed on a permanent label mounted on the outside of the cubicle. Label shall be interchangeable.

Thermostatically controlled heaters with a setting range of at least 15<sup>0</sup>C to 45<sup>0</sup>C for continuous operation at the rated AC voltage shall be provided in each local control cubicle installed outdoors to prevent condensation.

## 2.1.8 INTERLOCKING FACILITIES

Disconnectors, earthing switches, circuit breakers, etc. shall be provided with an interlocking system, which ensures safe operation of the equipment under all service conditions.

### (i) Mechanical:

Mechanical key interlocks shall be employed and shall be effective at the point where hand power is applied so that stresses cannot be transferred to parts remote from that point.

Emergency tripping devices shall be kept separate and distinct from the key interlocking system and shall be clearly labelled, suitably protected from inadvertent operation but readily accessible.

At existing substations where equipment is being extended, interlocking facilities and associated equipment shall be identical with and form a comprehensive extension to the existing interlocking scheme.

Circuit breakers shall be interlocked so that except under maintenance conditions it is not possible to close a circuit breaker unless the selected busbar and circuit disconnectors are closed.

Except as stated below, disconnectors shall be interlocked that they cannot be operated unless the associated circuit breaker is open. Where power transformers are banked together, the individual transformer disconnectors shall be interlocked so that it is not possible to make or break load current at the disconnectors.

### (ii) Electrical:

The interlocking shall prevent any incorrect operation of the circuit breakers, disconnecting switches and the earthing switches. The system shall be designed at least to fulfil the general requirements. The total interlocking scheme to be supplied by the Contractor shall be subjected to the approval of the Engineer at the early stage of the design phase.

The control units/local control panels allocated to each feeder bay shall contain all operating and interlocking controls, the protective circuit breakers of the drives etc. and all necessary indications. Local operation control by means of discrepancy switches must be provided for all switching devices, and the positions of the Disconnectors, the circuit breaker and the earthing switches shall be exactly represented in mimic diagrams.

## 2.1.9 ON LINE CONDITION MONITORING SYSTEM FOR HIGH VOLTAGE CIRCUIT BREAKERS (NOT APPLICABLE)

Where specified in the Scope of Works, a microprocessor based condition monitoring system which should provide diagnostic information of High Voltage Circuit breakers shall be supplied.

After every breaker operation the unit shall perform a Fingerprint analysis by comparing recorded data to a reference record with programmable limits which are held in memory. If any of the limits are exceeded, an alarm shall be activated to indicate the characteristics of the breaker have changed beyond the acceptable limits

Test records shall be stored within the unit's internal memory and shall be retrieved at a later date via direct computer link on site.

Records and summaries shall be downloaded from the unit to, a Windows based software package which is also to be supplied with the license. The software shall include a configuration program to allow local or remote modification of the unit. The following minimum functions shall be available in the offered system.

- Automatic "fingerprint" comparison of breaker characteristics
- Accumulated fault current arcing time (e.g.,  $I^2t$ ) calculated for each pole
- Alarms activated when maximum contact duty exceeded or breaker characteristic changes
- Local and remote communications
- Powerful Windows based communications and analysis software
- Recording : at least 2kHz

## 2.2 INDOOR SWITCHGEAR

### 2.2.1 MEDIUM VOLTAGE SWITCHGEAR

#### 2.2.1.1 General

This part of the Specification covers the design, ratings, testing, shipping, installation and commissioning of factory assembled, type tested switchgear.

The descriptions cover only those general aspects, which are considered minimum quality- and performance-requirements by the Engineer. Further detailed and specific data are contained in the drawings, data sheets and other documents that form part of these Bidding Documents.

The switchgear shall be complete, ready for installation, with all components furnished unless specifically excluded herein and as may be listed in Scope of Works /Technical Particulars & Guarantees under Employer's Requirements.

Spare parts, if required by the Bidder for operation & maintenance, shall be quoted, separately as required by the Schedules of Rates & Prices.

The complete documentation, drawings, manuals, etc. shall be included in the Supply and will be subject to the approval of the Engineer according to the requirements of these Specifications.

Standard designs and models from the Bidder's manufacturing program are preferred, provided they meet the requirements of these Specifications, serve the intended purpose, and can be shown to have at least five years of successful service in the field.

If a substantial improvement of any or all of the specified requirements expressed or implied herein is available from the Bidder, and this improved design offers economical advantages to the Employer, this should be offered as an alternative, together with the basic proposal which shall conform to the requirements of these Specifications.

All the equipment described in these Specifications is intended for continuous duty at the specified ratings under the specified ambient conditions. Unless otherwise noted, the switchgear shall be for front access only during operation and maintenance.

Data and documentation submitted with the Bidding Proposal shall enable the Engineer to evaluate the quotation against the requirements of the Specifications. Full descriptive information and filled-in data sheets are required as a minimum.

### 2.2.1.2 Switchgear Particulars

The description within these Specifications is made for the switchgear type using SF<sub>6</sub> gas as the insulation medium

Feeder cable terminations, cable plugs, stress cones etc. are part of the Scope of Supply for outgoing feeder cables.

The feeder bays or panels shall be delivered completely, including all necessary material for fixing them on suitable plinths or rails.

The switchgear equipment shall be dust-proof and vermin-proof and provision shall be made against condensation, particularly if the load is switched off.

The infeed transformer bay or panel shall be placed in such a way that the current stress of the busbars is minimized. In the case of the heavily loaded transformer feeders, requiring an ancillary bay or panel next to the transformer infeed may be provided to accommodate multiple cable sealing ends and auxiliary equipment. In this respect, the cable ducts for the cables running from the infeed transformers to the MV switchgear should be arranged to end exactly under the relevant transformer bay or panel.

Protection relays and their associated instrument transformers are part of Scope of Supply. The relays shall be installed in the low voltage compartments associated with each individual switchgear bay or panel and its circuit breaker. The functions of the protection relays are indicated in the typical single line diagrams in Drawings and their required performance shall be in accordance with Chapter 5 of Technical Specification – Grid Substation. If the Bidder is of the opinion that the indicated protection scheme is not optimal, he shall indicate this fact in his proposal along with suggested improvements.

### 2.2.1.3 Performance, Standards and Codes

The switchgear shall operate satisfactorily within its rated values in the environment specified in Chapter 1 of this specification.

The switchgear is planned to be installed indoors in an air-conditioned room with a maximum service temperature of +30°C. However, service with rated data shall be guaranteed also in case the air-condition-system fails, or will not be installed. Therefore, the maximum ambient shade temperature at Site shall be the basic design data for the switchgear.

Routine maintenance to any of its external components, including the protective relays and instrument transformers, shall not be required in less than five year intervals; internal components shall be maintenance-free for at least ten years, including the refilling of SF<sub>6</sub> gas (if any).

Performance, testing and rating of the switchgear shall conform to the latest edition of all relevant IEC Publications under the appropriate voltage category .

Bidder's proposing other than the above standards must specifically indicate the standards to which his switchgear conforms, and indicate all deviations (if any) from the above codes that affect performance and rating.

Compliance of the switchgear manufacturer and the Contractor with the provisions of this Specification does not relieve the Contractor of the responsibility of furnishing switchgear and accessories of proper design, electrically and mechanically suited to meet the operating guarantees at the specified service conditions.

## 2.2.1.4 Design and Construction

### Electrical Data and General Requirements

- a) Electrical key data as required by this Specification are stated in Scope of Works and in the enclosed single line diagram.
- b) The switchboard, when installed and operating under the ambient conditions shall perform satisfactorily and safely under all normal and fault conditions. Even repeated operations under full rated fault conditions shall not lead to diminished performance or significantly shortened useful life of the switchgear. Arc faults caused by external reasons shall be positively confined to the originating compartment and shall not spread to other parts of the switchgear.
- c) Temperature rise of current carrying parts shall be limited to the values stipulated in IEC 60694, i.e. +65°C for silver-plated contacts, +75°C for silver-plated connections, and +50°C for all other exposed parts, under rated current and the environmental conditions.
- d) Lightning Impulse withstand capability and power frequency withstand capability for the entire switchboard shall be in accordance with IEC 60694, Table I and values required in schedules of technical particulars & guarantees.
- e) Bracing of all mechanical components against the effects of short circuit current shall be a minimum of 2.5 times the rated symmetrical short circuit current.
- f) Thermal rating for all current carrying parts shall be a minimum of one second for the rated symmetrical short circuit current. If the maximum short circuit time must be extended, the  $I^2 \times t$  value shall remain constant.
- g) The auxiliary voltages as per Chapter 1 are to be considered for the design, in particular for the Motor control voltage, the Alarm voltage, the Close and trip voltage and the Space heater voltage.
- h) The switchgear shall be of the free-standing, self-supporting, dead front design with all high voltage equipment installed inside metallic and earthed enclosures, suitably divided into individual compartments, at least for the
  - busbar system(s)
  - circuit breaker
  - cable connections
  - low voltage compartment
- i) Partitions between feeder bays or panels are required to avoid fault spreading from one feeder bay or panel to the other one and to the outside.
- j) The row(s) of bays or panels shall be earthed through a suitable copper bar, which is to run along the full length of the switchgear, and to be connected to the station earthing, at least at two points.
- k) The erection of the switchgear shall not require any cutting, welding or drilling of material on site. Each line-up of switchgear shall be prepared for future

extension on either end without any drilling, cutting or welding on the existing equipment.

- l) The design shall provide for maximum levels of reliability, ease of operation and maintenance, and maximum flexibility. The possibility of field repairs and exchange of enclosure parts shall be taken into account. The panels shall be constructed identically to ensure that equivalent switchgear parts can be interchanged.

Design of the switchgear must allow for the removal of individual breaker bays, or parts thereof, without disturbing the remaining bays. It shall be possible to exchange an entire feeder, with or without its busbar section, without dismantling neighbouring bays.

- m) Busbars and their enclosures shall take thermal expansion of the entire switchboard into account. Suitable mounting facilities, bellows and compensators shall be provided where necessary.

### **Safety Requirements**

- a) The switchgear shall offer a maximum degree of safety for the operators and by-standers under all normal operating and fault conditions. In particular, it must be impossible to unwillingly, i.e. without the use of tools, touch live parts of the switchgear, or perform operations that lead to arcing faults.

For mechanical protection of the switchgear elements, panels with a minimum of Protection Class IP 41 is required, i.e. enclosed and inaccessible for granular foreign bodies during normal operation and protection against vertically falling water droplets.

All high voltage carrying parts shall be totally protected against contact with live parts.

- b) Should internal arcing occur, the release of pressurised air or gas by suitable pressure relieve devices into the atmosphere must occur in such a way that personnel standing at the operating position of the switchgear will not be injured. Furthermore, no part of the enclosure or any loose parts may fly off the switchgear in such an event, and no holes may burn through enclosures. All earthing connections must remain operational during and after an arc fault.
- c) All interlocks which prevent potentially dangerous fail-operations must be constructed such, that they cannot be by-passed easily, i.e. the operator must use tools or force to bypass them.
- d) Energy storing mechanism of breakers must be totally enclosed with the switchgear in the operating condition.
- e) All low voltage terminals remaining "live" after the main feeder has been disconnected shall be wired to particularly marked terminal blocks and shall carry suitable warning tags.



- f) The isolator/grounding selector switch and/or the line's side earthing switch must be able to be padlocked in the "ISOLATED" and the "OPEN" and the "GROUNDED" positions, respectively.
- g) For each outgoing cable feeder an inductive or capacitive voltage detector with cable live indication shall be provided, indicating any reverse voltage, i.e. at least by means of voltage transformers plus lamps (including lamp test facilities).

### 2.2.1.5 Isolator and Earthing Switches

- a) Means to safely isolate and ground any feeder in the switchgear shall be provided. Motor operated isolation/grounding switches suitably interlocked with the breaker shall be provided. In case of double busbar systems, the busbar selection isolators shall be provided with motor drive facilities, however, manual operation shall also be available for both single and double busbar system.
- b) Isolation/grounding switches shall be designed to withstand the rated and fault current of the largest breaker interrupter element that can be fitted into the switchgear.
- c) Designs where the actual grounding of the feeder is done via the circuit breaker, i.e. where the isolator is used only to pre-select the grounding position are also accepted.

Such three-way switches must have definitive stops at their "ON", "ISOLATED" and "GROUNDED" positions, with no direct movement from the "ON" through the "ISOLATED" into the "GROUNDED" position.

- d) View-ports or mechanical indicators connected directly and permanently to the operating shaft are required to positively display the actual switch position. Indirect position indicators are not acceptable.
- e) With the selector switch of any feeder in the "GROUNDED" position, it must be possible to safely exchange the breaker element while the remaining switchgear is live.

### 2.2.1.6 Circuit Breakers

- a) Vacuum circuit breakers or SF<sub>6</sub> with totally enclosed and maintenance-free contact system are acceptable.
- b) Circuit breakers shall conform to Publication IEC 62271-100 in terms of rating, testing and performance, but they may conform to the standards of the country of manufacture for construction requirements, provided these standards do not conflict with the corresponding IEC 62271-100 rules and are acceptable to the Engineer.
- c) Breaker operating mechanisms shall be of the electric DC motor operated, stored energy type, with provisions for manual operation in case of control power failure. All breakers must be electrically trip-free and have anti pumping circuits. After loss of control power, the springs of the operating mechanism shall be capable of performing a sequence of OFF-ON-OFF operations with rated data.

- d) A manually operable local trip push-button (mechanically working onto the trip shaft) shall be available, and all breakers shall be suitable for remote control.

Manual, mechanical ON-switching shall be prevented if interlocking condition exists. Mechanical indicators shall be provided to show the ON/OFF position of the breaker contacts. Operation counters shall be provided.

- e) Maintenance intervals of circuit breakers shall not be less than 25 full rated short circuit interruptions, 10,000 rated current interruptions, or 10 years, whichever comes first.

Replacement of the breaker interrupter must be possible (at gas-insulated switchgear, the remaining part of the switchgear may be kept "live" and must not involve the use of special tools or delicate alignments).

- f) Spare auxiliary contacts, 2 N/O, 2 N/C, 1 Impulse, rated at least as specified in schedule of technical particulars & guarantees shall be provided in addition to those required for breaker operation.

These contacts shall be wired to the terminal blocks for use at the LDC terminal cubicles. Additional contacts as required, e.g. for interlocking, shall be provided and incorporated in the control system.

- g) Rated nominal current of circuit breakers shall be selected to the rated values listed in Scope of Works & Technical Particulars & Guarantees in order to reach the required rating, once the breaker is installed inside its enclosure. The feeder nameplate shall indicate the actual site rating of the feeder at maximum ambient temperature in addition to the nominal rating of the breaker.

#### 2.2.1.7 Interlocking System

Electrical and mechanical interlocking, which shall at least fulfil the conditions as listed below, shall be provided. The final interlocking scheme shall be proposed by the Contractor and shall be subject to the approval of the Engineer.

- a) The interlock system must positively prevent an operator from reaching or creating unintentionally a dangerous or potentially dangerous condition. Systems that can be by-passed without the use of tools and/or force are not acceptable.
- b) All necessary electrical interlocks shall be provided as specified, particularly for the incoming feeders and the bus-tie breaker. Reference is made to the related sections of the High-Voltage switchgear of this Specification.
- c) When the manual emergency crank for the breaker is in use, it shall be impossible to control the breaker electrically (provision of limit-switch or de-clutching of the crank).
- d) All breakers for remote control shall have a key-operated switch, allowing the selection of LOCAL - REMOTE operation modes as detailed below.
- e) The interlocking of the circuit breakers of the SF<sub>6</sub> gas insulated switchgear type shall prevent the following in addition:

- operating the breaker with the isolator/grounding switch not fully engaged in any of its three stops
- closing or opening of the isolator/grounding switch whilst the breaker is closed.

### 2.2.1.8 Enclosures and Busbars

- a) Metal enclosures shall be made from steel or aluminium, offering mechanical and thermal properties suitable for this application. Enclosures shall withstand the full rated fault current during arcing faults without puncturing for at least 1 second or means have to be provided to trip any such fault current prior to puncturing (e.g. busbar protection).

In no case shall arcing cause holes in the outer freely accessible sides of the enclosed feeder compartment. Gases and vapours escaping under pressure shall be deflected by front and side covers in a direction such as to minimize the danger to an operator performing his normal operation duty.

- b) Assembled enclosures must withstand at least twice their rated internal operating pressure. This fact must be proven on each individual section of the switchgear.
- c) The guaranteed leakage rate of each individual gas compartment must be less than 1 % p.a. over the lifetime of the switchgear. Initial filling of the equipment must guarantee gas service periods of not less than 10 years.

Since pressure reducing valves cannot be considered absolutely safe, no pressurized gas storage bottles may be permanently connected to the equipment.

- d) Each breaker bay shall consist of at least the following gas-tight high voltage compartments:
- busbars
  - breakers
- e) Each gas-filled compartment is to be equipped with suitable static filters to absorb any humidity that penetrates through the enclosure materials over long periods of time.

Routine replenishment of insulating gas shall not be required in intervals of less than ten years.

Busbar compartments and breaker compartments must have their own independent gas supervision and alarm systems with contact pressure gauges for alarm and indication. They also shall be equipped with Indication of the current gas pressure by means of temperature – compensated indicators.

Gas monitoring and service piping shall be made of copper or stainless steel.

- f) Design of the switchgear must allow for the removal of individual breaker bays, or parts thereof, without disturbing the remaining bays.

- g) All operating elements and indicators of the switchgear must be located on, or be visible from the front side of the equipment.
- h) The fully enclosed busbars shall be made from electrolytic drawn copper. They shall be rated for the continuous current of the switchgear under the site conditions and shall be braced for the maximum peak short circuit current or the minimum of 2.5 times the rated symmetrical short circuit current whichever is higher.

Rounded edges shall be used to reduce the number of potential arc root points, and to retain the ability of the switchgear to carry the rated operating voltage in case of a total insulating gas loss in a compartment.

### 2.2.1.9 Instrument Transformers and Protective Relays

- a) All instrument transformers must be suitable for continuous operation for 20 % overload when installed in the switchgear under the ambient site conditions and for service under all rated and fault conditions.
- b) Accuracy classes and burdens shall be in accordance with IEC 61869 and scope of works of the Bidding document for current- and voltage-transformers.
- c) Cores for measuring instruments shall have accuracy classes of not less than 0.2 % and saturation factors below 5, cores for relaying shall have accuracies better than 5 % and saturation factors of more than 10.
- d) Current transformer ratios (secondary side) shall be as indicated in the scope of works of the Bidding document
- e) Current transformers must have shorting type secondary terminals. The current transformer-rating plate and the terminals must be accessible after power cables have been installed.
- f) Current transformers of the epoxy type, mounted inside the high voltage enclosure on ground potential are preferred; other designs require the approval of Engineer.
- g) Potential transformers must be able to withstand the full rated power frequency withstand and lightning impulse capability.
- h) Potential transformers for busbar metering shall be of the inductive type, mounted in a separate compartment of the bus coupler/sectionalizer switchgear bay panel or at the end of the busbars.

The ratio shall be as per single line diagram, the rated burden suitable for the measuring and metering equipment connected, however, with a minimum of 100 VA.

- i) The potential transformer shall be of the metal-enclosed, gas-insulated type or approved equal.
- j) Potential transformers on the line side of incoming feeders or the load side of outgoing feeders shall be of the inductive type, suitable for the measuring and

metering equipment connected to it. They may be mounted at or within the cable connection compartment.

### 2.2.1.10 Low Voltage Equipment and Control Circuits

- a) The feeder bay or panels LV compartment shall be completely enclosed by steel sheets of 2 mm minimum thickness and shall be separated from the other sections. It shall provide a protection degree IP 54, to accommodate protection relays and auxiliary devices. It shall have a separate access door with key-locks provided.
- b) In each LV compartment a main terminal board shall be provided to which all incoming auxiliary cables are connected.
- c) Mimic diagram, all instruments, operating elements and indicators of the switchgear, DC trip circuit test facilities, push buttons and lamps shall be mounted on the front of this compartment.
- d) Indicating instruments shall be included for the functions as specified in the Chapter 3.
- e) All control circuits shall be according to the specified standards and designed for the application as required and shall be subjected to the approval of the Engineer.
- f) All necessary auxiliary contacts shall be provided to enable remote control, remote alarm, and indication of the position/state of any circuit breaker, isolator and earthing device.

In addition, two potential-free NO and NC contacts shall be provided for the above purposes each and the contacts shall be connected to the terminal board and to the control room where specified.

- g) Completely separated and isolated circuits shall be used for switchgear control, tripping, alarms, and auxiliary devices.

These circuits shall have separate control power buses and feeders, suitably protected, for each power bus section with outgoing feeders, and for each pair of incoming power feeders and the associated bus-tie breaker in secondary selective systems.

- h) Each control circuit shall be protected by a two-pole miniature circuit breaker with auxiliary NC contact. The auxiliary contacts of all MCB's of the same circuit type, e.g. breaker motor control, alarm, space heater, trip, etc. shall be wired in series to suitable group alarm terminals.
- i) Control wiring shall be executed with finely stranded copper wires of at least 2.5mm<sup>2</sup> cross-section, insulated with flame-retardant PVC or TEFLON.

Wherever terminals are not marked permanently and conspicuously, each end of each control wire shall be permanently marked with plastic ferrules (closed ring type) and terminated with crimp-type pin or plug terminators.

Identification of control wires and terminals must conform to the symbols used in the circuit diagrams. All control wiring shall be installed such that the likelihood of damage during normal operation, maintenance and fault conditions is minimized.

- j) Terminal strips of the line-up type are preferred for all control wiring requiring external connections. Terminals must be corrosion-proof, and use indirect pressure, captive screw type mechanisms. Internal wiring terminations of the push-on type, e.g. AMP plugs, are acceptable, and wire-wrap connections are preferred for matrix-connections on electronic sub-assemblies.

Additionally, at least a 16 core pilot cable, allocated to each outgoing cable feeder, shall be considered. A terminal strip and separated routing channel for the pilot cable is to be provided.

- k) Terminal strips for different voltage levels must be physically separated from each other and suitably identified. Terminals carrying dangerous voltages even when the main breakers are off, must be marked with a particular colour and carry suitable warning labels.

Further terminals shall be provided for the current transformers, which shall permit instruments to be connected without interrupting the secondary current transformer circuits.

- l) Voltages for control, trip and alarm shall be monitored by built-in normally energized auxiliary relays, separate for each bus or feeder section. These relays shall be time delayed on drop-off and their contacts shall be wired to group alarm terminals.
- m) Remotely controlled breakers shall have key-operated selector switches installed in their low voltage compartment with the following functions. The key shall be removable in a "remote" position only.

The switch shall have these positions/functions:

LOCAL : The breaker can only be operated locally by its push-buttons or mechanically.

OFF : The breaker cannot be operated electrically.

REMOTE : The breaker can only be operated from the remote control room location.

- n) Space heaters shall be installed in each low voltage cabinet to prevent condensation. Each heater element shall have an integral thermostat for control. Each switchgear section shall have a common space heater feeder, fed from a separate power source, and protected by a two-pole MCB with auxiliary NC contact wired to a group alarm terminal.

### 2.2.1.11 Cable Terminations

- a) All high voltage cables will be connected from below through cut-outs in the floor. To maintain the totally insulated design concept of the switchgear, only fully insulated terminations shall be used. The cut-out in the floor shall be filled out with fire proof material after the cable termination work.

- b) A cable termination with direct solid dielectric-to-gas insulation transition shall be used.
- Suitable plug type connection facilities shall be provided; the actual cable terminators shall be supplied fitting to the cables for the outgoing feeders.
- c) Sufficient space must be provided in the switchgear to terminate and connect up to three XLPE or cables per phase. Suitable cable support and grounding facilities must be provided in this area.
- d) Low voltage control and signal cables are fed into the switchgear from above or below. Exposed runs of control cable through the switchgear structure shall be protected by suitable covers.
- e) Bidder's documentation shall clearly show all termination facilities and their dimensions.

#### 2.2.1.12 Nameplates

Each breaker bay shall be identified with its feeder designation engraved on laminated plastic tags of at least 40 x 100mm size.

Tag information will be supplied by the Engineer at site. If a second language will be required, a second tag of identical size shall be mounted adjacent to, or underneath the first one, but left blank for customer inscriptions.

The tags must be bolted or riveted onto a non-removable part of the cubicle. Stick-on or glued labels are not acceptable for this purpose.

Each cubicle shall have a rating plate with the information required by IEC 60298, i.e. at least the following:

- manufacturer's name
- type number
- serial number
- rated voltage
- rated frequency
- rated current
- rated interrupt power
- actual rating at site conditions.

Each device installed in the breaker bay, each terminal strip, and each indicating and operating element shall be identified with permanently attached plastic tags or labels of approved design. Inscriptions on these tags must coincide with those used on the drawings.

Each circuit breaker must have its own rating plate with information according to IEC 62271-100, i.e. at least the following:

- manufacturer's name
- type and serial number
- rated voltage

- rated insulation level
- rated frequency
- rated normal current
- rated short circuit breaking current
- weight
- rated duration of short circuit, if different from 1 second
- rated supply voltage of closing and opening devices
- rated supply voltage and frequency of auxiliary circuits
- actual rating at site conditions.

#### **2.2.1.13 Corrosion Protection**

The switchgear shall be treated and protected to withstand at least five years of operation after final taking over, under the site conditions without sustaining significant corrosion or attacks from fungus or rodents, provided the surfaces remain mechanically undamaged.

Reference is made to Technical Specification – Grid Substation ‘Protective Treatment for structural steel works’ of this Specifications and requirements specified there shall be fulfilled provided they are not contradictory to those below.

As a minimum painting standard for all steel surfaces, the following is applicable:

- cleaning to the bare metal by mechanical and/or chemical means
- phosphatizing, or priming with at least one coat of zinc or lead-based primer
- finish painting shall preferably consist of electro-statically applied and oven-dried epoxy-powder to a thickness of at least 80 microns. Alternatively, at least two coats of epoxy-based compound lacquer may be spray-applied.

If approved by the Engineer, manufacturers standard paint colour may be used, but a light grey finish with high scratch resistance is preferred.

All hardware used in the assembly of the switchgear must be either of corrosion proof material, or be hot dip galvanized.

Gas monitoring and service piping shall be made of copper or stainless steel.

#### **2.2.1.14 Inspection and Testing**

The switchgear is subject to inspection during manufacture. Routine testing of each switchgear bay shall be performed according to IEC 60694. The Contractor shall submit proposals for special tests, subject to the approval of the Engineer.

The accepted limits of test results for each test shall be provided in advance to perform the test.

Tests shall be performed generally at independent institutes, at the Contractor's premises if approved by the Engineer, and at site (if applicable) in the presence of the Engineer and further in strict accordance with:

- IEC 60298 for all the switchgear and control gear



(Note: For internal arc tests to be regarded as type test, performance shall be according to the IEC 60298 Appendix AA)

- IEC 62271-100, IEC 62271-101 and IEC 60694 for the circuit breakers
- IEC 60265 for MV switches
- IEC 61869 for current and voltage transformers
- IEC 60060, and others, as applicable.

Hereby, all test results and calculations evidencing the ratings under site conditions have to be submitted for approval to the satisfaction of the Engineer.

#### **2.2.1.15 Routine Tests (Minimum requirements):**

Tests shall be performed as per the relevant IEC including following tests.

- power frequency voltage dry test on each shipping assembly
- rated voltage test on all auxiliary circuits
- insulation test with 2 kV on all auxiliary circuits
- complete mechanical operation test
- function tests of all auxiliary devices, including all protective relays, alarm and trip circuits
- verification of wiring against drawings and specifications
- leakage test for insulating gas.

These tests shall be witnessed by the Engineer according to Chapter 11 of this Specification.

#### **2.2.1.16 Type tests**

Type tests shall be performed on switchgear bays and circuit breakers of each different type if type test certificates are not made available with the Bidding Proposal.

Type tests may be waived if satisfactory type test certificates are submitted with the Bid.

All defects detected as a result of testing shall be repaired by the manufacturer at his own expense and shall be documented and corrected prior to shipment. If, in the opinion of the Engineer, re-testing is required after such repairs, this shall also be at the expense of the Contractor.

Acceptance by the Engineer of any equipment shall not relieve the manufacturer and the Contractor from any of his performance guarantees, or from any of his other obligations resulting from this contract.

## 2.2.2 METAL ENCLOSED CAPACITOR BANKS

### 2.2.2.1 General

Reactive power compensation equipment shall be installed at the substation as indicated in Scope of Works. Capacitor banks and associated switchgear and control equipment shall automatically control the parameters of the Medium Voltage busbar or windings of the power transformers as mentioned in Automatic Regulation and Control. In addition facilities for continuous manual operation shall be provided. The total reactive power compensation requirement to be distributed evenly on the all power transformers as indicated in the Scope of Works. The compensation shall be switched in steps in value specified in scope of work at 33kV and the value specified in scope of works is the Mvar net value input to the system at the nominal voltage.

Capacitor banks shall be three phase banks in double “Y” connection of two equally rated star connected modules with ungrounded neutrals, which made up by connection of individual standard single phase capacitor units.

The general specifications of the installed medium voltage systems shall fulfil the following requirements:

1. Functionality
  - a. capacitive reactive power compensation / harmonic suppression
  - b. automatically switched steps for power factor control
2. Compensation System Design
  - a. tuned capacitor banks with steps and tuning frequencies shall be supported by studies
3. Configuration
  - a. Number of compensation systems and steps per system shall be according to the scope of works.
4. Data of compensation system
  - a. each compensation system equipped with HV fuses and vacuum contactors
  - b. iron core filter reactors
5. General system data
  - a. installation place, indoor, IP 41

### 2.2.2.2 Studies, Calculations and Reports to be submitted

Contractor has to carry out detailed study and submit a comprehensive report with preliminary design and calculations, justifying the values chosen for the design for approval by Engineer.

In this study the contractor has to submit calculations justifying the MVAR rating selected for step sizes of capacitor banks to produce step size specified in scope of work to the system. Further this study should include harmonics, switching inrush currents and transient studies.

Contractor also shall submit design proposal for the filter circuit according to the study and should submit how the capacitor system control and monitor the harmonic overload of the equipment. Further contractor shall prove that his design would prevent the equipment from additional resonances. Transformer impedance variation with tapping range and change of capacitance values due to aging of the capacitor bank for its life time shall be considered during the calculation of series and parallel resonance.

Contractor also have to prove that from his studies and calculations, all the over voltage levels including rated voltage and insulation level selected for designing the capacitors are suitable for the installation.

Further this should include calculations supported by the studies for selection of switchgear and justifying the switchgear ratings, proving that the switchgear is fully capable of handling all currents and surges that may occur under any switching operation of the capacitor bank installation. In addition the operational effect of the switchgear for the capacitors should also study and report.

The targeted harmonic reduction shall be confirmed by real time monitoring for each operation case mention in the study report after the installation. Measurement shall be carried out as per the IEC 61000-4-30.

#### **2.2.2.3 Shunt Capacitor Banks**

This part of the specification covers the design, manufacture, testing at the factory, delivery to site, erection, testing at site and commissioning of Medium Voltage shunt capacitor banks with associated switchgear and protection including all material and equipment required for a complete installation and for safe and reliable operation. This includes as current limiting and discharging devices, voltage and current transformers and all electrical connections of these and to the substation earthing network. Also included are the power cables from the switchgear to the capacitor banks, control cables between the substation and the capacitor banks, and the protection relays. Any other equipment or devices necessary for safe and reliable operation shall be provided even if not particularly mentioned here.

The shunt capacitor banks will be used for reactive power correction. Both Capacitor banks and capacitor units shall be designed, tested and installed in accordance with IEC 60871 if not otherwise mentioned in this specification. The rated Mvar output of the capacitor bank shall be available after considering the worse case imposed by the individual capacitor and reactor manufacturing tolerances.

The capacitor banks shall be suitable for indoor installation under the environmental and service conditions as laid down in the respective Chapters of these Specifications, and the capacitors must be fully capable to operate and be switched under these conditions.

Capacitor banks shall be three phase banks in Double-Y-connection of two equally rated star connected modules with isolated neutrals, which are made up by connection of individual standard single phase capacitor units.

#### **2.2.2.4 Capacitor Units**

Capacitor units may consist of one or several capacitor elements in the single container and insulated there from. Capacitor units shall be of the single phase type with both terminals being brought out through bushings.

The capacitor units shall have a dielectric to be formed of suitable materials having well proven record and should meet the requirements of IEC 60871.

Capacitor impregnant should have a well proven record. Detailed characteristics of the impregnant must be furnished, and the impregnant may not have any PCB compound. Low toxicity is required. The impregnant shall be a class III B (OSHA classification) combustible fluid and shall be easily disposable by burning without generating poisonous gases, or shall be biodegradable.

Sufficiently high insulation level must be provided between capacitor element and the container.

Internal fuses shall be provided according to the IEC 60871 and for disconnection of any faulty capacitor element in order to prevent total failure of capacitor unit or bank. Any fuse operation shall not affect adjacent elements or fuses.

Each capacitor unit shall be equipped with an internal discharge device, which reduces the residual voltage from crest value of rated voltage  $U_n$  down to 75 Volts or less within 10 minutes after disconnection.

#### **2.2.2.5 Unit Containers**

Capacitor units shall have housing of stainless steel. These shall be given a suitable number of coats of weather proof paint for resistance to corrosive atmospheres. The outer paint shall be high gloss in order to reduce dust deposition. Both capacitor connections shall be brought out through bushings with a minimum creepage distance specified in scope of works and terminals to ISO standard (metric), with the container insulated. The container shall have stud for earthing.

Lifting eye shall be provided on each side of tank for simplified installation of individual units.

The rupturing strength of the case when fitted with bushings etc. and sealed as when in service for both steady pressures and shock pressures shall be tested at the manufacturers works to demonstrate the ability of the case to withstand distortion due to internal pressure (e.g. pressure arising from dielectric, etc.).

#### **2.2.2.6 Power Losses**

The loss of the capacitor banks shall not exceed 0.2 W/kVAR. This shall include the losses due to the internal discharge resistors.

#### **2.2.2.7 Capacitor Tolerances**

Capacitor Tolerances shall be according to the IEC60871-1. Difference in capacitance between units or group of units when connected in series shall be selected to give minimum value to avoid over voltages due to such differences.

Capacitance values shall be maintained equally for 3 phases to avoid unbalance.

#### **2.2.2.8 Standard Temperature Category**

All Capacitors shall be design for standard temperature category of +5/D or higher in accordance with IEC 60871. Further the Capacitors shall be able to expose to direct ray of the sun through out the day.

#### **2.2.2.9 Maximum Permissible Overloads**

Capacitor units must be suitable for long duration operation under the maximum ambient temperature (Standard temperature category) at admissible voltage levels in

service between terminals according to the IEC 60871-1 clause 19.1. If the capacitor influences the air temperature (i.e. indoor installations), the ventilation and/or choice of capacitor shall be such that the standard temperature category limits are maintained. The cooling air temperature in such an installation shall not exceed the temperature limits of temperature category by more than 5 °C. Selection of admissible voltage level is the responsibility of the contractor. Contractor has to prove from his studies and calculations the levels selected is suitable for the installation.

Capacitor units must be suitable for continuous operation at an r.m.s. sine current up to 1.3 times the current which occurs at rated sinusoidal voltage and rated frequency excluding transients.

#### **2.2.2.10 Name Plate**

Following information shall be given on the name plate of each capacitor unit according to IEC 60871-1:

6. Manufacturer
7. Identification number and Manufacturing year.
8. Rated output in kVAR for three phase units total output shall be given.
9. Rated voltage  $U_n$  in kV
10. Rated frequency in Hz
11. Temperature category
12. Connection symbol
13. Insulation level in kV
14. Discharge device indicated by words and rated ohmic value
15. Indication for Internal fuse by wording
16. Chemical or trade name of impregnant.
17. Reference standard (IEC no) and year of issue.
18. Measured capacitance in absolute values.

Following information shall be given on the name plate of the completed capacitor bank: according to IEC 60871-1

1. Manufacturer
2. Rated output in MVAR. Total output to be given.
3. Rated voltage  $U_n$  in kV
4. Insulation level, both the rated power frequency short duration and peak value of the rated lightning impulse voltage in kV
5. Rated frequency in Hz
6. Connection symbol
7. Minimum time required between disconnection and reclosure of the bank.
8. Time to discharge to 75V.
9. Any special instruction for safety

### 2.2.2.11 Tests

#### Type tests:

Following type tests are required as per IEC 60871:

- Thermal stability test.
- Measurement of the tangent of the loss angle of the Capacitor at elevated temperature.
- AC voltage test between terminals and container, dry test.
- Lightning Impulse voltage test between terminals and container for capacitors intended for exposed installation.
- Short circuit Discharge test.
- Test of an external fuse in combination with a capacitor.
- Ionisation test on internal fuses.

Test certificates are to be submitted for the approval of the Employer/Engineer. Should no satisfactory type test certificate be submitted, then type tests shall be performed in the presence of the Employer/Engineer.

#### Routine tests on every capacitor bank:

Following routine tests must be carried out on every capacitor on completion in accordance with IEC 60871 and test certificates to be submitted:

- Capacitance measurement.
- Measurement of the tangent of the loss angle of the Capacitor
- Voltage test between terminals.
- AC voltage test between terminals and container.
- Test of internal discharge devices.
- Sealing Test.
- Discharge test on internal fuses.

#### Factory acceptance tests:

Factory acceptance tests are to be performed on each completed capacitor in the presence of the Employer/Engineer unless he waives the test. The factory acceptance tests shall be the same as mentioned above as routine tests.

### 2.2.2.12 Insulation levels and Rated Voltage of a Capacitor.

The r.m.s. value of the alternating voltage for which the capacitor bank is rated, and such voltage of the capacitor unit shall be decided by the contractor considering the influence of the capacitor itself. The rated voltage shall be higher than the maximum system voltage indicated below. Design calculations shall be submitted to the engineer justifying the selection of said voltages before manufacturing. Increase in the voltage due to the connection of shunt capacitors and voltage increase due to light load conditions shall be considered for the design.

The insulation levels shall be in accordance to the IEC 60871 and shall be not less than the values specified in Chapter 1 Grid Specification. Further correct insulation

requirements and insulation paths shall be selected from table 7 of IEC 60871-1 justifying the reasons and suitability. Other factors such as altitude of the installation site shall also consider when selecting the insulation levels.

### **2.2.2.13 Harmonic filter reactors**

Three phase harmonic filter reactors are of iron core type with air gap. They are suitable for indoor use with an ambient temperature of 55°C. These reactors are resin-impregnated. The terminals are of flat copper bar type. The harmonic filter reactor is connected in series between the capacitor unit and the neutral point (insulated).

The following mentioned losses of the reactors have to be seen as valid with maximum harmonic current at continuous operation mode.

### **2.2.2.14 Switching**

capacitor bank shall be switched only with capable circuit breaker or vacuum contactors, and have been tested for capacitive switching duty. Particularly if de-tuned or filter circuits have to be switched, the selection of the switching devices should be done under consideration of the increased rated capacitor voltages. In order to guarantee re strike-free switching operation, it is recommend applying switching device with higher voltage ratings.

The specification for medium voltage switchgear (refer to Chapter 2.3) shall apply, and additionally the Contractor must prove by calculations submitted for approval by the Employer/Engineer that the switchgear is fully capable of handling all currents and surges that may occur under any switching operation of the capacitor bank installation.

### **2.2.2.15 Protection**

For protection of the capacitor banks and their feeders, refer to Chapter 5.

### **2.2.2.16 Automatic Regulation and control**

Automatic regulation units with all necessary devices e.g. VT and CT shall be provided, which shall continuously monitor the power factor and reactive power flow at the Medium voltage (33 kV or 11 kV) windings of the power transformers or busbar. Automatic on and off commands shall be given to the circuit breakers of the individual capacitor banks based on following or combination of following criteria

1. Voltage, power factor and reactive power
2. Time of day function: Which allow the capacitor bank to switch based on time of day or week
3. Control one of the selected features (i.e. voltage, power factor or reactive power), individually while the bus section is opened and as a single bus, while the bus section is closed.

The regulation criteria will be decided at the time of detail engineering stage. However, care shall be taken that a suitable hysteresis between the on and off commands is maintained in order to avoid too frequent switching.

The control shall include monitoring of the voltage to prevent excessive high voltages.

The automatic regulation devices shall be incorporated in control cubicles located in the control room, together with manual/automatic selector switches, control switches for operation of the circuit breakers including position indication of isolators and CBs,

power factor meters, reactive power meters and alarm tableau. Suitable interlocking shall prevent any dangerous mal-operation.

### **2.2.2.17 Alarm Indication**

One alarm indication tableau for each group of capacitor banks and all associated equipment shall be mounted in the control cubicles. Any protection action, supply voltage failure or MCB trip shall initiate an alarm tableau of the substation, along with initiation of the existing horn or buzzer.

### **2.2.2.18 Control Panels**

The control panels shall be of the self standing fully enclosed sheet metal type, refer also to the specifications in other sections for similar panels.

The front panels shall exhibit a single line diagram of the complete reactive power compensation installation with control and check back as described for control room panels.

Measuring instruments shall include:

Power factor, active power, reactive power and THD meter for each busbar section  
Voltmeter with selector for each busbar section

Ammeter with selector switch for each capacitor bank  
Other controls shall include:

Local – remote switch (remote control facilities wired up to terminals in the panels)  
Automatic – manual switch

Alarm indication with multifaceted annunciator panels  
Lamp test pushbutton

The protection equipment shall be incorporated in the same cubicle. .

### **2.2.2.19 System and Human Safety**

System and human safety requirements differ depending on where the system is set up. Reactive power compensation systems for indoor is designed with internal arc classification (IAC) as per IEC 62271-200: 2011

Compensation systems shall consist of IAC test as free-standing system with pressure relief valves or with arcing channel.

### **2.2.2.20 Medium Voltage Metal Enclosed System**

#### **2.2.2.20.1 General**

This part of the Specification covers the design, ratings, testing, shipping, installation and commissioning of factory assembled, type tested metal enclosed system.

The descriptions cover only those general aspects, which are considered minimum quality and performance requirements by the Engineer. Further detailed and specific data are contained in the drawings, data sheets and other documents that form part of these Bidding Documents.

The panel shall be complete, ready for installation, with all components furnished unless specifically excluded herein and as may be listed in Scope of Works /Technical Particulars & Guarantees under Employer's Requirements.



Spare parts, if required by the Bidder for operation & maintenance, shall be quoted, separately as required by the Mandatory Spare Parts list.

The complete documentation, drawings, manuals, etc. shall be included in the Supply and will be subject to the approval of the Engineer according to the requirements of these Specifications.

Standard designs and models from the Bidder's manufacturing program are preferred, provided they meet the requirements of these Specifications, serve the intended purpose, and can be shown to have at least five years of successful service in the field.

If a substantial improvement of any or all of the specified requirements expressed or implied herein is available from the Bidder, and this improved design offers economical advantages to the Employer, this should be offered as an alternative, together with the basic proposal which shall conform to the requirements of these Specifications.

All the equipment described in these Specifications is intended for continuous duty at the specified ratings under the specified ambient conditions. Unless otherwise noted, the panels shall be for front access only during operation and maintenance.

Data and documentation submitted with the Bidding Proposal shall enable the Engineer to evaluate the quotation against the requirements of the Specifications. Full descriptive information and filled-in data sheets are required as a minimum.

#### **2.2.2.20.2 Panel Particulars**

The feeder bays or panels shall be delivered completely, including all necessary material for fixing them on suitable plinths or rails.

The equipment shall be dust-proof and vermin-proof and provision shall be made against condensation, particularly if the load is switched off.

The infeed transformer bay or panel shall be placed in such a way that the current stress of the busbars is minimized. In the case of the heavily loaded transformer feeders, requiring an ancillary bay or panel next to the transformer infeed, this may be provided to accommodate multiple cable sealing ends and auxiliary equipment. In this respect, the cable ducts for the cables running from the infeed transformers to the MV switchgear should be arranged to end exactly under the relevant transformer bay or panel.

Protection relays and their associated instrument transformers are part of Scope of Supply. The relays shall be installed in the low voltage compartments associated with each individual switchgear bay or panel and its circuit breaker. The functions of the protection relays are indicated in the typical single line diagrams in Drawings and their required performance shall be in accordance with Chapter 5 of Technical Specification– Grid Substation. If the Bidder is of the opinion that the indicated protection scheme is not optimal, he shall indicate this fact in his proposal along with suggested improvements.

#### **2.2.2.20.3 Performance, Standards and Codes**

The panels shall operate satisfactorily within its rated values in the environment specified in Chapter 1 of this specification.

The panels are planned to be installed indoors in an air-conditioned room with a maximum service temperature of +30°C. However, service with rated data shall be guaranteed also in case the air-condition-system fails, or will not be installed. Therefore, the maximum ambient shade temperature at Site shall be the basic design data for the panels.

Routine maintenance to any of its external components, including the protective relays and instrument transformers, shall not be required in less than five year intervals; internal components shall be maintenance-free for at least ten years, including the refilling of SF6 gas (if any).

Performance, testing and rating shall conform to the latest edition of all relevant IEC Publications under the appropriate voltage category.

Bidder"s proposing other than the above standards must specifically indicate the standards to which his switchgear conforms, and indicate all deviations (if any) from the above codes that affect performance and rating.

Compliance of the panels manufacturer and the Contractor with the provisions of this Specification does not relieve the Contractor of the responsibility of furnishing panels and accessories of proper design, electrically and mechanically suited to meet the operating guarantees at the specified service conditions.

#### **2.2.2.20.4 Design and Construction Electrical Data and General Requirements**

- a) Electrical key data as required by this Specification are stated in Scope of Works and in the enclosed single line diagram.
- b) The switchboard, when installed and operating under the ambient conditions shall perform satisfactorily and safely under all normal and fault conditions. Even repeated operations under full rated fault conditions shall not lead to diminished performance or significantly shortened useful life of the panes. Arc faults caused by external reasons shall be positively confined to the originating compartment and shall not spread to other parts.
- c) Temperature rise of current carrying parts shall be limited to the values stipulated in IEC 60694, i.e. +65°C for silver-plated contacts, +75°C for silver-plated connections, and +50°C for all other exposed parts, under rated current and the environmental conditions.
- d) Lightning Impulse withstand capability and power frequency withstand capability for the entire switchboard shall be in accordance with IEC 60694, Table I and values required in schedules of technical particulars & gurantees.
- e) Bracing of all mechanical components against the effects of short circuit current shall be a minimum of 2.5 times the rated symmetrical short circuit current.
- f) Thermal rating for all current carrying parts shall be a minimum of one second for the rated symmetrical short circuit current. If the maximum short circuit time must be extended, the  $I^2 \times t$  value shall remain constant.
- g) The auxiliary voltages as per Chapter 1 are to be considered for the design, in particular for CB Motor control voltage, the Alarm voltage, the Close and trip voltage and the Space heater voltage.

h) The panels shall be of the free-standing, self-supporting, dead front design with all high voltage equipment installed inside metallic and earthed enclosures, suitably divided into individual compartments, at least for the

- busbar system(s)
- circuit breaker
- cable connections
- low voltage compartment
- capacitors and reactors

i) Partitions between feeder bays or panels are required to avoid fault spreading from one feeder bay or panel to the other one and to the outside.

j) The row(s) of bays or panels shall be earthed through a suitable copper bar, which is to run along the full length of the switchgear, and to be connected to the station earthing, at least at two points.

k) The erection of the system shall not require any cutting, welding or drilling of material on site. Each line-up of switchgear shall be prepared for future extension on either end without any drilling, cutting or welding on the existing equipment.

l) The design shall provide for maximum levels of reliability, ease of operation and maintenance, and maximum flexibility. The possibility of field repairs and exchange of enclosure parts shall be taken into account. The panels shall be constructed identically to ensure that equivalent parts can be interchanged.

Design of the panels must allow for the removal of individual breaker bays, or parts thereof, without disturbing the remaining bays. It shall be possible to exchange an entire feeder, with or without its busbar section, without dismantling neighbouring bays.

m) Busbars and their enclosures shall take thermal expansion of the entire switchboard into account. Suitable mounting facilities, bellows and compensators shall be provided where necessary.

- **Safety Requirements**

a) The panel shall offer a maximum degree of safety for the operators and bystanders under all normal operating and fault conditions. In particular, it must be impossible to unwillingly, i.e. without the use of tools, touch live parts of the panels, or perform operations that lead to arcing faults.

For mechanical protection of the switchgear elements, panels with a minimum of Protection Class IP 41 is required, i.e. enclosed and inaccessible for granular foreign bodies during normal operation and protection against vertically falling water droplets.

All high voltage carrying parts shall be totally protected against contact with live parts.

b) Should internal arcing occur, the release of pressurised air or gas by suitable pressure relieve devices into the atmosphere must occur in such a way that personnel standing at the operating position of the switchgear will not be injured. Furthermore, no part of the enclosure or any loose parts may fly off in such an event, and no holes may burn through enclosures. All earthing connections must remain operational during and after an arc fault.

- c) All interlocks which prevent potentially dangerous fail-operations must be constructed such, that they cannot be by-passed easily, i.e. the operator must use tools or force to bypass them.
- d) Energy storing mechanism of breakers must be totally enclosed with the switchgear in the operating condition.
- e) All low voltage terminals remaining "live" after the main feeder has been disconnected shall be wired to particularly marked terminal blocks and shall carry suitable warning tags.
- f) The isolator/grounding selector switch and/or the line's side earthing switch must be able to be padlocked in the "ISOLATED" and the "OPEN" and the "GROUNDED" positions, respectively.
- g) For each outgoing cable feeder an inductive or capacitive voltage detector with cable live indication shall be provided, indicating any reverse voltage, i.e. at least by means of voltage transformers plus lamps (including lamp test facilities).

#### **2.2.2.20.5 Isolator and Earthing Switches**

- a) Means to safely isolate and ground any feeder in the switchgear shall be provided. Motor operated isolation/grounding switches suitably interlocked with the breaker shall be provided. In case of double busbar systems, the busbar selection isolators shall be provided with motor drive facilities, however, manual operation shall also be available for both single and double busbar system.
- b) Isolation/grounding switches shall be designed to withstand the rated and fault current of the largest breaker interrupter element that can be fitted into the panels.
- c) Designs where the actual grounding of the feeder is done via the circuit breaker, i.e. where the isolator is used only to pre-select the grounding position are also accepted.

Such three-way switches must have definitive stops at their "ON", "ISOLATED" and "GROUNDED" positions, with no direct movement from the "ON" through the "ISOLATED" into the "GROUNDED" position.

- d) View-ports or mechanical indicators connected directly and permanently to the operating shaft are required to positively display the actual switch position. Indirect position indicators are not acceptable.
- e) With the selector switch of any feeder in the "GROUNDED" position, it must be possible to safely exchange the breaker element while the remaining switchgear is live.

#### **2.2.2.20.6 Circuit Breakers**

- a) Vacuum circuit breakers or SF6 with totally enclosed and maintenance-free contact system are acceptable.
- b) Circuit breakers shall conform to Publication IEC 62271-100 in terms of rating, testing and performance, but they may conform to the standards of the country of manufacture for construction requirements, provided these standards do not conflict with the corresponding IEC 62271-100 rules and are acceptable to the Engineer

c) Breaker operating mechanisms shall be of the electric DC motor operated, stored energy type, with provisions for manual operation in case of control power failure. All breakers must be electrically trip-free and have anti pumping circuits. After loss of control power, the springs of the operating mechanism shall be capable of performing a sequence of OFF-ON-OFF operations with rated data.

d) A manually operable local trip push-button (mechanically working onto the trip shaft) shall be available, and all breakers shall be suitable for remote control.

Manual, mechanical ON-switching shall be prevented if interlocking condition exists. Mechanical indicators shall be provided to show the ON/OFF position of the breaker contacts. Operation counters shall be provided.

e) Maintenance intervals of circuit breakers shall not be less than 25 full rated short circuit interruptions, 10,000 rated current interruptions, or 10 years, whichever comes first.

Replacement of the breaker interrupter must be possible (at gas-insulated switchgear, the remaining part of the switchgear may be kept "live" and must not involve the use of special tools or delicate alignments).

f) Spare auxiliary contacts, 2 N/O, 2 N/C, 1 Impulse, rated at least as specified in schedule of technical particulars & guarantees shall be provided in addition to those required for breaker operation.

These contacts shall be wired to the terminal blocks for use at the LDC terminal cubicles. Additional contacts as required, e.g. for interlocking, shall be provided and incorporated in the control system.

g) Rated nominal current of circuit breakers shall be selected to the rated values listed in Scope of Works & Technical Particulars & Guarantees in order to reach the required rating, once the breaker is installed inside its enclosure. The feeder nameplate shall indicate the actual site rating of the feeder at maximum ambient temperature in addition to the nominal rating of the breaker.

#### **2.2.2.20.7 Interlocking System**

Electrical and mechanical interlocking, which shall at least fulfil the conditions as listed below, shall be provided. The final interlocking scheme shall be proposed by the Contractor and shall be subject to the approval of the Engineer.

a) The interlock system must positively prevent an operator from reaching or creating unintentionally a dangerous or potentially dangerous condition. Systems that can be by-passed without the use of tools and/or force are not acceptable.

b) All necessary electrical interlocks shall be provided as specified, particularly for the incoming feeders and the bus-tie breaker. Reference is made to the related sections of the High-Voltage switchgear of this Specification.

c) When the manual emergency crank for the breaker is in use, it shall be impossible to control the breaker electrically (provision of limit-switch or de-clutching of the crank).

d) All breakers for remote control shall have a key-operated switch, allowing the selection of LOCAL - REMOTE operation modes as detailed below.

- e) The interlocking of the circuit breakers of the SF6 gas insulated switchgear type shall prevent the following in addition:
- . operating the breaker with the isolator/grounding switch not fully engaged in any of its three stops
  - . closing or opening of the isolator/grounding switch whilst the breaker is closed.

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### 2.2.2.20.8 Enclosures and Busbars

a) Metal enclosures shall be made from steel or aluminium, offering mechanical and thermal properties suitable for this application. Enclosures shall withstand the full rated fault current during arcing faults without puncturing for at least 1 second or means have to be provided to trip any such fault current prior to puncturing (e.g. busbar protection).

In no case shall arcing cause holes in the outer freely accessible sides of the enclosed feeder compartment. Gases and vapours escaping under pressure shall be deflected by front and side covers in a direction such as to minimize the danger to an operator performing his normal operation duty.

b) Assembled enclosures must withstand at least twice their rated internal operating pressure. This fact must be proven on each individual section of the switchgear.

c) Design of the switchgear must allow for the removal of individual breaker bays, or parts thereof, without disturbing the remaining bays.

d) All operating elements and indicators of the switchgear must be located on, or be visible from the front side of the equipment.

e) The fully enclosed busbars shall be made from electrolytic drawn copper. They shall be rated for the continuous current of the switchgear under the site conditions and shall be braced for the maximum peak short circuit current or the minimum of 2.5 times the rated symmetrical short circuit current whichever is higher.

Rounded edges shall be used to reduce the number of potential arc root points, and to retain the ability of the switchgear to carry the rated operating voltage in case of a total insulating gas loss in a compartment.

### 2.2.2.20.9 Instrument Transformers and Protective Relays

a) All instrument transformers must be suitable for continuous operation for 20 % overload when installed in the switchgear under the ambient site conditions and for service under all rated and fault conditions.

b) Accuracy classes and burdens shall be in accordance with IEC 61869 and scope of works of the Bidding document for current- and voltage-transformers.

c) Cores for measuring instruments shall have accuracy classes of not less than 0.2 % and saturation factors below 5, cores for relaying shall have accuracies better than 5 % and saturation factors of more than 10.

d) Current transformer ratios (secondary side) shall be as indicated in the scope of works of the Bidding document

e) Current transformers must have shorting type secondary terminals. The current transformer-rating plate and the terminals must be accessible after power cables have been installed. Current transformers of the epoxy type, mounted inside the high voltage enclosure on ground potential are preferred; other designs require the approval of Engineer.

- f) Potential transformers must be able to withstand the full rated power frequency withstand and lightning impulse capability.
- g) Potential transformers for busbar metering shall be of the inductive type, mounted in a separate compartment of the bus coupler/sectionalizer switchgear bay panel or at the end of the busbars.

The ratio shall be as per single line diagram, the rated burden suitable for the measuring and metering equipment connected, however, with a minimum of 100 VA.

- h) The potential transformer shall be of the metal-enclosed, gas-insulated type or approved equal.
- i) Potential transformers on the line side of incoming feeders or the load side of outgoing feeders shall be of the inductive type, suitable for the measuring and metering equipment connected to it. They may be mounted at or within the cable connection compartment.

#### **2.2.2.20.10 Low Voltage Equipment and Control Circuits**

- a) The feeder bay or panels LV compartment shall be completely enclosed by steel sheets of 2 mm minimum thickness and shall be separated from the other sections. It shall provide a protection degree IP 54, to accommodate protection relays and auxiliary devices. It shall have a separate access door with key-locks provided.
- b) In each LV compartment a main terminal board shall be provided to which all incoming auxiliary cables are connected.
- c) Mimic diagram, all instruments, operating elements and indicators of the switchgear, DC trip circuit test facilities, push buttons and lamps shall be mounted on the front of this compartment.
- d) Indicating instruments shall be included for the functions as specified in the Chapter 3.
- e) All control circuits shall be according to the specified standards and designed for the application as required and shall be subjected to the approval of the Engineer.
- f) All necessary auxiliary contacts shall be provided to enable remote control, remote alarm, and indication of the position/state of any circuit breaker, isolator and earthing device.

In addition, two potential-free NO and NC contacts shall be provided for the above purposes each and the contacts shall be connected to the terminal board and to the control room where specified.

- g) Completely separated and isolated circuits shall be used for switchgear control, tripping, alarms, and auxiliary devices.

These circuits shall have separate control power buses and feeders, suitably protected, for each power bus section with outgoing feeders, and for each pair of incoming power feeders and the associated bus-tie breaker in secondary selective systems.

- h) Each control circuit shall be protected by a two-pole miniature circuit breaker with auxiliary NC contact. The auxiliary contacts of all MCB's of the same circuit type, e.g. breaker motor control, alarm, space heater, trip, etc. shall be wired in series to suitable group alarm terminals.
- i) Control wiring shall be executed with finely stranded copper wires of at least 2.5mm<sup>2</sup> cross-section, insulated with flame-retardant PVC or TEFLON.



Wherever terminals are not marked permanently and conspicuously, each end of each control wire shall be permanently marked with plastic ferrules (closed ring type) and terminated with crimp-type pin or plug terminators.

Identification of control wires and terminals must conform to the symbols used in the circuit diagrams. All control wiring shall be installed such that the likelihood of damage during normal operation, maintenance and fault conditions is minimized.

j) Terminal strips of the line-up type are preferred for all control wiring requiring external connections. Terminals must be corrosion-proof, and use indirect pressure, captive screw type mechanisms. Internal wiring terminations of the push-on type, e.g. AMP plugs, are acceptable, and wire-wrap connections are preferred for matrix-connections on electronic sub-assemblies.

Additionally, at least a 16 core pilot cable, allocated to each outgoing cable feeder, shall be considered. A terminal strip and separated routing channel for the pilot cable is to be provided.

k) Terminal strips for different voltage levels must be physically separated from each other and suitably identified. Terminals carrying dangerous voltages even when the main breakers are off, must be marked with a particular colour and carry suitable warning labels.

Further terminals shall be provided for the current transformers, which shall permit instruments to be connected without interrupting the secondary current transformer circuits.

l) Voltages for control, trip and alarm shall be monitored by built-in normally energized auxiliary relays, separate for each bus or feeder section. These relays shall be time delayed on drop-off and their contacts shall be wired to group alarm terminals.

m) Remotely controlled breakers shall have key-operated selector switches installed in their low voltage compartment with the following functions. The key shall be removable in a "remote" position only.

The switch shall have these positions/functions:

LOCAL : The breaker can only be operated locally by its push-buttons or mechanically.

OFF : The breaker cannot be operated electrically.

REMOTE : The breaker can only be operated from the remote control room location.

n) Space heaters shall be installed in each low voltage cabinet to prevent condensation. Each heater element shall have an integral thermostat for control. Each switchgear section shall have a common space heater feeder, fed from a separate power source, and protected by a two-pole MCB with auxiliary NC contact wired to a group alarm terminal.

#### **2.2.2.20.11 Cable Terminations**

a) All high voltage cables will be connected from below through cut-outs in the floor. To maintain the totally insulated design concept of the switchgear, only fully insulated terminations shall be used. The cut-out in the floor shall be filled out with fire proof material after the cable termination work.

b) A cable termination with direct solid dielectric-to-gas insulation transition shall be used.

Suitable plug type connection facilities shall be provided; the actual cable terminators shall be supplied fitting to the cables for the outgoing feeders.

c) Sufficient space must be provided in the switchgear to terminate and connect up to three XLPE or cables per phase. Suitable cable support and grounding facilities must be provided in this area.

d) Low voltage control and signal cables are fed into the switchgear from above or below. Exposed runs of control cable through the switchgear structure shall be protected by suitable covers.

e) Bidder's documentation shall clearly show all termination facilities and their dimensions.

#### **2.2.2.20.12 Nameplates**

Each breaker bay shall be identified with its feeder designation engraved on laminated plastic tags of at least 40 x 100mm size.

Tag information will be supplied by the Engineer at site. If a second language will be required, a second tag of identical size shall be mounted adjacent to, or underneath the first one, but left blank for customer inscriptions.

The tags must be bolted or riveted onto a non-removable part of the cubicle. Stick-on or glued labels are not acceptable for this purpose.

Each cubicle shall have a rating plate with the information required by IEC 60298, i.e. at least the following:

- manufacturer's name
- type number
- serial number
- rated voltage
- rated frequency
- rated current
- rated interrupt power
- actual rating at site conditions.

Each device installed in the breaker bay, each terminal strip, and each indicating and operating element shall be identified with permanently attached plastic tags or labels of approved design. Inscriptions on these tags must coincide with those used on the drawings.

Each circuit breaker must have its own rating plate with information according to IEC 62271-100, i.e. at least the following:

- manufacturer's name
- type and serial number
- rated voltage
- rated insulation level
- rated frequency

- rated normal current
- rated short circuit breaking current
- weight
- rated duration of short circuit, if different from 1second
- rated supply voltage of closing and opening devices
- rated supply voltage and frequency of auxiliary circuits
- actual rating at site conditions.

#### **2.2.2.20.13 Corrosion Protection**

The enclosure shall be treated and protected to withstand at least fifteen years of operation after final taking over, under the site conditions without sustaining significant corrosion or attacks from fungus or rodents, provided the surfaces remain mechanically undamaged.

Reference is made to Technical Specification – Grid Substation „Protective Treatment for structural steel works“ of this Specifications and requirements specified there shall be fulfilled provided they are not contradictory to those below.

As a minimum painting standard for all steel surfaces, the following is applicable:

- cleaning to the bare metal by mechanical and/or chemical means
- phosphatizing, or priming with at least one coat of zinc or lead-based primer
- finish painting shall preferably consist of electro-statically applied and oven-dried epoxy-powder to a thickness of at least 80 microns. Alternatively, at least two coats of epoxy-based compound lacquer may be spray-applied.

If approved by the Engineer, manufacturers standard paint colour may be used, but a light grey finish with high scratch resistance is preferred.

All hardware used in the assembly of the switchgear must be either of corrosion proof material, or be hot dip galvanized.

#### **2.2.2.21 Inspection and Testing**

The switchgear is subject to inspection during manufacture. Routine testing of each switchgear bay shall be performed according to IEC 60694. The Contractor shall submit proposals for special tests, subject to the approval of the Engineer.

The accepted limits of test results for each test shall be provided in advance to perform the test.

Tests shall be performed generally at independent institutes, at the Contractor's premises if approved by the Engineer, and at site (if applicable) in the presence of the Engineer and further in strict accordance with:

- IEC 60298 for all the switchgear and control gear

(Note: For internal arc tests to be regarded as type test, performance shall be according to the IEC 60298 Appendix AA)

- IEC 62271-100, [IEC 62271-101](#) and IEC 60694 for the circuit breakers
- IEC 60265 for MV switches

- IEC 61869 for current and voltage transformers
- IEC 60060, and others, as applicable.

Hereby, all test results and calculations evidencing the ratings under site conditions have to be submitted for approval to the satisfaction of the Engineer.

#### **2.2.2.22 Routine Tests (Minimum requirements):**

Tests shall be performed as per the relevant IEC including following tests.

- power frequency voltage dry test on each shipping assembly
- rated voltage test on all auxiliary circuits
- insulation test with 2 kV on all auxiliary circuits
- complete mechanical operation test
- function tests of all auxiliary devices, including all protective relays, alarm and trip circuits
- verification of wiring against drawings and specifications
- leakage test for insulating gas.

These tests shall be witnessed by the Engineer according to Chapter 11 of this Specification.

#### **2.2.2.23 Type tests**

Type tests shall be performed on switchgear bays and circuit breakers of each different type if type test certificates are not made available with the Bidding Proposal.

Type tests may be waived if satisfactory type test certificates are submitted with the Bid.

All defects detected as a result of testing shall be repaired by the manufacturer at his own expense and shall be documented and corrected prior to shipment. If, in the opinion of the Engineer, re-testing is required after such repairs, this shall also be at the expense of the Contractor.

Acceptance by the Engineer of any equipment shall not relieve the manufacturer and the Contractor from any of his performance guarantees, or from any of his other obligations resulting from this contract.

#### **2.2.2.24 Availability Performance**

In general, wherever possible, the following principles shall be followed in the design of the control and protection circuits:

1. Provide standard and least complex design as much as possible while meeting required performance criteria.
2. Use of modular construction and components with high tolerance levels to permit rapid replacement of modules with failed components or subassemblies.

3. Use of design practices, surge protection, filtering, and interface buffers to assure immunity of sensitive components and circuits against damage and interference by induced voltages and currents in external cabling and cubicle wiring.
4. Use of fail-safe and self-checking designs.
5. Use of software that has been thoroughly tested and proven.
6. Designs which, in the event of component or software failures, provide for the seamless transfer to a less complex operating mode.
7. Provision for alarm, fault indication, monitoring and test facilities.
8. Provision of clear, easily-read drawings and manuals with sufficient details and cross references to facilitate repair, servicing, purchase of additional/replacement spares and operating and maintenance.
9. Use of equipment designed to be maintained, repaired, and operated at the substation without the need for special operating and maintenance environment, test equipment, special tools, or complex operating sequences wherever possible.
10. Physical separation of redundant control cables, cubicles, and power circuits where feasible.
11. Sufficient diagnostic features to detect defects and failures and enable fast repair and maintenance.
12. Sufficient spares to ensure the availability and reliability is achievable for the at least fifteen (15) years.

#### **2.2.2.25 Predicted Availability Performance**

Contractor shall provide data, and calculations to support the availability requirements as outlined by CEB. The unavailability calculations for the following must be provided in the proposal.

1. forced outages
2. scheduled outages
3. Average number of forced outages/year
4. Average number of scheduled outages/year
5. Average forced outage duration
6. Average scheduled outage duration
7. Spare equipment to meet Reliability, Availability, and Maintainable (RAM) requirements

#### **2.2.2.26 Availability Performance Guarantee Period**

The Bidder shall guarantee the quoted availability for 5 a five-year period. CEB will monitor and record the availability information.

If the actual failure rate of capacitor units (cans) exceeds the guaranteed annual failure rate, Contractor shall, at the option of CEB:

(a) Pay CEB an amount equal to the cost of a ten (10) year supply of capacitor units corresponding to the amount by which the actual failure rate exceeded the guaranteed failure rate, or

(b) Supply, without cost to CEB, additional spare capacitor units equal to the difference between the actual failure rate and the guaranteed failure rate over a ten (10) year period.

The option shall be exercised within six (6) months after completion of the failure rate analysis.

## **2.2.3 HIGH VOLTAGE 145 KV & 245 KV METAL-CLAD, SF<sub>6</sub> INSULATED SWITCHGEAR**

### **2.2.3.1 Common Features**

This specification covers the requirements for the supply of metal-clad, gas-insulated, indoor switchgear for the rated voltage of 145kV & 245 kV.

The switchgear shall be of compact design, fully metal-clad and of the sulphur-hexa-fluoride (SF<sub>6</sub>) insulated type. It shall be constructed for the indicated busbar system, and shall include all necessary switches, current and voltage transformers, as detailed in Employers Requirements. The switchgear shall be supplied complete with all auxiliary equipment necessary for operation, routine maintenance, repairs or extensions.

The switchgear shall be designed for continuous operation under all system operating conditions including sudden change of load and voltages, short circuits within its ratings, and under atmospheric conditions at site. The equipment shall be designed to withstand normal operating voltage even if the inside gas pressure decreases to 100 kPa.

The temperature rise limits shall be in accordance with IEC 62271-203. The switchgear shall be capable of carrying the specified rated current continuously at maximum ambient shade temperatures in closed rooms as specified. The maximum temperature rise of the external surface of enclosures accessible during normal operations shall not exceed 30 K.

Components that may require to be renewed and standard assemblies that may be transferred from one circuit to another, shall be interchangeable and where required this shall be demonstrated by the Contractor. To secure minimum time of repair, all driving mechanisms shall be interchangeable to those of other feeders or spare parts as a complete unit. The arrangement of the switchgear shall be in such a way that any part can be removed without dismantling, interruption or disturbance to adjacent feeders or circuits.

The switchgear shall be constructed of suitable material and thickness to withstand the mechanical and thermal stresses due to the rated short circuit currents.

Where necessary, suitable arrangements shall be provided for the thermal expansion and contraction of the busbars without application of excessive stress to the supporting structure, and for different settlements of foundations in case of joints in the respective basement(s).

The fully enclosed busbars shall be made from electrolytic drawn copper or aluminium alloy, They shall be rated for the continuous current of the switchgear under the environmental conditions as specified without exceeding their permissible temperature rise.

Busbars and all electrical connections shall be made of approved materials, and suitable measures shall be taken to prevent corona discharge, particularly at edges and corners.

The switchgear bays each shall be earthed through an appropriate tinned copper earth bar which is to run also along the full length of the switchgear, and to be suitably connected to the station earthing, at least at two opposite points.

The insulators should furthermore confine any internal faults to the respective section of the switchgear. Each insulator used shall be tested for partial discharge as a routine test prior to assembly in the switchgear.

Rupture diaphragms shall be provided in each compartment except the circuit breaker to allow for pressure relief and a high degree of protection under fault conditions. It shall be ensured that nobody standing in the control aisles is exposed to any avoidable danger.

Particular attention shall be paid to the sealing of the housing joints, so that the SF<sub>6</sub> gas need not be replenished within reasonable periods. The gas leakage rate may in no case exceed 1% per year. Particular preference will be given to switchgear with low gas losses guaranteed.

The Contractor shall indicate the requirements and provide the lifting appliances as appropriate to the size and weight of the switchgear parts that require to be lifted in respect to erection, maintenance or repair.

Any supporting structures shall be made of galvanized steel, and all structures shall be corrosion protected.

All motors shall be in accordance with IEC 60034. The starting current at full voltage is not to exceed six times the rated full load current. Motors are to be designed to operate 15 % below and 10 % above nominal voltage without injurious over-heating.

Further on, the GIS-design shall provide to be very space-saving and lightweight. The local control panels shall be integrated in the GIS-design or free standing and shall be factory-tested

The Bidder is requested to propose his most recent and most compact GIS-design as an alternative. He shall clearly indicate the outer dimensions of the quoted GIS as well as the static and dynamic loads and the floor requirements (e.g. floor evenness, capacity of lifting facilities etc.).

The GIS shall be of tubular design; cubicle design and oddly shaped designs are not accepted.

All supporting structures for the switchgear bays, for the related overhead line-, cable-, and transformer- connection enclosures shall be a part of bidder's supply.

145/220kV Cable feeder connection chambers have to be designed as cable termination receptacles. The flange of the cable termination shall be tightly bolted to the GIS enclosure, and provision shall be made that the cable screen connection can separately be brought out and looped through a core current transformer. The cable connection compartment shall have facility to attach a test adapter for HV testing of the switchgear and the cable. For the purpose of HV testing for the cable by DC voltage, a removable link shall allow isolation of the switchgear. The bidder may however propose other methods for this purpose.

Busbars and circuit breakers and other HV equipment shall either be accommodated in one tube (three-phase enclosure) or three separate tubes (Single phase enclosure).

Aluminium casing of the metal-enclosed switchgear is preferred in order to reduce the weight of the switchgear and eddy currents.

Special tools and equipment that are required for operation and maintenance shall be offered in this bid.

The initial gas-filling shall be included in the Scope of Supply and sufficient extra gas shall be included for compensation of possible losses during installation and commissioning. A gas service cart with pressure-vessel, vacuum pump, and all required gauges and fittings for servicing the gas insulated switchgear shall be included in the Supply.

#### **2.2.3.2 Extent of Main Contract Works**

The contract works shall be carried out in accordance with the requirements of this specification and shall include the design, manufacture, supply, testing at works, transport to site, erection and testing, commissioning of Gas Insulated Switchgear and associated equipment as specified.

The HV bushings, bus ducts, cable end units and cables shall be included in the scope of supply.

The GIS shall be located in a permanent building, which will be ventilated and maintained, reasonably dust free.

In addition, the construction of a switchgear building including control room and complementary buildings and civil works as detailed in Technical Specification – Grid Substation shall be included in the scope of supply.

#### **2.2.3.3 Requirements for the SF<sub>6</sub> gas-insulated switchgear**

##### **2.2.3.3.1 Extension:**

The quoted switchgear shall be of modular design and capable of extension in the future by the addition of extra feeders, bus couplers, busbars, circuit breakers, disconnectors, and other switchgear components without necessarily dismantling any major parts of the equipment. Where a double busbar system is specified it shall be possible to extend the switchgear by adding further feeders with at least one of the busbar systems and the existing feeders remaining continuously in service.

The Bidder is requested to demonstrate clearly in his submitted documents the suitability of the overall system's design in these respects.

##### **2.2.3.3.2 Repair**

Where a double busbar system is specified: In case of any internal arc fault in a busbar, busbar disconnector or circuit breaker, repair works must be possible without shutting down the complete substation and at least one busbar and the undisturbed



feeders must remain in operation. In the submitted documents, clear demonstration concerning this requirement shall be given by the Bidder, i.e. sequence of repair work steps and description of necessary restrictions during these works.

Further on, the Bidder is requested to clearly describe strategies how to overcome failure of any principle device of the quoted overall system and give a worst-case scenario for the possible consequences of a failure of any such device.

#### **2.2.3.3.3 Pressure relief**

Automatic pressure relief shall be incorporated for each of the sectionalized gas enclosures as a precaution against explosion in the event of an internal arc fault. Pressure relief shall be by means of bursting discs with deflection devices to ensure that personnel who may be present will not be endangered.

In the interest of long term gas-tightness bursting disks out of metal rather than graphite shall be preferred.

#### **2.2.3.3.4 Sectionalization**

The switchgear gas enclosures must be sectionalized, with gas tight barriers between sections or compartments. The sections shall be so designed as to minimize the extent of plant rendered inoperative when gas pressure is reduced, either by excessive leakage or for maintenance purposes, and to minimise the quantity of gas that has to be evacuated and then recharged before and after maintaining any item of equipment.

Each bay shall consist as a minimum of the following arc- and gas- tight high voltage compartments:

- bus section
- circuit breaker
- potential transformer

The arrangement of gas sections or compartments shall be such that it is possible to extend existing busbars without having to take out of service more than one busbar at any time. For limitation of any internal arc to the concerned bay and to reduce the extent of necessary gas works each busbar must be sectionalised bay by bay.

The electrical connections between the various gas sections shall preferably be made by means of multiple contact connectors so that electrical connection is automatically achieved when bolting one section to another. The surface of the connector fingers and conductor tubes on such connections shall be silver plated.

Each gas compartment must be independent, external gas pipe connections are not acceptable.

#### **2.2.3.3.5 Support Insulators and Section Barriers**

The support insulators and section barriers / insulators shall be manufactured from the highest quality material. They shall be free from all voids and the design shall be such as to reduce the electrical stresses in the insulators to a minimum. They shall also be of sufficient strength to ensure that the conductor spacing and clearances are maintained when short circuit faults occur.

Insulation material used for post type and gas tight type insulators shall not be stressed more than indicated by long term tests on full scale insulators, to allow for ageing effects.

Routine tests shall be carried out during the manufacture of the switchgear to ensure that all insulators are free of partial discharge at a voltage which is at least 10 % higher than the rated voltage and the measured value shall not exceed 2pC. These tests shall be according to IEC 60270.

Gas section barriers including seals to the conductor and enclosure wall shall be gas-tight and shall be capable of withstanding the maximum pressure differential that could occur across the barrier, i.e. with a vacuum drawn on the one side of the barrier and on the other side, at least the maximum gas pressure that can exist under normal operating or maintenance conditions and in case of internal arc fault with the safety factor greater than or equal 2.0.

### **2.2.3.3.6 Gas system**

#### **2.2.3.3.6.1 Gas seals**

All gas seals shall be designed to ensure that leakage rates are kept to an absolute minimum under all normal pressure, temperature, electrical load and fault conditions. The Bidder shall guarantee a gas loss of less than 1 % per annum for each individual gas compartment of the switchgear. Initial filling of the equipment must guarantee gas service periods of not less than 10 years.

All gas seals located in the flanges of the equipment enclosures shall be of the O-ring type. The material and method of sealing used and the maximum gas leakage rate that can normally be tolerated under working conditions shall be stated in the Bid.

Appropriately sensitive leakage tests shall be performed on each shipping unit prior to dispatch from the factory and prior to commissioning.

#### **2.2.3.3.6.2 SF<sub>6</sub> Gas Density and Pressure**

The rated pressure of the SF<sub>6</sub> insulating gas in the metal clad equipment shall be as low as is compatible with the requirements for electrical insulation and space limitations to reduce the effects of leaks and to ensure that there is no chance of the gas liquefying at the lowest ambient temperature. The initial gas pressure or density at the time of charging the equipment shall provide a sufficient margin above the minimum allowable operating pressure for the plant to be safely operated for a reasonably long period before recharging is necessary.

#### **2.2.3.3.6.3 SF<sub>6</sub> Gas Purity**

The SF<sub>6</sub> switchgear shall be designed to use with gas complying with the recommendations of IEC 60376 at the time of first charging with gas. All SF<sub>6</sub> gas supplied as part of the contract shall comply with the requirements of IEC 60376 as a minimum.

#### **2.2.3.3.6.4 Gas Monitoring Devices**

Each gas compartment must have its own independent gas supervision and alarm systems with contact density gauges for alarm and indication. Alarms shall be wired to and indicated in the local control cubicles. Each compartment shall provide the following functions by means of suitable fittings and valves:

- (i) Indication of the current gas pressure by means of temperature – compensated indicators.

- (ii) Monitoring of pressure and alarming of pressure losses in two stages.
- (iii) Access for evacuating and filling via a gas service cart and especially for the circuit breaker compartments:
- (iv) Indication and monitoring of pressure and alarming of pressure losses in two adjustable stages and additionally one contact for blocking of the circuit breaker.

#### **2.2.3.3.6.5 SF<sub>6</sub> Gas Treatment**

Under normal operating conditions it shall not be necessary to treat the insulating SF<sub>6</sub> gas between major overhauls. Self-sealing vacuum couplings shall be provided on each individual equipment module to facilitate cycling and recharging.

All gas compartments shall be fitted with a static filter to absorb residual and entering moisture inside the high voltage enclosures. Filters inside the breaker compartment shall also be capable of absorbing gas decomposition products resulting from the switching arc. The moisture content of the breaker compartment during service shall thereby keep less than 50ppm (by weight) and 100ppm (by weight) for all other compartments. The filters and desiccants shall be effective for the duration of time between major overhauls.

Notwithstanding this, the insulators in the circuit breaker shall be made of any epoxy resin composition that will resist decomposition products in contact with moisture in the circuit breaker.

External gas pipes between different gas compartments as well as any kind of centralised gas supply and/or gas control system is not acceptable.

#### **2.2.3.3.6.6 Supply of SF<sub>6</sub> Gas**

The contract shall include the supply of all SF<sub>6</sub> gas necessary for the first filling and putting into commercial operation the complete switchgear installation being supplied.

#### **2.2.3.3.6.7 Gas Filling and Evacuating Plant**

All apparatus necessary for filling and evacuating the SF<sub>6</sub> gas into and from the switchgear equipment shall be supplied by the Contractor to enable any maintenance work to be carried out.

Where any item of the filling and evacuating apparatus is of such a weight that it cannot easily be carried by maintenance personnel, it shall be provided either with facilities for lifting and moving with the overhead cranes or with suitable wheels resp. rollers.

The apparatus for filling or evacuating all gases to be used shall be provided with all necessary pipes, couplings, flexible tubes and valves for coupling to the switchgear gas compartments. They shall preferably be fitted with permanent vacuum couplings through which the gas is pumped into or evacuated from the compartments.

Details of the filling and evacuating apparatus that will be supplied, as well as a description of the filling and evacuating procedures, shall be provided at the time of Bidding.

### 2.2.3.3.7 Metalcladding

The metal enclosures for the SF<sub>6</sub> gas insulated equipment modules shall be made of steel or aluminium Enclosures. And shall withstand the full rated fault currents during arcing faults according to IEC 60512 without gas release for at least 200ms and without fragmentation of 500 ms. The enclosure shall be of single phase or three phase encapsulation design.

The bursting pressure of the enclosure shall be not less than 3.5 times the design pressure for cast enclosure and 2.3 times the design pressure for welded enclosures.

The gas-filled enclosures shall conform to the pressure vessel code applied in the country of manufacture.

All flanges shall be directly connected with good metallic contact. Insulators or insulating material between the flanges shall be avoided in order to get the best electrical connection between the different enclosure modules.

### 2.2.3.3.8 Expansion Joints and Flexible Connections

If necessary, the number and position of expansion joints or flexible connections are to be determined by the manufacturer to ensure that the complete installation will not be subject to any expansion stresses which could lead to distortion or premature failure of any piece of the equipment, support structures or foundations.

Expansion joints, flexible connections and adjustable mountings shall be provided to compensate for reasonable tolerances in the manufacture of associated equipment to which the SF<sub>6</sub> switchgear may be connected and to ensure that unreasonably excessive accuracy is not required when installing such equipment and constructing the associated foundations or support structures, e.g. transformers or the interconnection of isolated sections of switchgear by means of long SF<sub>6</sub> busbar or duct installations.

### 2.2.3.3.9 Finish of Interior Surfaces and Cleaning

The finish of interior surfaces of the metal clad enclosures shall facilitate cleaning and inspection. Any paints or other coatings that may be used shall be such that they will not deteriorate when exposed to the SF<sub>6</sub> gas and other vapours, arc products, etc., that may be present in the enclosures. They shall not contain any substances, which could contaminate the enclosed SF<sub>6</sub> gas or affect its insulating properties over the entire life time.

The equipment shall be manufactured and assembled at the manufacturer's works under conditions of the utmost cleanliness. In general, very dusty conditions will exist at all sites in the country of destination, so that, a maximum degree of pre-assembly shall be performed at the manufacturer's works.

### 2.2.3.3.10 Type Tests

Type tests shall be carried out on the metal enclosed switchgear components as well as the complete control circuits in accordance with the relevant IEC-standards. The performance of the components of the switchgear shall be substantiated by test data relevant to the particular designs offered.

Evidence of type tests shall be submitted with the Bid and shall include dielectric tests, temperature rise tests, short-time current tests and mechanical endurance tests together with evidence of tests to verify the making and breaking capacity of the

included switching devices and other primary components. A comprehensive list of type test reports shall be included in the Bid.

#### **2.2.3.3.11 Spare parts**

The Bidder is requested to supply a list of recommended spare parts for at least five years of normal operation. The recommended spare parts shall be quoted in schedules.

The Bidder shall guarantee at least ten years counting from the end of guaranteed period of supply of spare parts respective replacement parts or complete bays for future extensions for the Gas Insulated Switchgear with full compatibility to the originally installed system.

### **2.2.3.4 Particular Requirements of Primary Electrical Equipment**

#### **2.2.3.4.1 Circuit Breakers**

##### **General**

The circuit breaker must be designed in accordance with the latest state of technology. Due to their advantageous switching and breaking behaviour circuit breakers of the self-blast or puffer principle shall be offered. The breakers are to be restrike-free.

The SF<sub>6</sub> circuit breakers for the circuits detailed below shall comply with the following general requirements for circuit breakers and the latest revisions of the relevant IEC specifications.

Lock-outs shall be incorporated in each circuit-breaker to prevent operation whenever gas pressure, hydraulic pressure, etc. are less than the set values for satisfactory operation of the circuit breaker, or in case of any endangering irregularity.

Any decomposition products from the arcing process as well as any residual gas-contained moisture shall be precipitated in a molecular filter cartridge.

##### **Breaking capacity**

The total breaking time from energising the trip coil at rated control voltage to final arc extinction shall be as short as possible, but in any event not greater than 60 ms.

The circuit breaker shall be capable of breaking all currents from zero up to the specified maximum fault current in accordance with the relevant IEC publications. Official test reports shall be submitted with the Bid as evidence that the offered circuit breaker meets the specified rating.

For triple pole breaker operation via command, the pole discrepancy shall be less than 5ms.

##### **Auto-Reclosing**

If auto-reclosing is required, the circuit breakers shall be capable of tripping and reclosing according to the specified IEC duty cycle O - 0.3 s - CO - 3 min - CO.

The operating mechanisms shall have sufficient stored energy for completing an CO-CO-duty cycle with auxiliary power switched off.

##### **Closing Devices**

All electrically operated closing devices and any mechanism charging motors or devices shall be suitable for operation at any voltage between 120 % and 80 % of the nominal control voltage measured at the device terminals.

The breaker shall close correctly when an electrical closing pulse of 50 ms duration is applied to the closing solenoid.

The total wattage drawn by the closing solenoid at nominal control voltage when closing shall not exceed 500 W per circuit breaker.

### **Tripping Devices**

Each circuit breaker shall be equipped with two shot trip system per mechanism. The one shot trip system shall be electrically separate from the other system.

All electrical tripping devices shall be suitable for operation at any voltage between 120 % and 70 % of the nominal voltage, measured at the device terminals.

An emergency hand tripping device (mechanical) shall be provided in the operating mechanism.

The tripping devices of a circuit breaker shall be capable of operating satisfactorily down to 70 % of the normal control voltage (measured at the device terminals) when the circuit breaker is carrying no current.

The total wattage drawn by the opening solenoid at nominal control voltage when tripping shall not exceed 500 W per circuit breaker pole.

### **Anti-Pumping**

All circuit breaker mechanisms shall be provided with means to prevent pumping while the closing circuit remains energised, should the circuit breaker either fail to latch, or be tripped during closing due to the operation of the protective relays.

### **Operating Mechanisms**

Circuit breakers shall be equipped with factory assembled, operating mechanisms of independent spring type, hydraulic type or any other proven type. Hydraulic pipe working on site or a common system for a substation is not acceptable. Pneumatically (compressed air) operating mechanisms are also not accepted.

Hydraulic mechanisms shall be completed with all control equipment and the only external requirement for operation shall be electrical supply. All electrical motors for driving the hydraulic pumps shall be AC operated but control, opening and closing devices shall be DC operated, to allow electric/ remote operation also in case of AC supply failure. The motor running time for recharging for the 100% condition shall not exceed 75s after an OCO command (auto re-closing)

Operating oil pressure shall be maintained automatically and a highly reliable device shall be provided to give indication of the available operating energy.

Low oil /gas pressure shall be detected by some suitable method and dependent on the pressure shall initiate one or more of the following operations:

1. start pump motor / gas compressor,
2. block auto-reclosing if pressure insufficient to complete a break-make-break operation,
3. block closing if pressure insufficient to complete a make-break operation,
4. block tripping if pressure insufficient to complete a break operation (not applicable if circuit breaker is spring opened).

Circuit breakers having independent operating mechanisms for each individual phase shall be equipped with appropriate means to guarantee synchronicity of the pole

movement and shall block tripping, closing and auto-reclosing of all phases if the operating oil pressure is low in one or more of the mechanisms.

### **Hydraulic system (If applicable)**

Hydraulic systems without accumulator gas for energy storage will be preferred. In case this is not foreseen with the proposed GIS-design, appropriate means for detecting loss of nitrogen (or other accumulator gas) from the main accumulator(s) shall be provided and, in the event of excessive loss, all hydraulic operations of the circuit breaker shall be blocked. An alarm contact shall be provided to indicate this condition.

### **Indicating Devices**

Mechanical devices shall be provided to clearly indicate whether a circuit breaker is open or closed.

Each circuit breaker shall be provided with an operation counter per mechanism to record the number of tripping operations performed.

### **Testing Facilities**

Facilities shall be provided with the switchgear to enable timing tests to be carried out after all switchgear has been charged with SF<sub>6</sub> gas. The facilities shall be such that it is not necessary to open up any gas section to make test connections to the circuit breaker primary terminals.

All details of the test facilities to be provided with the switchgear shall be submitted with the Bid.

#### **2.2.3.4.2 Disconnectors**

##### **General**

The SF<sub>6</sub> metal clad disconnectors and earthing switches shall comply with the following general requirements and the latest revision of the relevant IEC publications.

The Disconnectors shall switch under conditions of zero current, i.e. they shall have no-load break attributes. However, bus-transfer current switching according to IEC standards 62271-102 must be possible. They shall be designed in such a manner as to prevent alteration of the switch position during short circuit conditions. Fluttering of the contacts must, in any case, be impossible.

All disconnectors and earthing switches shall be provided with motor-driven or motor-charged mechanisms as applicable. They shall also have facilities for manual operation and the necessary operating handles shall be provided.

The busbar and line earthing switches shall be fully insulated and connected to earth by a removable bolted link in order that the earthing switch may be used for various test purposes.

The insulation shall be capable of withstanding an applied power frequency voltage of 2 kV. In addition they must have fault making capacity. The continuous current carrying capacity at least should be suitable for rated busbar current and 15 min.

All main contacts, male and female, shall either be silver plated or shall have silver inserts.

An approved mechanically operated indicator shall be provided on each Disconnector's operating mechanism to show whether the Disconnector is in an opened or closed position. The related position indicators shall be visible easily.

## Operating Mechanisms

Mechanisms shall be arranged either mechanically or electrically so that all three phases of any particular disconnecter or earthing switch operate simultaneously.

### a) Spring operation

Spring-operated mechanisms shall also be suitable for hand operation by crank or lever. The mechanisms shall be arranged for blocking electrical operation when the manual operation device is inserted.

The mechanism of fault making earthing switches shall be equipped with a motor suitable for operation from the auxiliary supply specified, and a set of springs so arranged that energising of the motors would cause the springs to be charged and then released. The springs in turn shall close the earthing switch.

Spring charging motors shall be suitable for operation at any voltage between 80 % and 120 % of the voltage specified, measured at the motor terminals.

### b) Electric motor operation

Electric motor-operated mechanisms shall also be suitable for hand operation, independent of the power supply. Facilities shall be provided for blocking electrical operation when the manual operation device is inserted.

All electric motors shall be AC operated. The motor running time for closing and opening shall not exceed 5s.

For disconnectors and earthing switches having three mechanisms (i.e. one per phase) it shall be ensured that all three phases open or close whenever they are electrically operated either by remote or local means.

### c) Hand operation

Cranks, Handles or levers shall be provided, together with all necessary operating rods and rod guides for emergency manual operation. The mechanisms shall be arranged for blocking electrical operation when the manual operation device is inserted.

## 2.2.3.4.3 Earthing Switches

Earthing switches shall be designed for induced current switching according to IEC 62271-102 standard.

### a) High-speed earthing switches

High-speed earthing switches shall be provided at the outgoing end(s) of every feeder, and at the busbars. They shall be constructed to withstand the short circuit conditions, if and when accident switched onto a live counterpart, i.e. they shall have fault-make attributes. The contacts shall withstand the rated short circuit current of the switchgear for one second without burning or welding. They must be capable of switching capacitive currents no less than 10A at 15 kV and inductive currents no less than 160 A at 15 kV. The closing time of the switch shall not be more than 50 ms after release of the spring mechanism.

The switches shall be provided with a stored energy drive mechanism. Padlock facilities plus padlocks shall be provided for the operating mechanism to be securely locked in either open or closed position.

Emergency hand-operating facilities (with padlocking facilities) shall be provided which shall allow the operations of the earthing switches in case of motor- or supply-failure.



b) Maintenance earthing switches

Maintenance earthing switches shall be provided on both sides of every circuit breaker and for every busbar section. They shall withstand the rated short circuit current of the switchgear for one second without damage.

Locking and emergency facilities shall be provided as for the high-speed earthing switch above.

#### 2.2.3.4.4 Measurement Transformers

##### Current Transformers

Current transformers shall be of the ring core design. The secondary windings shall be embedded in cast resin and terminals shall be located outside the gas enclosure. No slip-on types are acceptable. All current transformers shall conform with IEC 61869.

They shall have a short time primary current rating not less than that of the associated switchgear. Secondary windings of each current transformer shall be earthed at one point only. The thermal rating of the current transformer shall allow, at site conditions, a 20 % continuous overloading referred to nominal rating of the current transformer.

All current transformers are to be provided with an identifying label giving manufacturer, type, ratio, class, output and serial number. Where multiple ratio secondary windings are executed, the above mentioned label shall clearly indicate the terminal connection required for each ratio, and they must be clearly indicated on the appropriate diagrams and drawings.

The beginning and end of each secondary winding and all secondary taps shall be wired to suitable terminals accommodated in a terminal box mounted directly on the current transformer section of the SF<sub>6</sub> switchgear.

Provision shall be made for earthing of the secondary windings inside the terminal box.

The minimum rated output of current transformers shall be 30 VA or otherwise approved, based on a stability calculation to be submitted by the Contractor. The magnetizing curves for each current transformer protection core shall be submitted for approval. The Contractor has to increase the rating at no additional cost to the Purchaser if necessary to achieve linear protection relay operation.

The windings shall be located in accordance with the requirements of the single-line diagrams or typical feeder drawings as per Drawings.

To guarantee the correct protection relay operation, through-fault stability calculations shall be submitted showing the correctness of the chosen current transformers core, i.e. rated output, class of accuracy, rated accuracy limit factors, the rated primary current, turns ratio, knee-point e.m.f. and resistance of the secondary windings (corrected to the maximum service temperature).

The current transformers supplier is bound to cooperate closely with the protection supplier, and to make all required data available for relay calculations at an early stage of the Contract period. Reference is made to Chapter 5; Protection, metering and Control of this specification.

For outgoing feeders, the Contractor shall make sure that the current transformers characteristics match the data of the relevant opposite feeder, this requirement supersedes the figures as may be stipulated in the Bidding Documents.

## Voltage Transformers

SF<sub>6</sub> insulated voltage transformers shall be of the inductive type, constructed and tested in accordance with IEC 61869-3 and shall be able to withstand the full rated power frequency and BIL voltages specified for the entire switchgear.

They shall be fully encapsulated, the gas compartment to be segregated from the adjacent compartments to prevent an arc to move between them. The voltage transformer and neighbouring compartment may however be belonging to the same gas section. Minimum rated output shall be 100 VA, if not specified or approved otherwise.

The thermal rating of the voltage transformer shall allow, at site conditions, a 20 % continuous overloading referred to nominal rating of the voltage transformer.

Secondary fuses (if applied) shall be of the HRC type, suitably covered and complying with IEC 60269, or secondary circuits shall be suitably supervised by MCCB's of adequate characteristics.

The beginning and end of each secondary winding and all secondary taps shall be wired to suitable terminals accommodated in a terminal box mounted directly on the voltage transformer section of the SF<sub>6</sub> switchgear.

Provision shall be made for earthing of the secondary winding inside the terminal box.

### 2.2.3.4.5 Bushings

#### General

Outdoor bushings, for the connection of conventional external conductors to the SF<sub>6</sub> metalclad switchgear, shall be provided where specified. Bushings shall generally be in accordance with the requirements of IEC.

In the case of HV cables Generator Transformers, where another Contractor would be supplying the Cable, the Contractor supplying GIS and the manufacture of the GIS switchgear is required to co-ordinate the design of SF<sub>6</sub> filled cable termination enclosures with that of cable sealing ends supplied by other manufacturers such that responsibility for integrity of gas or oil pressure compartments is clearly defined. In such a case type & size of the cable will be specified.

The dimensional and clearance requirements for the metalclad enclosure will be in the responsibility of the designer/manufacture of the bushings in order that the design of the enclosure may be completed. The switchgear manufacturer shall in turn provide the designer/manufacture of the bushings with the necessary design details for the bushing flange to ensure that a suitable gas-tight connection for the metalclad enclosure can be obtained.

The switchgear manufacturer shall negotiate and collaborate directly with the manufacturers of the transformer respectively the reactor when designing the above items of equipment.

### Insulation Levels and Creepage Distances

All bushings shall have an impulse and power frequency withstand level that is higher than or equal to the level specified. The levels are applicable to normal sea level atmospheric conditions.

The creepage distance over the external surface of outdoor bushings shall be no less than specified.

### **Bushing Types and Fittings**

Bushings being SF<sub>6</sub> insulated will be preferred to the conventional condenser types. Bushing arc gaps are not required.

The terminals on the outdoor bushings shall be a solid circular stem / NEMA-pad with the dimensions specified. Stems / pads shall be either copper or aluminium; copper shall be electro-tinned. The clamps for connecting the outdoor conductor(s) to the stem / pad shall be provided by the Contractor.

### **Mechanical Forces on Bushing Terminals**

Outdoor bushings shall be capable of withstanding a cantilever force applied to the terminal of at least 5000 N.

#### **2.2.3.4.6 H.V. Power Cable Circuits**

##### **General**

The following requirements are applicable to the switchgear equipment where the H.V. power cables are terminated directly in the SF<sub>6</sub> switchgear using cable sealing ends designed for use in SF<sub>6</sub> gas.

The final connection of the new H.V. cable circuits in the switchgear building will be by means of individual single-phase cables, with one cable per phase.

All cable end modules shall be suitable for connecting single core XLPE-cables for a maximum continuous voltage of 145 /245 kV and a core cross section of up to 800 /2000 mm<sup>2</sup>.

Bidders are requested to quote cable sealing ends with a design that helps reducing the works on the gas compartments. The cable termination shall be fully dry insulated for easy mounting and testing and it shall be free of maintenance. It shall be fully type-tested.

##### **Cable testing procedure**

The H.V. DC-testing of the cables shall be possible without opening the gas compartment of the cable termination module. The bidder shall propose the method of testing of the cable.

For testing the cable from the opposite end, only the line disconnecter shall be opened during cable testing. Removable bolted links or similar connections will be accepted only in case of transformer feeders without line disconnectors. The design of the link and connections shall ensure that when removed the resulting gap can withstand the impulse and power frequency test voltages applicable to the switchgear and the cable H.V.-D.C. test voltage, for a period of 15 minutes, when the chamber is filled to the minimum rated working SF<sub>6</sub> gas density or pressure.

The Contractor shall supply all necessary test facilities and equipment, i.e. test bushing, test adaptor, test transformer or resonance test set etc., and the cost shall be included into the contract price.

#### **2.2.3.5 Local Control / Marshalling Kiosks**

A local control Cabinet (LCC) shall be provided for each individual switch bay.

Each LCC shall contain the local control and indication devices associated SF<sub>6</sub> circuit breakers, disconnectors and earthing switches and the d.c. protection fuses, links and supervisory relays specified. The LCC shall also be a marshalling or junction point for all protection, control, alarm, indication and D.C. power supply circuits from the associated SF<sub>6</sub> circuit-breakers, disconnectors, earthing switches and gas monitoring, alarm and protection system. All cables to the control room will be terminated in the marshalling kiosks.

For the above facilities the LCC shall generally be provided with the following features:

- (a) A mimic diagram for the indicating switches and local /off /remote switches. Preferably a mosaic panel shall be used to allow easy extensions / modifications without the need of drilling and cutting.
- (b) Any interposing relays associated with the circuit-breaker, disconnector etc. control switches.
- (c) The alarm and indication equipment specified.
- (d) Fuses and links. These shall be mounted in the interior of the local control/ marshalling kiosks.
  - a. Cable terminal blocks for terminating and marshalling auxiliary supply cables, control, indication and alarm circuit cables from the switchgear and the remote control room.
  - b. Bay controller units for the substation automation system (Ref. Chapter 5)
  - c. Switchgear interlocking schemes.

The kiosks shall be located on the switch house floor. A general arrangement drawing of the kiosk showing the position of all important and the mounting position shall be submitted at the Bidding stage.

All cable connections between control cubicle and circuit-breakers, disconnectors and earthing switches shall be by prefabricated multicore cables with multi-point plug-in connections on both ends.

The LCC will be installed indoors but care must be taken with the design to ensure that all LCC are drip and splash proof. The kiosks shall also be dust and vermin proof.

All required calling between the Local Control Cabinet and the station Control Room shall be supplied. See Chapter 5 for details of control and protection Schemes.

#### **2.2.3.6 Requirements for the protection scheme**

Due to the high importance of the Gas Insulated Switchgear a fast and selectively operating protection scheme is required. It shall be in accordance with approved international standards such as IEC.

Generally the protection scheme shall consist of a busbar protection, a main feeder protection and a fully independent back-up feeder protection as specified in the following Chapter 5, Protection, metering and control and schedules.

A selectivity analysis based on an overall network calculation should be supplied by the Contractor. Based on this analysis the Contractor shall set up a suitable protection

scheme with his respective standard relays. The final layout of the protection scheme shall be subject to approval by the Engineer.

The protective relays shall be preferably mounted in the integrated local control panels of the Gas Insulated Switchgear in order to reduce the amount of wiring. Where this is not possible due to space or general design restrictions the Bidder is requested to clearly indicate the location of the protection relays.

### 2.2.3.7 Inspection and maintenance

Due to the fact that the operational integrity of the fully metalclad SF<sub>6</sub> insulated switchgear is not subject to external influences, such as pollution, moisture, dust, etc. the switchgear should be practically maintenance-free.

Inspection should be made not earlier than every five years. During inspection it must be not necessary to open the switchgear enclosures, thus avoiding interruption of substation operations. Inspection involves as maximum checking the SF<sub>6</sub> gas densities or pressures, checking of hydraulic fluids and lubrication of the moving components in the operating mechanisms outside of the enclosure. Functional testing of the close and trip coils, auxiliary switches, pressure and control switches etc. should also be made.

As a minimum the following maintenance period shall be considered as acceptable:

- circuit breaker : 5000 interruptions at rated current or 20 full rated short circuit interruptions or 10 years which ever comes first
- disconnectors: : 1000 closing and opening operations
- fast acting earthing switch : 2000 closing and opening operations or 2 making operations onto fault current.

The Bidder is requested to clearly describe his monitoring philosophy and the amount of information that will be provided.

## 2.3 POWER QUALITY ANALYZER

### 2.3.1 General

The Power Quality Analysing (PQA) instrument shall be suitable for the power studies of a permanent installation in 132/33kV transmission grids. The instrument shall be capable of capturing, recording and analysing the power quality and intermittent disturbances of an electrical power system.

The PQA shall be installed in a separate panel adjacent to the Disturbance Fault Recorder (DFR) panel. 132kV and 33kV busbar voltages shall be continuously monitored and there should be additional eight analogue channels (4 currents and 4 voltages) to monitor a 132kV or 33kV bay whichever client needs to monitor. To fulfil this requirement, all 132kV and 33kV CT and VT circuits shall be available in the PQA panel (or in the DFR panel) and required accessories for connection in current and voltage circuits to a selected bay, shall be supplied.

The equipment covered by this section shall be type tested and should be in total compliance with the standards of the International Electrotechnical Commission (IEC).

### 2.3.2 Type Test Requirements

The PQA shall be type-tested in accordance to recognized standards. The manufacturer shall provide type test certificates issued by an internationally recognized

independent test authority, outside the manufacturer's laboratories. The hardware and software offered with this contract is field proven according to the references and standards. Failure to furnish the type test reports will be considered as non-compliant.

### 2.3.3 References and Standards

The system should comply at least with the following referenced standards :

IEC/EN 61010-1:1992/93 , IEC/EN 61010-2-031 , IEC/EN 61326-1, IEC 61000-4-7 Etc..

### 2.3.4 Technical Requirement

#### 2.3.4.1 Functions / Tasks

The PQA system shall be able to perform the following tasks with the highest accuracy.

- Disturbance detection , record for analysis
- Load and Energy Measurements.
- Voltage, Current and Power Analysis
- Logging of all electrical data for detailed analysis
- Transient analysis for Voltage
- Signalling Voltage and Power
- Monitor Power Quality according to EN 50160 or any other applicable standard
- Check the functioning of the ripple control system

#### 2.3.4.2 System description & Design requirement

The Power Network Analyser shall be suitable for locating interference sources and to assess the voltage quality in line with the applicable standards.

The PQA instruments shall be supplied with all necessary accessories for measurement and related software for evaluation and analysis. (Specially clip on type current probes are to be supplied since the CT secondary circuits are not allowed to open for any serial connection of the instrument.)

The equipment should be robust (IP65) and should perform under harsh/ extreme environmental conditions.

The system shall possess a data memory that provides a method of effecting long-term recordings. These recordings are to be used for detailed evaluations and analysis to assess the disturbance and the voltage quality.

#### 2.3.4.3 Measuring Parameters :

The system shall equally perform as a data logger, recording, measuring the data for long periods of time and transferring them online to an analysis computer (typically a notebook).

The measuring data can be displayed and retrieved while the data logger is in operation without interrupting the measurements through the available interfaces such as Ethernet, RS 232, USB or via Modem.

The unit shall measure eight voltages for permanent monitoring ( 132kV & 33kV Busbar voltages) and 4 currents and 4 voltages for bay monitoring. The system shall be able to perform the following functions.

- Power quality as per EN 50160, IEEE-1159, IEC 61000-4

Harmonics, Interharmonics, Flicker, Voltage variations [under voltage, sag , swell , over voltage] ,Unbalance ,Frequency

The above mentioned PQ parameters should be presented in a manner to obtain a clear overview. The “Analysis Window” display should reflect all types of measuring parameters independently in parallel to each other on the screen.

- Averaging intervals for 20ms...24h

RMS voltage, RMS current, Active power, Apparent power, Power factor, Energy

- Oscilloscope representation

Voltage, Current

The oscilloscope function is used to evaluate current and voltage waveforms and also be used to represent amplitude spectrums of Voltage, currents and power.

- Frequency spectrum

Voltage, Current, Active power, Reactive power, Symmetrical components,

- Disturbance source detection

Evaluation of flicker sources, detect sources of voltage dips, detect sources of distortion, analysis of resonance

- Analysis of signalling voltages

Measurement of signaling voltages on 3 voltage channels, Measurement of signaling frequency Level of ripple control signals

- Transients

Fast – sampling for transient analysis in order to record transient switching or lightning surges.

100 kHz to 10 MHz programmable sampling rate per for 4 voltage channels

20 ms to 2s recording period

Triggering at voltage levels of high-frequency signal components,

6 kV input voltage range

## Features :

### (a) Memory Management

The memory shall be able to be configured independently in order to optimize the network analysis . The instrument shall be able to allocate independent memories to record the data continuously at different averaging periods :

- Daily averaging

- 10 minute averaging (for standard power quality assessment)
- User definable (selectable from 1 minute to suit any application)

Each memory can give continuous data on V, A W, VA, Var,  $\cos \phi$ , kWh, Hz, Harmonic distortion, flicker and phase balance. Each trace can further be displayed as maximum, or average.

The instrument should possess, additional programmable memories to trigger and record the following parameters during power system disturbances:

- Events – voltage sags or surges from 1  $\mu$ s recorded with amplitude and duration
- High speed RMS – averaging times from 10ms recording V,A, W, VA,  $\cos \phi$ , kWh.
- 3 – second average of harmonic voltage, current, power and power factor which can be displayed as THD or individual harmonics from 1 –50. It is preferable if the identification of Harmonics direction [ Import or Export ] could be done along with the calculation of useful Harmonics power.
- Oscilloscope - wave shape capture triggered on wave shape faults, peak exceedance, phase shift or amplitude changes.
- Transient voltages – sampled up to 10MHz to give high-resolution wave shape analysis.
- Ripple control – High resolution analysis of ripple control signals with definable signal voltage, center frequency and bandwidth.

#### (b) Sensors / Transducers

The following sensors and the ranges shall be made available by the manufacturer upon request and be able to be used with the equipment.

- The Voltage sensors [voltage probes] shall be available for 100 mV / 1V / 5V /10V /63.5V/110V /, 400 V/ 480 V [for transient measurement] and should be supplied accordingly when the requirement is determined at the time of order.
- The Current sensors shall be available in multiple ranges for direct measurement and through clamp on probes the range shall cover 1A,. ( The currents probes of instrument shall have the facility connect the measuring circuit without opening it)

#### (c) Intelligent Sensors

It is required that the connected sensors ( current and voltage ) should be able to calibrate and the calibrated data to be stored in a non-volatile memory in order to ensure the high level of data integrity and for easy diagnosis. [position to cross check the calibration data in line with the hardware settings ]

#### (d) Trigger conditions :

All triggering criteria and memories can be individually programmed for pre – trigger, recording time and hold – off.



Each initiated trigger shall be able to cross trigger the other individually programmed triggers in order to record the whole behavioral picture. As an example a trigger on transient voltage disturbance can also be set to trigger the oscilloscope and or the high – speed RMS.

Any of the triggered memories can be time/date triggered allowing the system to have all triggered memories recording simultaneously at a pre – determined time

The system shall be able to determine the trigger thresholds automatically. This operation shall not require any settings, if required the user shall also be able to set the trigger thresholds manually.

The system shall trigger and record when the values exceeded the preset limits [ thresholds ] of any triggering criteria such as harmonics, RMS values and powers, oscilloscope views of current and voltage, transients and signalling voltages. It is also possible to trigger upon exceeding one or more harmonics (1 – 50).

*(e) Sampling :*

The sampling rate is synchronized to the main frequency and should be greater than 5000Hz.

In addition a programmable sampling facility up to 10 MHz for transient monitoring on the 4 voltage inputs is essential.

Sampling of all channels shall be synchronised based on a common quartz clock signal.

*(f) Storage :*

The PQA shall be equipped with at least 2 GB hard in order to store the measuring data. The Analyser shall be capable of either overwriting the oldest data or stopping when memory is filled.

The memory management could be circular or linear. In the case of linear storage no more data is stored on reaching the memory limit. In the case of circular storage the oldest data records are overwritten.

All operating parameters and configuration data should be stored in a non-volatile memory so that the PQA shall return to normal operation after a power-up.

*(g) Measurement in Logging mode :*

The following measurements should be in logging mode ,

Rms values, max. values, flicker level, voltage dips, overvoltages, supply interruptions, (short and long-term), harmonics, interharmonics, THD, voltage unbalance, signal voltages, harmonic power by magnitude and phase, ripple control signal analysis, transients.

*(h) Measurement in On-line mode*

The following measurements should be in on-line mode

Oscilloscope current and voltage , FFT of time functions, distortion factors, active and reactive power spectra, rms values, mean values, active power, power factors, positive sequence, negative sequence and zero phase sequence systems.

*(i) Communication and Data Transmission :*

The PQA instrument shall be capable of communicating with the analysis station [personal computer (PC) ] through a direct connecting Ethernet Network 100Mbits, a dial-up modem via a dedicated telephone line , or direct RS232. connection.

*(j) Multi-Tasking*

The PQA shall perform numerous measurements simultaneously without swapping hardware or software modules.

*(k) Measuring cycles*

As per IEC 61000-4-7 :

- Frequency 3 s, 10 s, 10 min, 1 h, 24 h
- RMS voltage 10 ms, 3 s, 10 min, 1 h, 24 h
- Harmonics 160 / 320 ms

As per IEC 61000 :

- Flicker 20 ms, 10 min, 2 h

*(l) Measurement intervals:*

10 ms, 0.16 s, 0.32 s, 3 s (10 s), 10 min, 1 h, (2 h), 24 h, 1 week

*(m) Housing :*

Housing, plugs and sockets of the PQA must be made of non-conducting material only. The equipment must be capable of working under harsh conditions; protection class IP65 is preferred, if not at least IP50.

The PQA must be conforming to CE and corresponding to the EN61010 standard regarding "Safety Regulations for Electrical Measuring, Monitoring, Control and Lab Devices".

*(n) Power Supply Input*

The instrument shall have a wide range of power supply input which is connectable to DC voltage as follows:

- Direct current, 100 V to 375 V

*(o) UPS Backup Battery*

The PQA must be able to continue the measurement during a power failure at least for 5 minutes.

*(p) Inputs :*

The PQA shall provide an indicating LED for each input channel in order to check whether the right sensors are connected and if the measured value is within its range.

**Analogue Inputs :**

The PQA system shall be equipped with 32 galvanically isolated analogue channels (24 x voltage and 8 x current inputs) in compliance to the following.

- Insulated (each input separate), 600 V CAT III
- Rated input voltage 0.2 V rms
- One 16-bit A/D converter with anti-aliasing filter per channel
- Accuracy error <1 % from 0 ... 2.5 kHz
- Analogue Input Filtering - Each channel shall have a low-pass filter as a protection against voltage transients.
- A/D Conversion - Each channel should be equipped with a 16-bit A/D-converter and an anti-aliasing filter.

### Digital Inputs

The PQA shall provide an indicating LED for each input channel in order to check the status of each input. If Breaker Switch capacitor bank is available, the breaker positions and Auto/manual mode status shall be considered as digital inputs.

The PQA shall be equipped with at least 32 inputs, in compliance to the following:

- Galvanically Isolated (each input),

### Digital Outputs :

The system shall be equipped with at least 6 programmable digital alarm outputs.

## 2.3.5 Software Requirement

The PQA instrument shall be capable of communicating with the analysis station [Personal Computer (PC)].

The following features / functions should be available in the software for easy and user friendly analysis.

### 2.3.5.1 Controlling & Data Analysis :

- The measuring results are displayed graphically as level time diagrams or cumulative frequency functions.
- The data can be superimposed in one diagram. Each data point can be selected by mouse-controlled cursor.
- All the sections of a diagram can be exported as a text table. This table can be used with "Cut & Paste" in Windows via clipboard or the measured data can be saved as a text file. The table format allows for importing into spreadsheet applications.
- Several analysis windows can be opened simultaneously. The analyzed data is maintained until the respective window is closed again.

### 2.3.5.2 Configuration & Data Management

- configure the instrument remotely via modem or Ethernet
- Possibility to modify existing configuration without disrupting the measurement and without resetting the memory of the instrument

- User to define manual trigger level values for RMS, sine waveform, Power (P), transients, individual harmonics (V&I)
- User settable pre-trigger and total recording time for triggered recordings
- Retrieving the user-selected data files (events list, PQ, transient..etc...) at user specified interval
- Allow the user to partially delete uninteresting data from existing data file on the PC to reduce size on disk

### **2.3.5.3 Data Analysis Tools**

- Allow viewing selected parameters online (phasor diagram, oscillogram, harmonic spectrum, RMS dashboard)
- Offer a user-sizable graphic display area
- Rapid overview of the power quality and it should be able to determine the voltage quality at once.
- User selectable time period to be displayed on the graph
- Allow the user to display an event list that can be sorted (by event type, date, phase, duration...)
- View the triggered recording graph of an event (dip, swell, transient...) by simply double-clicking it on an event in the event list
- User to easily add, remove or hide a curve (RMS, Oscilloscope) from an existing graph in a few clicks.
- Allow the user to open several windows from different records to compare them simultaneously on one screen
- Export any graph being viewed to MS Word or MS Excel format
- Export all data points to MS Excel data lists.

### **2.3.5.4 COMMISSIONING TESTS**

#### **2.3.5.4.1 Test Equipment**

Details of the test equipment and instruments used shall be noted in the test sheets in cases where the instrument or equipment characteristics can have influence on the test results

The bidder's test equipment shall be of satisfactory quality and condition and, shall be appropriately calibrated by an approved authority or standard at the Contractor's expense.

The test instrument calibration expire dates are to be clearly indicated and such evidences shall be available at sites for engineer's reference.

The testing requirements detailed under this Specification may be verified only by instruction of the constructional techniques.

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### 2.3.5.4.2 Documentation and Format of Test Results

The bidder shall submit the necessary sets of test schedules and copies prior to the commencement of the tests. One legible copy of the test results as taken on site immediately after the tests are completed and shall be handed over to the CEB.

The bidder shall record the results of the tests clearly, in an approved form and with clear reference to the equipment and items to which they refer and get the certification of employer's representative who witnessed the test so that the record can be used as the basis for the maintenance tests during the working life of the equipment. The required number of site test reports shall be provided by the bidder to the CEB as soon as possible after completion of the tests.

The test results shall be forwarded in both in hard copy and electronic format (MS-Word or PDF)

The test templates, custom made parameter files used in test instruments (such as RIO/XRIO files and Test Docs for OMICRON or any other electronic files which are used by the Contractor for testing) shall also be forwarded in electronic format.

### 2.3.5.5 DRAWINGS

Four (4) paper copies and CAD files in AutoCad Ver 2010 of each of the drawings specified below shall be provided.

#### Panel Drawings

Complete set of panel schematic drawings with modifications to the existing drawings.

#### Instruction books and test results

Instruction books shall include exact information for all auxiliary equipment, such as GPS terminals. It will not be considered sufficient to include only "typical" device instruction books. Instruction books shall include copies of all final drawings.

## 2.4 DOCUMENTATION

The switchgear supplied under this Contract shall be documented to the extent as to allow the Engineer, as well as the operator, to fully understand the product, its theory of operation, its application and performance. Furthermore, it must enable the Engineer to efficiently communicate with the manufacturer about all aspects of operating, maintaining and servicing the switchgear.

The following documents must be submitted to the Engineer:

- final drawings and documents as per requirements of this Specification, plus:
- field wiring schedules, including identification of all wires, terminals and terminal strips,
- complete schematic circuit diagrams of each cubicle
- device location drawings

- bill of material showing complete re-ordering information for all replaceable parts
- spare parts location, identification and price list
- installation, operation and maintenance instructions.
- Recommended procedure for replacement of parts or entire unit for circuit breaker, Disconnectors and earth switches.

Prior to shipment, copies of all routine test certificates shall be made available to the Engineer. If, during testing, changes are made to the equipment, these deviations must be corrected in the drawings submitted, to reflect the accurate "as built" condition of the switchgear on the stage of handing over.

These corrections must be completed immediately following the actual changes. The final set of drawings certified "as built" must be available for commissioning and start-up of the switchgear.

All data provided for this equipment shall show the equipment as specified and ordered. Typical drawings are not acceptable unless they are revised to show only the equipment being furnished. The format, standards, and quality and quantities of drawings shall be manufacturer's standard, but shall be subject to the Engineer's approval as per the requirements of this Specification.

Language in all documents and drawings shall be English; dimensions shall be in metric SI-units only.

## **2.5 TEST AT MANUFACTURE'S WORK**

### **Circuit Breakers**

#### **a) Type Tests:**

Circuit Breakers shall be covered by type test reports issued by a recognised short-circuit testing station certifying the operation of the circuit breaker at duties corresponding to the operation of the rated breaking capacities of the circuit breakers. The test duties shall not be less than the requirements of IEC 62271-100. Test certificates shall be submitted with the Bid.

Repetition of type tests may be waived at the Engineer's discretion if adequate type tests have already been performed on the circuit breaker type to be supplied at an independent test laboratory and copies of the type test reports are supplied giving detailed test information, including results.

Otherwise one circuit breaker of each type ordered under the Contract shall be fully type tested in accordance with IEC 62271-100. For SF<sub>6</sub> circuit breakers the gas pressures, gas supply conditions, test conditions, and the measuring and recording of the result are to be approved.

#### **b) Routine tests:**

Each circuit breaker ordered under the Contract shall be fully assembled at the manufacturer's works and subjected to routine tests in accordance with IEC 62271-100.

Circuit breakers, Disconnecting and Earth switches shall have functional tests carried out as described in relevant clauses in this specification including checks in the interlocking.

### **Disconnecting and Earthing Switches**

Type and routine tests to IEC 62271-100.

Routine high voltage and mechanical test of insulators.

Sample and type tests of insulators.

### **Bushings**

Routine, sample and type tests to IEC.60137.

### **Hollow Insulators**

Routine and type test to IEC 60233.

### **Structures**

Sample assembly tests and galvanizing tests.

### **Current and Voltage Transformers**

Type and Routine tests to IEC 61869.

Type tests shall include lightning impulse tests.

Current transformers installed for differential protection shall be routine tested as sets.

### **Auxiliary Transformers, Motors, rectifiers, Contactors and control gears**

As appropriate IEC or British Standard as required by this specification.

### **245 kV, 145 kV, 36 kV and 12 kV Switchgear**

Type tests shall have been successfully carried out and been suitably documented for the switchgear type proposed by the bidder. Test certificates shall be submitted with the bid.

Routine tests of each switchgear bay have to be successfully carried out in accordance with the IEC recommendations. Special tests may be agreed upon between and the Engineer prior to order placement.

Routine factory tests, minimum:

Pressure test on each enclosure. The test pressure for all cast housings shall be twice and for all welded housing 1.5 times the design pressure. Gastight bushings between the gas compartments must be able to withstand twice the service gas pressure at one side against 0 bar (absolute) on the other.

At least 10% of welds must be subjected to non destructive X-ray or ultra sonic methods (random checks, according to pressure vessels regulations).

Partial discharge test on each insulator before insulation in the switchgear. No measurable partial discharge (less than 10pC) shall occur on the insulator when 110% of rated voltage is applied. This test must be carried out on each post type insulator and bushing used in the switchgear.

Gas leakage test on each transport unit. A Helium gas leakage test or other approved with a suitable accuracy must be carried out on each transport unit before dispatch.

The following test shall also form a part of the routine tests. These tests may be witnessed by buyer's authorised representatives on a non-interference basis:

Power frequency voltage dry test and partial discharge measurement on each transport unit.



Insulation test with 2 kV on all auxiliary circuits.

Resistance measurement on the main circuits of each transport unit.

Mechanical testing of the switching devices.

The Engineer must be informed at least three (3) weeks in advance regarding tests, which he desires to witness. The purchaser shall immediately be informed of any changes in the testing schedule.

Engineer or his representatives shall be allowed access to all those areas in the manufacturer's factory where the equipment covered by this contract is produced at all reasonable times for purpose of inspection and obtaining information of the progress of work.

Acceptance by the Engineer or his representatives of any equipment shall not relieve the manufacturer of his performance guarantees or from any of his other obligations resulting from the order.

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**CHAPTER 3 - SMALL WIRING AND ANCILLARY ELECTRICAL APPARATUS**

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## CHAPTER 3 - SMALL WIRING AND ANCILLARY ELECTRICAL APPARATUS

### 3.1 SMALL WIRING

All control panel wiring, secondary control wiring in circuit-breakers, motor starters, control gear and the like shall be carried out in a neat and systematic manner with cable supported clear of the panels and other surfaces at all points to obtain free circulation of air.

In all cases, the sequence of the wiring terminals shall be such that the junction between multi-core and terminals is effected without crossover. Except where terminals are approved by the Engineer for use with bare conductors, claw washers or crimped connectors of approved type shall be used to terminate all small wiring. Insulating bushes shall be provided where necessary to prevent the chafing of wiring.

All panel wiring shall comply with the requirements of BS.6231, Type A or B, as appropriate. Conductors shall be copper and have cross sections of 1.5mm<sup>2</sup>, 2.5mm<sup>2</sup>, 4mm<sup>2</sup> or appropriate. Single stranded conductors should only be employed for rigid connections which are not subject to movement or vibration during shipment, operating or maintenance. Flexible conductors equivalent to 30/0.25 mm (1.5 sq. mm) or smaller sizes generally shall only be employed with written approval.

All terminals for copper wires shall conform to IEC 60947-7.

For low voltage cabling and wiring, separate cables shall be used for each of the following groups:

- auxiliary power supply
- control and check back
- measuring
- communication

All control and power cables shall be armoured and all cables except those for auxiliary power supply must be shielded with annealed copper tape. Cables shall conform to IEC 60228, IEC 60287, IEC 60811 and IEC 60885.

The minimum cross-section of each copper wire shall be at least as given below:

- 4.0 mm<sup>2</sup> for current transformer circuits and heavy power consumers up to 20 A
- 2.5 mm<sup>2</sup> for all power consumers such as motors, heaters, lighting, etc. up to 10A
- 1.5 mm<sup>2</sup> for all instrument and control wiring, however, the maximum permissible voltage drop is < 5 % for the furthest point at full load
- 0.8 mm<sup>2</sup> for all telephones wiring

Wire colours are preferably to comply with British Standard 158, viz.:

#### Colour of wire Circuit particulars

Red Red-phase connections in current and voltage transformer circuits only.

Yellow Yellow-phase connections in current and voltage transformer circuits only.

Blue	Blue- phase connections in current and voltage transformer circuits only.
Green	Connections to earth.
Black	AC neutral connections, earthed or unearthed, connected to the secondary circuit of current and voltage transformers. AC connections other than those above and connections in AC/DC circuits.
Grey	Connections in DC circuits.

Alternatively, where equipment is wired in accordance with a manufacturer's standard diagram, wiring may be carried out in a single colour except that all connections to earth shall be green.

Wiring tables must indicate wire colours, numbers designated to all equipment/instruments and shall be drawn as viewed from the back of the panel.

All wires shall be fitted with numbered ferrules (hand written numbers are not accepted) of approved type at each termination. At points of inter-connection between wiring, where a change of numbering cannot be avoided, double ferrules shall be provided. Such points shall be clearly indicated on the wiring diagram.

All secondary wiring to be performed at Site shall enter the terminal block at one side only. The panel wiring shall terminate in one or more terminal blocks accommodated at the side or bottom of each panel or compartment.

Internal wiring between instruments or other devices not using the terminal block shall be permitted within the same compartment only.

The markers on all wiring directly connected to circuit breaker trip coils, tripping switches, etc., shall be of a colour, preferably red, different from that of the remainder and marked "trip". No wires may be teed or jointed between terminal points.

Electrical wiring and instruments shall be so located that leakage of oil or water cannot affect them.

Bus wiring between control panels, etc., shall be fully insulated and to be completely segregated from the main panel wiring.

Generally, all signal, monitoring and protection circuits as well as shunt trips of circuit breakers shall be fed by DC. All other circuits may be controlled by AC. Also, contactor operating circuits shall be controlled by AC with the contactor solenoids preferably designed for DC with a pre-connected rectifier bridge.

All metallic cases of instruments, control switches, relays, etc., mounted on control panels or in cubicles, steel or otherwise, shall be connected by means of copper conductors of not less than 2.5 sq. mm cross section to the nearest earth bar. These conductors may be bare or have insulation coloured green.

### 3.2 TERMINAL BOARDS

All terminals for wires shall conform to IEC 60947-7.

All terminal boards shall be mounted in accessible positions and, when in enclosed cubicles, are preferably to be inclined towards the door. Spacing of adjacent terminal boards shall be not less than 100 mm and the bottom of each board shall be not less than 200 mm above the incoming cable gland plate.

Separate terminations shall be provided on terminal boards for the cores of incoming and outgoing cables including all spare cores.

Where cores of multicore cables and internal cubicle wires have crimped ends, not more than two may be connected to any one terminal. When left bare, they shall have individual terminals and where bridging connections are necessary, these shall be incorporated in the terminal boards.

Acceptable types of terminals are:

- (i) Screw or stud type used with crimped ring type termination. Screws and studs shall be not less than of size M6, but stainless steel and bronze down to size M5 may be used, provided that the current carrying capacity is adequate. All studs shall be provided with nuts, washers and lock washers.
- (ii) Inspection clamp type whereby the standard conductor or crimped termination is clamped between plates by a screw having a suitable locking device. Terminal entries shall be shrouded such that not less than three full threads. Screws shall be of plated steel, stainless steel or phosphor bronze and size M3 or M4.

Terminal assemblies shall be to be of the unit form suitable for mounting collectively on a standard assembly rail, secured from the front and giving the required number of ways plus ten percent spare.

LV AC and DC power circuit terminals shall be segregated from other terminals and shall be fitted with non-flammable plastic covers to prevent contact with any live parts. They shall have warning labels, with red lettering, mounted thereon in a conspicuous position.

All connections shall be made at the front of the terminal boards and no live metal shall be exposed at the back.

Insulating barriers shall be provided between each group of power circuit terminals and between the terminal categories, the height and the spacing being such as to give adequate protection to the terminals.

### **3.3 CONTROL SWITCHES AND PUSHBUTTONS**

Control switches and pushbuttons shall comply with IEC 60947-5-1.

#### **3.3.1 General:**

Conventional control switches for electrically operated circuit-breakers and motor operated disconnectors shall be of pistol grip or other approved discrepancy type and arranged to operate clockwise when closing the circuit-breakers and anti-clockwise when opening them. They shall be designed to prevent accidental operation. When switches of the discrepancy type are approved, operation is to be effected by two independent movements.

Conventional switches for other apparatus shall be operated by shrouded pushbuttons or to have handles of the spade type, the pistol grip type being reserved for circuit-breaker operation only. Control, reversing, selector and test switches shall be mounted, constructed and wired so as to facilitate the maintenance of contacts without the necessity for disconnecting wiring.

Where necessary, control switches shall be capable of being locked in appropriate positions but control switches for circuit breakers and for motor operated setting devices shall be of the non-locking type with spring return to the "neutral" position. Such switches shall be controlled by independent springs, the use of contact springs alone for restoring not being acceptable.

All pushbuttons shall be of non-retaining type made of non-hygroscopic, materials, non-swelling and fitted to avoid any possibility of sticking.

The contacts of all switches and pushbuttons shall be strong and to have a positive wiping action when operated.

Control switches for use in direct control schemes shall be rated for substation battery voltage.

All control switches shall be provided with labels in addition to clear indication as to the direction of each operation, for example, “open”, “close”, “raise”, “lower”, etc.

### 3.3.2 Electrical Control Locations:

Equipment may be electrically controlled from a number of different control points as specified in the appropriate chapters of this Specification. The control positions shall be designated as follows:

**Local Control:** Located adjacent to the item of plant to facilitate maintenance, inspection and emergency operation.

**Remote Control:** Located at a substation control room where specified items of Plant are monitored and controlled by direct wire connection.

**Supervisory Control:** Located at a System Control Centre or where principal items of plant at a number of substations are remotely controlled via a SCADA (Supervisory Control And Data Acquisition) system.

### 3.4 ELECTRICAL MOTORS

All AC motors shall be of the induction type in accordance with IEC.60034 and, unless otherwise specified shall have cooling type ICOI suitable for continuous operation and direct on-line starting.

They shall be suitable in all respects for service under the conditions at site. Main conductor and slot insulation shall be non-hygroscopic and in accordance with IEC.

If any motors supplied under this Contract shall be located outdoors, such motors shall be weatherproof and, where necessary, protected from overheating by the sun with a canopy of approved design.

Motors shall be capable of operating continuously at rated output at any frequency between 48 and 51 cycles per second and at any voltage within 10% of nominal value. Motors shall be designed to operate for a period of not less than five minutes at a voltage of 25% below the nominal value and at normal frequency without injurious overheating. If required by the Engineer, the Contractor shall demonstrate that the motors comply with this requirement.

Each motor shall be protected by a motor protective unit with adjustable thermal over current and short circuit device.

The starting current at full voltage is not to exceed six times the rated full load current.

Motor bearings shall be of the rolling type and the cage locating the balls or rollers is not to be in contact with the racers. Vertical shaft motors shall have approved thrust bearings.

The ends of motor windings shall be brought out to terminal boxes and the arrangement is such as to permit easy changing over of any two-phase leads.

All terminals shall be fitted with an approved sealing chamber, conduit entry or adapter plate, as required, together with the necessary fittings to suit the type of cable supplied.

### **3.5 STARTERS AND CONTACTORS**

Where starters shall be provided under this Contract, each motor is to be equipped with two or three pole control gear as appropriate and suitable, unless otherwise specified, for direct starting.

Contactors shall be mounted in ventilated metal cubicles. Where two or more contactors are contained in the same cubicle, barriers shall separate them. The cubicles shall be complete with all locks, cable-sealing arrangements for boards and accessories. All secondary wiring shall be so arranged and protected as to prevent its being damaged by arcing.

Starters shall be of the electrically held-in type with integral “start” and “stop” pushbuttons mounted externally on the door, with integral interlocked disconnectors. Where required, auxiliary switches should be included for the operation of “red” and “green” indicating lights on remote instrument panels. All AC contactor coils shall be connected between phases for 400V working.

All motor contactors and their associated apparatus must be designed to operate for a period of not less than five minutes at a voltage of 25% below the nominal value and at normal frequency without injurious overheating.

Contacts of level switches, pressure switches, temperature switches, limit switches, etc. shall be of the snap-action type, the creeping action type and mercury contacts not being acceptable.

Contact devices transforming thermal variables into binary signals for the interlocking system shall be separate, i.e. contact devices serving in common for interlocking and other purposes shall not be accepted.

### **3.6 INSTRUMENTS AND METERS**

#### **3.6.1 Indicating Instruments:**

Where panel mounted analog instruments are required, they shall be of the flush mounted pattern with dust and moisture proof cases and shall comply with IEC 60051.

These indicating instruments shall have 72 mm square case to standards.

Instrument dials in general should be white with black markings and should preferably be reversible where double scale instruments are specified.

Scales shall be of such material that no peeling or discoloration will take place with age under humid tropical conditions.

The movements of all instruments shall be of the deadbeat type.

The meters and instruments shall be similar and aesthetically compatible with the existing equipment and to the satisfaction of the Engineer.

Wherever possible, instrument shall be provided with a readily accessible zero adjustment.



### 3.6.2 Electrical meters

Where electromechanical meters are required, they shall comply with IEC 60051 and shall be of industrial grade accuracy. Three-phase power measuring instruments shall be of the three-phase unbalanced load pattern wherever the current and voltage reference permit.

Where precision grade metering is specified meters shall be calibrated to precision grade accuracy to BS. 5685: or IEC 60051. Due allowance shall be made for the errors of current and voltage transformers with which they shall work and whose accuracy class shall be Class 0.2.

Meters shall be fitted with suitable devices for the transmission of impulse to a summator. VAR-hour meters shall be complete with phase shifting transformers as necessary. (The angular deflection of all the meter indicating current, voltage, power, VARs shall be 270 degrees).

Meter dials should be white with black markings and should preferably be reversible where double scale instruments are specified.

### 3.7 INDICATING LAMPS AND FITTINGS

Indicating lamps fitted into the fascias of switch and instrument cubicles or panels shall be adequately ventilated.

Lamps shall be easily removed and replaced from the front of the panel by manual means preferably not requiring the use of extractors.

The bezel of metal or other approved material holding the lamp glass shall be of an approved finish so as to permit access to the lamp and lamp glass.

The lamps shall be clear and shall fit into a standard form of lamp holder. The rated lamp voltage should be ten percent in excess of the auxiliary supply voltage, whether AC or DC. Alternatively, low voltage lamps with series resistors will be acceptable.

The lamp glasses shall comply with BS 1376 and BS. 4039 and shall be in standard colours, red, green, blue, white and amber. The colour is to be in the glass and not to be interchangeable. Transparent synthetic materials may be used instead of glass, provided such materials have fast colours and are completely suitable for use in tropical climates.

Continuously energised indicating lamps, if employed, shall in general be normally energised from the station LVAC supply. In addition, facilities shall be provided for manual changeover from the AC supply to the station DC supply via an automatically resetting switch arranged to reset after a time interval of approximately five minutes.

Lamps and relays incorporated in alarm fascia equipment may be arranged for normal operation from the station battery, subject to the approval of the Engineer.

Lamp test facilities shall be provided so that all lamps on one panel can be tested simultaneously by operation of a common push-button. Where alarm fascia are specified, all alarm and monitoring indications (apart from circuit breaker and disconnecter position indications) shall be incorporated in the fascia.

### 3.8 400 V SWITCHGEAR

The 400 V Switchgear shall be switchboard type. Switchboards for supplies to "Substation Service" are of the single busbar, air insulated multi-cubicle or multi-box factory built assembly type, incorporating air break, manually operated miniature circuit

breaker units and disconnecter units, suitable for installation in the substation building on a 400 V, three-phase, four-wire, 50 Hz system, having the neutral solidly earthed.

### **3.9 AC SWITCHBOARD SPECIFICATION:**

LVAC Switchboard shall be in accordance with IEC 60439.

#### **3.9.1 Rating**

Incoming supplies to all switchboards will be protected at the point of supply by circuit breakers. All switchboards should be suitably rated for a prospective short circuit breaking capacity of not less than 25 kA at 415V.

#### **3.9.2 Temperature Rise**

Switchboards shall be capable of carrying continuously the currents specified in the Employer's Requirements without exceeding the maximum temperature given in the appropriate IEC Standards.

#### **3.9.3 Busbars**

Switchboards shall include three-phase busbars and one neutral busbar of high conductivity copper supported to withstand all normal and fault condition stresses.

The neutral busbars shall have a rating not less than that of the associated phase busbars. The main circuit equipment shall have a busbar rating of not less than 400 amperes for 3-phase use and feeder circuit equipment a busbar rating of not less than 100 amperes for 3-phase use.

#### **3.9.4 Construction**

Each switchboard shall consist with a fabricated steel busbar chamber running horizontally at a height convenient for the operation of switches. The switchboard shall be of a type, which is readily extensible and suitable for use in a tropical climate. Each circuit shall be clearly labelled to show the destination of the associated cable, the "ON" and "OFF" positions of the switches being clearly indicated.

Distribution boards be of the metal enclosed free standing type with protective insulating barriers between the phases and between phase and neutral. Neutral connections for each circuit shall be made direct to the neutral busbar in each distribution board via removable links. The metal casing of the distribution boards be provided with knock-out or other approved cable entries for accommodation of the cables and cable glands the number and size of such knock-outs being such that the breakers can be used in any combination of single-phase and three-phase circuits.

Cubicles type switchboards, where specified, shall be so arranged that the cubicles housing the respective control units are grouped to form a multi-tier arrangement and a further part shall where possible constitute a cabling and wiring chamber of ample dimensions in which terminal boards, cable boxes and gland plates shall be located.

### **3.10 DIESEL GENERATOR**

#### **a) General**

The CEB safety practice requires the installation of emergency diesel generator in the substations. The diesel generator set shall have a capacity of 25 kVA or above.

The generator shall be suitable for 24 h continuous operation.

In case of a complete blackout of the auxiliary power supply, the emergency diesel generator set shall be sufficient to meet the electrical demand of:

- battery chargers
- security lighting
- plus 20% safety margin.

The diesel generator set shall be supplied at a hot dip galvanized steel base frame in a packaged unit, fully installed and ready for operation.

The Diesel generator set will be accommodated on the ground floor of the substation in the designated room.

A local service provider shall be available for the offered diesel generator model.

#### **b) Diesel engine and auxiliaries**

The engine shall be water-cooled, with a closed circuit radiator and fan and shall be suitable for indoor installation.

Electrical motor and battery with on-board charger shall start the diesel engine. The capacity of the battery shall be such as to ensure three consecutive starts of the diesel engine within 10 minutes.

The diesel engine shall be directly coupled to the generator and both installed together on a common base frame. Vibration absorbers shall be used to prevent transmission of vibrations to the surrounding area.

#### **Lubrication System**

The engine and the generator shall be fully pressure-lubricated. The oil pump shall be gear driven from the main shaft.

#### **Fuel supply and injection system**

For the supply of the diesel engine with fuel, a tank of adequate capacity for three days\* continuous operation shall be provided.

All necessary means such as pumps, pipes, filters etc. shall be provided to accomplish the filling of the engine tank by tank truck.

The tank shall be fitted with visual level indicator and level alarm devices for remote indication.

#### **Air intake and exhaust system**

The engine shall be fitted with an outdoor installed oil wetted air filter.

Temperature-resistant materials shall be used for the exhaust piping and the required expansion bellows. Exhaust silencers shall be galvanized. Expansion joints in the exhaust pipe shall be made of metal.

Flexible connection to the air intake duct, exhaust line and all other external pipe work shall be provided.

#### **c) Control and monitoring equipment**

The engine shall be equipped with all necessary local switches and control equipment for starting, stopping and speed variations etc.

The generator set shall start-up automatically when the AC 400 V busbar voltage falls after a time adjustable up to 10 minutes.

Upon resumption of normal power supply, the system has to be brought back to normal operation conditions manually.

The engine shall be designed for automatic emergency shut-down if it is being operated at over speed or with low lubricating oil pressure. In addition, a manual stop button shall be provided.

The following control, indication and alarm equipment shall be provided as a minimum on the local control board:

- level indication of the fuel tank with alarm at 20%
- pressure indication of the lube oil with low pressure alarm
- temperature indication of the bearings with high temperature alarm
- emergency diesel generating set in operation (indication)
- generator overload alarm
- operating hour meter and start-up counter
- speed indication with alarm and trip signals
- generator voltage, current, frequency, active and reactive power indication
- automatic synchronizing equipment
- manual synchronizing equipment such as double voltmeter, double frequency meter, synchronoscope, etc.
- manual/automatic synchronizing selector switch
- switches for manual adjustment of generator voltage
- generator circuit breaker ON/OFF control switch and indication
- generator protection relays activation (alarm and trip signals)
- other alarm and trip signals

Alarm shall be annunciated individually on the local annunciator unit on the local control board and remotely in the substation control room as a group alarm.

#### **d) Generator**

The generator shall be air-cooled with forced ventilation.

A still-stand heater shall be provided to protect the generator against humidity during standstill. Still stand heater shall automatically initiate when the set is being out of the service.

The generator winding insulation shall be according to class F. The temperature rise, however, at rated load shall not exceed the figures for class B insulation.

The generator shall tolerate the sudden application or rejection of 50% of its rated power without unacceptably high voltage fluctuations in excess of  $\pm 5\%$ .

A brush less rotating diode rectifier exciter shall be provided.

Voltage regulator with automatic and manual control shall be provided.

The diesel generator set shall be equipped with a synchrocheck device for parallel operation with the substation AC system. This is for testing the engine from time to time in the load condition and for switch-over to normal grid after an operation of the

diesel generator set. Manual synchronizing shall also be possible and therefore, the relevant instrumentation shall also be provided.

The diesel generator set shall at least be protected against the following cases:

- Over temperature protection (stator windings)
- Over current protection
- Overload protection
- Over speed protection

**e) Factory testing**

The ratings, calculation sheet, etc. for the diesel generating facility shall be submitted by the Bidder.

The plan for the tests at manufacturer's work, site and commissioning shall be prepared by the Contractor for the approval of the Engineer.

### **3.11 SOLAR PHOTO VOLTAIC SYSTEM**

#### **3.11.1. GENERAL**

The Solar Photo Voltaic system and other associated system elements shall be designed to ensure continuity of operation under all working conditions and to facilitate inspection, maintenance and repairs. Every effort shall be made during design and selection of equipment, with a reasonable safety margin, to ensure;

- a) Trouble free operation of the solar PV system during its intended design life
- b) Safety of operating personnel, equipment and accessories
- c) Continuous supply of spare parts in case of faulty situation

The Bidder shall comply with the latest of the following standards and codes.

- a) Protection, power quality and operational standards specified by the Ceylon Electricity Board for net metering schemes
- b) Relevant IEC (International Electro-technical Commission) standards for Solar PV systems

The supplier of solar photovoltaic system shall be a registered supplier of the Sri Lanka Sustainable Energy Authority (SLSEA) and shall be complied with the requirements published by the Sri Lanka Standard Institution (SLSI). The installation shall comply with the Net Energy Metering manual published by the Ceylon Electricity Board.

#### **3.11.2. SOLAR PV MODULES**

**a) Requirements**

The solar photo voltaic modules intend to use for the proposed solar PV systems should be made out of poly crystalline silicon cells and photo electrical conversion efficiency shall be 15% or higher. Module rating shall be 260Wp or higher while rated output of each module shall be within  $\pm 3\%$  of the declared value. Solar PV Modules shall perform in an operating environment where the temperature level ranging from 10°C to 85°C and relative humidity is 95%. Module fill factor shall be 70% or higher and shall be built to withstand against 50 m/s of wind speed.

The economic life of Solar PV Modules should be more than 25 years. Those shall be encapsulated and sealed to protect silicon cells from external environment and prevent ingress of moisture during its economic life. Solar cell surface shall be coated with anti-reflective coating and module frame shall be made out of corrosion resistant material. Further, it shall be compatible with the mounting structures to prevent corrosion.

Solar cell shall be certified to latest of IEC standards and safety shall be qualified accordance with IEC 61730 or latest.

#### **b) Identification and Labeling**

Solar modules shall be provided with identification labels including following essential information pertaining to design and manufacture of solar cells and modules.

- I. Name of the PV module manufacturer
- II. Country of origin of solar cells
- III. Country of origin of solar module
- IV. Date and year of manufacture of solar cells
- V. Date and year of solar module manufacture
- VI. Type or model number
- VII. Serial number
- VIII. Module I-V curve
- IX. Power rating
- X. Name of testing agency for IEC certification
- XI. Date and year of obtaining IEC qualifying certificate for solar PV module
- XII. Maximum permissible system voltage for which the module is suitable

#### **3.11.3. INVERTER**

##### **a) Requirements**

The inverter operation shall be based on Maximum Power Point Tracking (MPPT) principle. The grid interconnection protection scheme required at the grid interface shall be built in to inverter or separately as per the standards and requirement specified by the Ceylon Electricity Board. The Bidders shall be expected to thorough with the protection scheme required at the grid interface prior to choosing the Inverter. Further, it shall be protected against incorrect polarity of DC input.

The nominal Inverter power output shall be delivered to the existing low voltage system at three (03) phases, 400V, 50 Hz. The operating range of the Inverter shall be  $\pm 10\%$

nominal voltage and -6% / +4% of power frequency. These settings should be adjustable to set the Inverter operating range. The required system capacity shall be met using multiple of central inverters based on the capacity requirement.

The Inverter efficiency shall be at least 97% and the applicable IP class shall be IP 65 or higher. It shall be built with capability to synchronize with low voltage system including anti-islanding protection. Further, data logging, remote monitoring and data transferring functions shall also be embedded to the Inverter. The warranty period of the Inverter shall be minimum of ten (10) years.

The power quality of the Inverter output shall be as specified by the standard and specifications of Net Metering Scheme stipulated by the Ceylon Electricity. Selection of equipment and installation shall be in accordance with the latest of IEC 61727, IEEE 1547, IEE 17th Edition Wiring Regulations or latest available equivalent standards.

#### **3.11.4. COMBINER BOXES**

##### **a) Requirements**

Combiner Boxes and bus bars shall be suitably rated to handle the expected current flow at the combiner box. The array combiner boxes shall be sealed to prevent ingress of dust, vermin and moisture. The IP rating shall be IP 65 and a test point for fault detection shall be provided. Combiner boxes shall be embedded with suitable arrangement for array isolation and disconnection. It shall be fitted with cable glands for both incoming and outgoing cables which should be properly terminated at the combiner box. Protective devices shall be installed at combiner boxes to protect against over voltages and lightning conditions. Ground fault protection shall be provided either at combiner boxes or at inverters. The Cables shall be provided with proper markings for identification.

#### **3.11.5. CABLES**

##### **a) Requirements**

All DC/ AC cables ratings shall be selected for the maximum expected voltage and be able to handle maximum expected current in case of a short circuit condition. Cross section area of the conductors shall be selected such that energy losses are within the stipulated limits and voltages are managed at stipulated limits to facilitate trouble free operation of the equipment and PV system.

Cables shall be terminated using proper tools and to be taken through either conduits or cable trays and the same shall be firmly secured. All exposed cables, conduits and cable trays shall be resistance to UV radiation, heat and abrasion. The calculation of current rating, drops and cable de-rating factors shall be in accordance with the relevant IEE 17th Edition Wiring Regulations.

#### **3.11.6. EARTHING**

##### **a) Requirements**

All non-current carrying metal objects such as solar PV panel frames, mounting structures, enclosures etc shall be grounded using unbroken earth wire. Earth wire shall be neither disconnected nor connected via fuse or any other link which has the tendency for physical opening or separation. The earthing system shall be electrically connected to provide return to earth path from all equipment irrespective of their mechanical connection.

Earth resistance shall be less than one (1) Ohm. Test point shall be provided for earth electrode for inspection and testing. The earth wire conductor shall be made out of copper and shall be designed to withstand expected highest current.

### **3.11.7. MONITORING AND DATA ACQUISITION SYSTEM**

#### **a) Requirements**

The proposed Monitoring and Data Acquisition system shall be designed for the solar PV system for sensing, collecting and storing of following system data and shall be monitored locally by the station computer, smart phone/tab and in-built display of the inverter.

- I. Inverter power output, line and phase currents for all three phases
- II. Measurement of DC voltage and current at Inverter
- III. Energy exported to the low voltage system

Recorded data shall be time stamped and should be provided in ASCII or Excel format and the internal memory of the system shall be stored such data for at least 6 months.

### **3.12 MAIN CIRCUIT BREAKERS**

The Moulded case circuit breakers or air circuit breakers shall be provided for protection and disconnection of the main circuit of AC power supply system.

The circuit breakers shall be of 4 poles, high speed fault limiting, thermal/magnetic type to IEC 60947 or equivalent standard with quick make and quick break trip free mechanisms which prevent the breaker being held in against overloads or faults.

Tripping arrangements shall be such as to ensure simultaneous opening of all phases. Arc extinction shall be by de-ionising arc chutes or other suitable means.

The dolly shall have three positions, "on", "off" and "tripped". To reset from the "tripped" position the dolly shall first pass into the "off" position.

Circuit Breakers on the main switchboard shall have facilities for locking in the "off" position.

The rupturing capacity of the ACB shall not be less than that of the switchboard itself, or if this is not the case back up fuses must be included.

### **3.13 MOULDED CASE CIRCUIT BREAKERS (MCCB)**

Moulded case circuit breakers shall be provided for each feeder circuit protection and disconnection and mounted in the switchboards. The MCCBs shall be designed to comply with the requirements of IEC 60947. The MCCBs shall be equipped with a



padlocking device to lock the MCCB toggle in the “OFF” position. Trip ratings and frame sizes of all MCCBs shall be suitably rated for loads and the available short circuit currents.

### 3.14 MINIATURE CIRCUIT BREAKERS

Facilities shall be provided for protection and isolation of circuits associated with protection, control and instruments. They shall be of approved type and grouped, as far as possible, both on the panels and the associated wiring diagrams.

Facilities for protection and isolation of control and tripping circuits are preferably to be mounted on the outside of control panels.

Miniature circuit breakers shall comply with IEC 60898 of 1995 or IEC 60947.

Where miniature circuit breakers are used on control, protection and alarm supplies, tripping shall cause an alarm to be displayed locally as well as in the remote and supervisory control locations.

MCBs shall be positioned at the bottom of the face of relay and control boards.

### 3.15 SWITCHFUSES AND DISCONNECTORS

Each switch-fuse or disconnect switch unit shall be housed in a separate metal compartment and provided with a hinged metal door interlocked with the switch mechanism so that:

- (1) The door cannot be opened whilst the switch is closed.
- (2) The door, on opening, automatically locks the switch in the “off” position. Facilities shall be incorporated to allow for the deliberate release of this interlock for maintenance purposes, should it be desired to observe the switch in operation.

An insulating barrier shall be fitted to segregate the fuses and neutral link from the switch and the connections of the latter shall be effectively shielded by an inner metal screen when the compartment door has been opened to obtain access to the fuses.

The switch-fuses may be either of the combination fuse-switch type or of the type with the switch and fuse in separate units. In either case, interlocking shall be provided to prevent access to the fuses until the associated switch is opened and provision shall be made for padlocking the switch in the “on” and “off” positions.

The switch shall have a quick make and quick break action independent of the speed at which handle is operated and shall be entirely suitable for switching the inductive loads associated with motor circuits.

### 3.16 FUSES

Fuses shall be of the HRC cartridge type for operation at a prospective fault level of not less than 25 kA and conforming to IEC 60269. The mountings of the fuses shall be such that they can be readily withdrawn and replaced whilst the associated busbars and circuits are live.

### 3.17 INTERLOCKS ON SWITCHBOARD & FUSEBOARDS

Incoming circuits at switchboards and fuse boards are not provided with fuses or circuit breakers, the circuits being protected on each case at the point supply. Interconnector

circuits with other 400 V boards shall be provided with fuses or circuit breakers at both boards.

Switchboards shall be provided with electrical or mechanical key type interlocks in order to prevent the two normal incoming supplies being paralleled.

### **3.18 ACCESSORIES**

Following accessories shall be provided for the switchboards.

#### **3.18.1 Termination of cables**

Terminations for control cables shall be made in accordance with IEC 60439.

Special attention is drawn to Chapter 10.9, which details the general requirements for cable boxes and glands.

#### **3.18.2 Earthing**

Earth metal of switchboards, fuse boards and distribution board shall be bonded together and earthed to the main station earthing system. Earthing connections shall be carried out in bare copper strip with cross sectional area of 150 sq.mm.

### **3.19 JUNCTION BOXES, TERMINAL BOXES AND MARSHALLING KIOSKS**

#### **3.19.1 General**

All junction boxes, terminal boxes and marshalling kiosks shall be constructed of steel or cast iron. Each shall be provided with an earth stud.

All main equipment shall be arranged so that it is accessible from the front of the box or kiosk.

All junction boxes, terminal boxes and marshalling kiosks shall be properly labelled as per the wiring diagrams.

Enclosures for electrical apparatus are to afford the following degrees of protection classified in IEC.60529.

- (i) Outdoor marshalling boxes or kiosks - IP54- also provision of a thermostatically controlled 230 VAC anti-condensation heater and having screened drainage holes.
- (ii) Auxiliary switches and associated terminals - IP54 - as (i) but with heater control switch common to other apparatus on the same circuit.
- (iii) Outdoor junction boxes - IP54.
- (iv) Outdoor instruments - IP65.
- (v) Outdoor motors - IP54.
- (vi) Indoor control relay and low voltage AC & DC cubicles - IP41 - also provision of a thermostatically controlled 230V AC anti-condensation heater and indicating light common to a group of cubicles.

## 3.20 MARSHALLING KIOSKS

### 3.20.1 Switchgear Marshalling Kiosks

For each circuit bay an outdoor marshalling cubicles or kiosk shall be provided for the marshalling of all ancillary equipment cabling associated with the circuit, e.g. busbar selector and line isolating switches, current and voltage transformers, etc., to be routed via trunk multicore cables to remote control and relay panels.

Kiosks shall be provided with the necessary terminal blocks, cable gland plates, etc., for termination of multicore cables.

The kiosks shall be free-standing and of weatherproof and vermin proof sheet steel construction.

All fastenings shall be integral the doors and provision made for locking. Doors shall be rigid, and fitted with weatherproof sealing-material suitable for the climatic conditions specified.

The kiosks shall be well ventilated through vermin-proof louvers comprising a brass gauze screen attached to a frame and secured to the inside of the cubicle.

Any divisions between compartments within the cubicles shall be perforated to assist air circulation. In addition, an anti-condensation heater of an approved type shall be provided and controlled by a single pole switch mounted within the cubicle.

### 3.20.2 Transformer Marshalling Kiosks

The transformer ancillary apparatus shall be mounted in an approved heated and ventilated cubicle, attached to the transformer for the accommodation of the following equipment: -

- (a) Temperature indicators, (if not separately mounted) cooler control “Auto-Hand” selector switch and test links and ammeter for the winding temperature indicator circuits as specified in Chapter 10.
- (b) Control and protection equipment for the tap change gear including an isolating switch in the incoming circuit capable of carrying and braking the full load current of the motor and of being locked in the open position. Provision shall also be made for termination of secondary wiring of current transformers.
- (c) Control and protection equipment for the cooling plant including isolating switches in the incoming circuit each capable of carrying and breaking the full current of all cooling plant motor of one radiator bank and of being locked in the open position.

The control facilities shall include a cooler selector switch, which can be padlocked in either position to select either cooler for remote control. Local control of the selected cooler shall be provided.

- (d) Terminal boards and gland plates including glands where specified for incoming and outgoing cables.

All doors shall be fastened by integral handle with provision for locking each door.

The temperature indicators shall be so mounted that the dials are not more than 1700mm from ground level and the door(s) of the compartment shall be provided with

glazed windows of adequate size or otherwise, where separately mounted, their enclosure shall have a degree of protection not less than IP65.

Facilities shall be provided to permit the temperature indicators with capillary tubing and bulbs to be removed from the cubicle. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the cubicle.

To prevent internal condensation an approved type of metal clad heater shall be provided, controlled by a watertight rotary switch mounted on the outside of the cubicle and a 5 A fuse inside the cubicle.

All internal wiring shall be so placed as not to obstruct access.

All wiring, connections, terminals, boards, and links shall be in accordance with Chapters 3.1 and 3.2.

Labels in addition to those specified in General Technical Specification shall be provided on the outside of the kiosks to identify the compartments.

All three-phase relays, contactors, isolating switches and thermal devices shall be marked with appropriate phase colour. Apparatus in which the phase elements are mounted vertically they shall be coloured red, yellow, and blue from top to bottom.

### **3.21 GAUGE CUBICLES AND PANELS**

Gauge and instruments shall be grouped whenever possible and housed in suitable cubicles. Where circumstances do not justify cubicle accommodation, they may be secured to flat back panels but in such cases the approval of the Engineer is first to be obtained.

Cubicles shall be sheet metal having a minimum thickness of 2 mm. The construction shall employ folding techniques with the use of standard rolled sections or other reinforcement where necessary. The stiffness shall be such as to prevent maloperation of relays or other apparatus by impact. The front of the panel shall have a smooth well-finished surface.

### **3.22 KEYS AND KEY CABINETS**

If key-locked switches are specified, they shall be provided with approved lock for locking in the respective position. A similar lock shall be provided for each selector switch for locking the switch in any of its positions.

Approved means shall be provided for locking the cubicle doors, live terminal shutters, etc.

In general, each lock or padlock used shall be different from the others and shall be supplied with three keys. All keys shall fit to a master key system and six master keys to open any lock or padlock shall be supplied. The cabinet door keys shall be identical and shall be twelve in number.

All locks and padlocks shall be of brass and where they are fitted to switchboards or similar cubicles they shall have the visible parts chromium plated.

The Contractor shall submit for approval a key list and plan/ schedule for the intended system to be provided for securing the electrical operations and interlocking by keys.

Where a group of locks is supplied under any part of the Contract, a cabinet of approved design shall be supplied at the Station Control Room for the accommodation of all padlocks and/or keys while not in use. The padlocks and keys shall be engraved

with an agreed identifying code or inscription and this shall be repeated in the cabinets on engraved labels.

### 3.23 LABELS

Labels shall be provided inside each junction box or kiosk to describe the denominations of the various items of equipment. Where the kiosk is divided into compartments each door shall have an external label to identify the compartment.

#### 3.23.1 Labels and Instruction Plates on Instruments

Labels written in the language(s) indicated by the Engineer shall be provided for all instruments, relays, control switches, push buttons, indication lights, breakers, etc.

In the case of instruments, switches and control switches where the function is indicated on the dial plate or on the switch escutcheon plate, no label is required.

Relays shall be clearly labelled according to their function in the circuits, and to their related equipment, which shall be identical to the designations as used in the circuit manuals.

Instruction plates in English language showing the sequence diagrams or cautions for maintenance shall be fitted inside of the front door of the electrical switchboards.

Sample of writings shall be submitted before hand for approval to the Engineer.

#### 3.23.2 Circuit Labels

Circuit labels shall be made of synthetic resin with black letters on a white background, engraved in the English language. The sizes of the circuit labels shall be subjected to the approval of the Engineer at site.

In the case of indoor circuit breakers, starters, etc., transparent plastic material with suitably contrasting colours and engraved lettering may be acceptable. However, samples shall be submitted to the Engineer at site for approval.

MV switchboards and transformers shall have red labels with 7.5cm high white letters reading:

DANGER ..... VOLTS

in the approved language(s).

LV switchboards and switch-room doors shall have suitable labels (in colours as given below) with 5 cm letters reading:

MAINS 400 VOLTS

Busbar risers and sub-switchboards shall have similar labels, but with letters 3 cm high.

The colours of labels shall be as follows:

- AC Mains                      Yellow label with black letters
- Protection System      White label with red letters
- Emergency System      Red label with white letters
- DC Battery Supply      White label with black letters

All fixing facilities of labels shall be made of stainless steel.

### 3.23.3 Labels and Identification for Conduits, Boxes, etc.

Labels for conduits shall be of aluminium tape with 6mm minimum height, embossed ciphers. Other types of labels may be accepted subject to the approval of the Engineer.

The interior of each piece of equipment shall be clearly marked to show the phases and, for this purpose, either coloured plastic discs screwed to fixed components, or identification by means of plastic sleeving, or tape shall be used.

All conductors shall have their outer covering coloured to the phase colour or, alternatively, appropriately coloured plastic sleeves may be utilized at all cable terminations in fuse-boards, switchgear, etc.

### 3.23.4 Labels and Identification for Cables

When completely installed, each cable shall have permanently attached to it at each end and at intermediate positions as considered necessary by the Engineer, non-corrosive metal plates upon which the identification number of the cable, voltage rating, conductor size and make shall be engraved or stamped.

Cable identification numbers shall comply with the cable schedules, which shall be prepared by the Contractor according to the cables actually laid. These cable schedules shall indicate the cable numbers, cable sizes, approximate lengths, voltage, number of conductors, conductor size, termination and connections at each end, and along the cable route.

All cables in cable pits and at entries to building blocks shall be labelled, utilizing the aforementioned type of label.

**CHAPTER 4 - STORAGE BATTERIES, CHARGERS**  
**DC SWITCHBOARDS AND INVERTERS**

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## **CHAPTER 4 - STORAGE BATTERIES, CHARGERS, DC SWITCHBOARDS AND INVERTERS**

### **4.1 GENERAL**

All batteries, chargers and distribution equipment shall be suitable for switchgear tripping and closing duties, alarm and indications, emergency lighting, and all other items of equipment covered by this specification.

The charger supply may be either three-phase 400V or single phase 230V 50Hz and the Contractors requirement shall be declared in Technical Particulars & Guarantees.

The complete equipment shall preferably be a manufacture's standard, but any departure from this Specification shall be subjected to the approval of the Engineer.

A durable instruction card shall be included in each set. Means shall be provided using diodes to prevent excess voltage causing damage to connected apparatus when a battery is being charged.

### **4.2 TYPE OF BATTERIES**

The batteries shall be of the high performance Nickel Cadmium pocket plate type complying with IEC.60623 and shall be designed for a life expectancy of at least 20 years under the conditions of service likely to be encountered by the equipment detailed in this Specification.

A complete set of test and manufacture accessories suitably boxed, shall be provided for each battery. A syringe hydrometer and a durable instruction card shall be included in each set.

Battery cases are of high impact translucent plastic.

The electrolyte shall be free from impurities and the Potassium Hydroxide used shall comply with IEC 60993. Dilution of the alkaline and topping up of cells shall be carried out using distilled water only.

Cells shall be permanently marked with the following information.

Manufacture's reference number and code

Year and month of manufacture

Voltage and nominal capacity at the 10 hour discharge rate

A small electrically operated water purifier shall be provided where specified in Scope of Works.

### **4.3 STORAGE BATTERY**

The Contract includes two storage battery banks of NiCd batteries, with 02 battery chargers and one DC (Direct Current) switchboard as requested in the Scope of Works.

The minimum rated capacity of each battery bank shall be as per the scope of works and the rating of the batteries shall be as specified in Technical Particulars & Guarantees.

The following criteria shall be adopted. The rating of the battery shall be calculated in accordance with IEEE 1115, for a final voltage per cell of 1.1V.



The rating of battery shall be such that when charged to 100% of its rated capacity at the start of the duties, it shall be sufficient to supply the demands set out as follows with the charger disconnected.

The standby duty requested is as follows

- (1) Supply all standing DC loads for control, protection alarms etc.
- (2) Supply all transformer circuits standing loads.

After supplying the above coincidental loads for a period of 08 hours, the battery shall be capable of two sequential closing and tripping operations of each HV & MV circuit breaker. Following this duty the battery terminal voltage shall not be less than 90% of the nominal voltage.

All quantities derived in this manner shall be quoted in the Bid, but shall not be used for ordering materials until specifically approved by the Engineer.

The electrolyte capacity and general design of the batteries shall be such that inspection and maintenance, including topping up of the electrolyte, shall be at the intervals of not less than twelve months.

#### **4.4 48V DC SYSTEM FOR COMMUNICATION AND SCADA EQUIPMENT**

##### **4.4.1 DC-DC Converter system**

DC-DC Converter system shall be powered from station DC Supply (110V DC or 220V DC) and the nominal output shall be 48V DC. The system shall consist of at least two DC-DC converters and all converters shall share the load equally. In case of failure of one converter, other converters shall be capable of bearing the full load (sharing the full load equally). Outputs of all converters shall be galvanically isolated from input supply and there shall not be any current circulation among converters due to parallel operation. Current limiting function shall be built in to the individual converters to prevent damages due to overload or short circuit conditions. The individual outputs of the converters shall be fed to the common output of the DC-DC converter system through a suitable mechanism and through suitable circuit breakers or semiconductor fuses. The common output of the DC-DC converter system shall be fed to the 48V DC distribution board (described below) through a suitable circuit breaker. The current rating of the converter system shall be not less than 25A.

##### **4.4.2 48V DC distribution board with protection**

The 48V DC distribution board shall be fed from 48V DC supply derived from DC-DC converter system. There shall be outputs for all existing communication equipments and at least five extra outputs for future expansion. All outputs shall be protected with circuit breakers individually and be capable of switching on / off

individually. A master switch shall be provided to switch on / off entire 48V DC supply.

#### 4.4.3 Alarming system

- i) Output Over voltage detection equipment to give local indication and remote alarm when the output of 48V DC supply voltage rises more than 52V.
- ii) Output Under voltage detection equipment to give local indication and remote alarm when the output of 48V DC supply voltage falls less than 45V. A time delay shall be incorporated to prevent initiation during temporary voltage drops caused by transient conditions including circuit-breaker closing operations.
- iii) Input Over voltage detection equipment to give local indication and remote alarm when the input of 48V DC supply voltage rises more than
  - a) 118V for stations having 110V DC supply
  - b) 236V for stations having 220V DC supply
- iv) Input Under voltage detection equipment to give local indication and remote alarm when the input of 48V DC supply voltage falls less than
  - a) 105V for stations having 110V DC supply
  - b) 210V for stations having 220V DC supply

A time delay shall be incorporated to prevent initiation during temporary voltage drops caused by transient conditions including circuit-breaker closing operations.

- v) Earth leakage detection equipment to give local indication and remote alarm of the occurrence of a negative earth fault

Provision of “local Indication” by lamps on the front of the charger cubicle and provision for “Remote Alarm” by changeover contacts (rated at 5A for voltages between 30 and 250V AC or DC) on the devices to energize a group alarm relay.

Above all alarms shall be grouped in to two categories “Priority” and “Non Priority” basis and those two group alarm shall be incorporated to the Substation Automation System.

#### 4.4.4 Over / Under voltage cut-off system

- i) Output Over voltage cut-off equipment to cut-off the system when the output of 48V DC supply voltage rises more than 55V.
- ii) Output Under voltage cut-off equipment to cut-off the system when the output of 48V DC supply voltage falls less than 35V. A time delay shall be incorporated to

prevent initiation during temporary voltage drops caused by transient conditions including circuit-breaker closing operations.

iii) Input Over voltage cut-off equipment to cut-off the system when the input of 48V DC supply voltage rises more than

- a) 125V for stations having 110V DC supply
- b) 250V for stations having 220V DC supply

The system shall operate up to not less than the above mentioned input over voltage limit with full power.

iv) Input Under voltage cut-off equipment (if any) SHALL NOT cut-off the system when the input of 48V DC supply voltage falls NOT LESS THAN

- a) 90V for stations having 110V DC supply
- b) 180V for stations having 220V DC supply

The system shall operate down to not more than the above mentioned input under voltage limit with full power.

The system shall be able to operate a time delay shall be incorporated to prevent initiation during temporary voltage drops caused by transient conditions including circuit-breaker closing operations.

#### 4.4.5 Grounding

The positive terminal of the 48V DC supply system shall be grounded in order to provide a

-48V DC supply for communication and SCADA equipment.

#### 4.4.6 Instrumentation

- i) 48V DC supply output voltmeter.
- ii) 48V DC supply output ammeter.

These instruments shall be provided in the front of the cubical / cabinet.

#### 4.4.7 Operating and storage temperature

The system shall be capable of operating at ambient temperature between 0°C and 55°C with full power.

The storage temperature range shall be -20°C to 85°C.

#### 4.4.8 Operating and storage humidity

The operating and storage humidity range shall be 5% and 95% .

#### 4.4.9 Spares

- a) A complete set of manufacturer recommended spares shall be provided.
- b) Spares shall be available for five years from the date of commissioning.

#### 4.4.10 Test at site

All functional tests (alarms, signals, output voltage regulation, output voltage ripples, etc.) and any other test(s) proposed by the manufacturer (if any).

#### 4.4.11 Information to be submitted with the bid

A technical specification of the equipment, which shall include a description of the design, operation, construction, performance and maintenance aspects of the equipment.

### 4.5 LOCATION

The batteries shall be installed in the battery room. This room shall be properly ventilated by an extract fan with fan failure alarm/indication.

These batteries shall not be housed in the same room as any acid battery whether supplied under this Contract or not. The charging equipment and distribution switchboards are to be housed in a separate room.

The batteries shall be numbered and are to be mounted in double tiers on timber stands and arranged in a manner such that each cell is readily accessible for inspection, test and maintenance including topping up of the electrolyte.

There shall be a minimum clearance of 40mm between earthed metal and any conductor.

Connections between the battery and the distribution cubicle shall be made in PVC insulated cable.

### 4.6 BATTERY FUSES

Cartridge fuses shall be provided in both positive and negative leads and positioned as close to the battery as possible and shall be rated for at least three times the maximum battery discharge current at the highest operating voltage. The fuses shall be mounted on the end of the battery stand or rack. Fuses shall be inside a transparent box and cables must be insulated. These fuse links shall comply with BS.88 Class DC.40 and shall be bolted in position without carriers. A warning label shall be fitted to warn personnel of the dangers of removing a fuse whilst the load is connected.

### 4.7 BATTERY CHARGERS

Two battery chargers shall be provided for each storage battery. The battery charging system shall be designed as duplicate system.

Each battery charging equipment shall comply with the requirements of IEC. 60146 as applicable. And it shall be of the thyristor controlled automatic constant voltage type

with current limit facilities and shall be suitable for supplying the normal constant load and at the same time maintaining the battery to which it is connected in a fully charged condition while floating across the load and charger.

Arrangements shall be made such that in the event of the battery becoming discharged during AC supply failure, the rate at which recharging commences is as high as possible consistent with maintaining the automatic charging constant voltage feature and with the connections remaining undisturbed as for normal service.

Each charger shall also incorporate a boost charge feature which shall, after having been started, provide an automatically controlled high charge rate sufficient to restore a fully discharge battery to the fully charged state within twelve hours without excessive gassing or any form of damage to the battery. The boost charge shall be initiated manually.

Each charger shall operate satisfactorily within the permitted tolerances for AC supply voltage and frequency variations as specified in chapter 1. The design of the charger shall be such that it will operate satisfactorily from this supply without harm to itself, the battery or any equipment connected to D.C. auxiliary supply system.

A suitable voltage dropper shall be provided to control the system within the continuously allowable limits during boost charging and other high charging conditions.

Each charger shall be capable of automatically and continuously supplying the constant load with the battery disconnected. Under such conditions, the charger shall still maintain the nominal system voltage as previously specified without any damage to itself and the ripple shall not exceed 10% r.m.s of the no load output voltage.

Each charger shall also be capable of sustaining without damage to itself, a continuous permanent short circuit across its output terminals. The use of fuses, MCBs or other similar devices will not be acceptable in meeting this requirement.

Should the AC supply fail while a battery is on boost charge the switching arrangements shall automatically revert the charger to the float charge status and then reconnect the battery supplies in parallel.

#### **4.8 BATTERY CHARGER ALARM DEVICES**

The following shall be provided:

- (i) Over voltage detection equipment to give local indication and remote alarm when the charger voltage rises more than five volts above its normal automatic float voltage. This alarm shall be disconnected whenever the charger is operating on boost charge.
- (ii) Under voltage detection equipment to give local indication and remote alarm when the system voltage falls below 80% of its normal automatic float charge. A time delay shall be incorporated to prevent initiation during temporary voltage drops caused by transient conditions including circuit-breaker closing operations.
- (iii) Charger fails detection equipment to give local indication and remote alarm if the voltage from the charger falls below the nominal floating charge voltage. Suitable blocking diodes shall be provided to prevent the battery voltage being supplied to the equipment so that only the charger voltage is effective in causing the alarm.

The device shall not operate on switching surges or transient loss of voltage due to faults on the AC system. The voltage at which the alarm operates shall be adjustable for operation over a range to be approved by the Engineer.

- (iv) Rectifier: fuse operation detection equipment to give local indication and remote alarm of diode/thyristor and surge circuit protection fuse operation.
- (v) Earth leakage detection equipment to give local indication and remote alarm of the occurrence of an earth fault and to give discrimination between positive and negative earth faults with relevant annunciations. Test circuits shall be incorporated to simulate positive and negative faults by operation of test pushbuttons.

Provision of “local Indication” by lamps on the front of the charger cubicle and provision for “Remote Alarm” by changeover contacts (rated at 5A for voltages between 30 and 250V AC or d.c.) on the devices to energise a group alarm relay.

Above all alarms shall be grouped in to two categories “Priority” and “Non Priority” basis and those two group alarm shall be incorporated to the Substation Automation System.

#### **4.9 BATTERY CHARGER INSTRUMENTATION AND CONTROLS**

In addition to the necessary controls for float and boost charging, the following are to be provided on the front of the cubicle:

- (i) Charger Output/ battery Voltmeter.
- (ii) Charger dc Load Ammeter.
- (iii) Load Ammeter.
- (iv) AC Supply MCB. A link shall be provided in the supply neutral.
- (v) Charger operating on Boost Charge indicating lamp (Amber).
- (vi) Isolating switches for each battery.

#### **4.10 DC SWITCHBOARD**

The distribution switchboard shall be of the cubicle type or otherwise incorporated in the cubicles for battery chargers. Two-pole miniature circuit breakers shall be fitted to the d.c. Switchboard required by substation services but as a minimum requirement that set out in Scope of Works.

Each circuit shall be adequately labelled with its requirement function.

The switchboard shall comply with the requirements of IEC. 60439.

DC bus-bar voltage shall be monitored continuously and shall give an alarm (operated by AC) in the event of DC failure.

Facilities shall be provided at the auxiliary supply panel to identify DC earth faults of each outgoing feeder separately.

#### **4.11 INVERTER POWER SUPPLY**

All A.C. supplied required for SAS system equipment (Chapter 5) shall be powered by two set of inverter equipment, with the inverter normally supplying the load. The inverter shall be the PWM type, providing a single phase output.

### 4.11.1 Operating principle

The typical inverter distribution system is shown in the drawing.

The each inverter input shall be connected to the substation 110V DC power supply. D.C. supplies to the inverter shall be separately monitored. The output of the each inverter shall continuously supply the AC power requirements of the total SA system equipment. But normal operation two section of SAS loads are powered by individual inverters.

The output of the inverter shall be maintained within the voltage and frequency tolerances of the load at all times.

In the event of one Inverter failure situation, the relevant out put busbar shall be connected via Bus section breaker by means of automatic transfer switch.

### 4.11.2 Information to submitted with the bid

The Bidder shall submit the following with the bid.

- A technical specification of the equipment, which shall include a description of the design, operation, construction, performance and maintenance aspects of the equipment.
- MTBF calculations shall be included, to justify the “system” MTBF proposed (Based on an ac mains MTBF of 1000 hours and an MTTR of 6 hours)
- Inverter system efficiency at 25%, 50%,75% and 100% load.

### 4.11.3 Configuration

The power supply shall comprise two inverter, a static switch with associated control electronics, Automatic Transfer Switch, and inverter distribution with two busbars.

### 4.11.4 Inverter

#### 4.11.4.1 Output voltage static regulation

The inverter output voltage shall be maintained to  $\pm 1\%$  of the nominal value during the following conditions of UPS loading:

- 0 to 100% load
- load power factors over the range 0.7 lagging to unity
- inverter dc voltage input range
- specified ac mains input supply voltage and frequency

load current waveform having a relative harmonic content varying between zero and 50%. The latter waveform having a crest factor not exceeding 2.5 and individual harmonics not exceeding the following values:

- 3<sup>rd</sup> harmonic - 44% of fundamental
- 5<sup>th</sup> harmonic - 33% of fundamental
- 7<sup>th</sup> harmonic - 18% of fundamental
- 9<sup>th</sup> harmonic - 7% of fundamental
- 11<sup>th</sup> harmonic - 10 % of fundamental

#### 4.11.4.2 Output voltage dynamic response

The dynamic output voltage variations shall not exceed  $\pm 10\%$  of the rated output voltage under any circumstances of instantaneous load changes. The output voltage shall be restores to within the 3% of the rated output voltage within 100 ms.

#### 4.11.4.3 Frequency deviation

The inverter shall control the output voltage of the inverter such as to maintain synchronism with the ac mains during variations in mains frequency within the load equipment operating limits. During variations exceeding these limits, the inverter shall revert to internal (unsynchronized) frequency control.

Under unsynchronized operation the frequency of the output voltage shall be maintained within  $\pm 0.1\text{Hz}$  of 50Hz.

#### 4.11.4.4 Other requirements

Under load equipment fault conditions the inverter shall provide overload values of output current for limited periods of time together with a thermal trip facility. In the case of a short circuit load applied to the inverter (with no bypass available), failure to clear the fault shall cause the inverter output to shut down.

The inverter shall include a battery high/low volt disconnect facility.

The inverter shall have the output neutral connection solidly bonded to earth via a removable link, to ensure that MCBs operate under earth fault conditions.

#### 4.11.4.5 Rating

The inverter shall be rated to continuously energies the load (comprising the delivered load together with 50% spare for future use).

#### 4.11.4.6 Instrumentation and alarms

- a) The following instrumentation shall be supplied as a minimum on the inverter system
- inverter dc input current
  - inverter output volts
  - inverter output frequency
  - inverter output current
- b) The following alarms shall be supplied as a minimum:
- inverter input voltage high/low
  - inverter fail
  - bypass to load
  - fault in auto transfer scheme
  - distribution MCB trip

Each alarm shall be provided with local annunciation and one set of potential free contacts, for alarm grouping and at least two groups shall be connected to the SAS Alarm-Event system.

#### 4.11.4.7 Inverter distribution

The distribution system shall be designed for incoming and outgoing ac supplies as follows:

- Separate supplies incoming from the inverter and the maintenance switch. Each incoming ac supply to the inverter distribution shall be connected to the distribution busbar through a double pole switch.
- Each load equipment shall be connected to a distribution outlet. The use of teed supplies to more than one load equipment will not be permitted.



Double pole miniature or moulded case circuit breakers to IEC 60947-2 shall be supplied, fitted with auxiliary contacts that operate when the circuit breaker trips.

The MCBs shall be rated to meet the load requirements and shall be labeled with the destination of the load. Outgoing connections shall be brought to terminals mounted in the cubicle, provided with strip connectors and cable lugs. The number of outlets shall cater for the quantity of load equipment items plus 50%, with a minimum of 10 outlets being provided.

#### 4.12 TEST AT MANUFACTURE'S WORK

Battery	-	Type test in accordance with IEC 60623.
	-	In addition the Contractor shall demonstrate that the battery will perform the duties specified.
Battery Charger	-	Type and Routine Tests according IEC 60146
DC Switchboard	-	Type and Routine Tests according to IEC 60439
Inverter	-	routine tests according to relevant standards

#### 4.13 TEST AT SITE

Tests at site shall cover the following at a minimum:

- All functional tests (alarms, signals, voltage regulation, booster charge, etc.) described in the battery charger and Inverter manual.
- Charging and Discharging test for all battery banks as per IEC.
- Insulation tests of circuits.
- Ripple measurement in output voltage waveform of the Inverter.
- Auto Transfer Scheme of the Inverter.

**CHAPTER 5 - PROTECTION, MONITORING, METERING AND CONTROL**

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## 5.1 ARRANGEMENT OF FACILITIES

There shall be two control & protection IEDs hereafter known as “Main1” and “Main2” to provide required protection and bay switchgear control for line bays, bus couplers/ bus sections and transformers with voltage levels above and including 132kV. Both IEDs shall have identical control & protection functions necessary for the respective bay. For voltage levels below and including 33kV there shall be only one IED providing both control and protection functions (33kV Transformers , 33kV Bus couplers/ Bus Sections and 33kV feeders)

Control Protection and Substation Automation System (SAS) supplier shall be the manufacturer of either Main 1 or Main 2 control & protection IED as per manufacturer eligibility under chapter 5.7 and 5.23.6. The SAS software shall be a product of this supplier. He shall be responsible for providing the Control/Protection and SAS panels as per the specifications in chapter 5.2 including design, engineering and commissioning. Commissioning of the Control, Protection and SAS shall be carried out by the Authorized Commissioning Engineer/s of the supplier. Partners of the supplier are not allowed to offer, configure, supply, test and commission the control, protection and the SAS system

Protection and control equipment shall be mounted on panels and boards as specified and shall be erected in permanent buildings on the substation sites. For air insulated substation at every voltage level in all bays except the exceptions mentioned below control, metering and protection equipment shall be mounted on the same panel. For following bays separate panels shall be used.

- 220kV Control/Protection Panel of 220kV/132kV/33kV system transformer bays

Control and protection equipment shall be housed in the 220kV control/protection panel. There shall be a separate panel for automatic voltage regulator relay (AVR) and it's accessories and mechanical tripping flag relays This is further explained in chapter 5.12.

- 132kV Control/Protection Panel of 132kV/33kV transformer bays

Control and protection equipment shall be housed in the 132kV control/protection panel. AVR relay and the mechanical tripping flag relay shall be housed in a separate panel. This is further explained in chapter 5.12.

For gas insulated substations there shall be two panels. A panel equipped with a mimic control mechanism for local controls shall be installed in front of the respective GIS bay. This panel shall be equipped with necessary switchgear controlling equipment and status indicating equipment. Further information is available in the chapter 5.8.2.2. Another panel shall be installed in a separate room which is identical to the protection/control panel discussed above for an air insulated substation.

Unless otherwise approved, the order of the panels shall be as specified reading from left to right facing the panels.

If existing protection is required to be modified for any reason, e.g. in order to operate with newly installed equipment, the Contractor shall supply all the necessary relays, panels, wiring terminals, wiring, etc. in order to ensure satisfactory performance.

This shall include the modification of the "remote end" (other station and/or other switchgear part) of any protected circuit. The Contractor shall also modify / improve the corresponding drawings, erect all necessary equipment and perform the commissioning in accordance with the requirements shown in this Bidding Document.

Where additional relay equipment is to be installed in an existing station, it is the responsibility of the Contractor for the protection equipment to ensure that the existing batteries and chargers have sufficient capacity to meet the additional load requirements of the new



equipment. The characteristics and the appearance of all such equipment shall be under the approval of the Engineer. A design concept shall be applied using decentralized modules for alarm (monitoring) and tripping functions operating independently of each other.

All components shall be suitable for the local climate and the control and protection panels shall be dust and moisture-proof to withstand all prevailing climatic conditions. The specified maximum ambient temperature shall be taken into consideration in closed rooms, as the perfect operation of the air-condition system in the rooms shall be assumed as not guaranteed. The Contractor shall design the systems and select equipment accordingly.

All equipment on the front face of panels associated with the HV and MV switchgear shall be flush mounted on the front panel of the control unit allocated to the feeder, or in front of the cubicle.

All equipment as well as the terminals of the panels shall be easily accessible. Space for at least one panel at each row of panels in addition to the final extension stage shall also be provided.

The instruments, relays, switches etc. on the front of the panels shall be arranged in such a way that a good overview, reading and maintenance will be guaranteed. Furthermore, all instruments, relays, etc. shall be clearly labelled in relation to their functions and to the equipment to be protected or supervised, or to the location of any measuring point. Labelling shall be identical in panels and on drawings.

Where appropriate, each item of the plant is to be equipped with all necessary auxiliary switches, contactors and mechanisms for indication, protection, metering, control, and interlocking, supervisory and other services. All auxiliary switches are to be wired up to a terminal board on the fixed portion of the plant, whether they are in use or not in the first instance.

For the necessary fire precautions in cubicles, reference is made to Civil Specification.

## **5.2 CONSTRUCTION OF CUBICLES**

Manufacturer of either Main 1 or Main 2 protection and control IEDs shall be responsible for providing the Control/Protection and Substation Automation System(SAS) panels (eligibility of the manufacturer is given under 5.7). All cubicles shall be constructed or braced rolled steel section, with recessed panels and substantial mounting sheets for power and control cable work. All steelwork shall be constructed of steel sheets with a minimum thickness of 2mm. The minimum Width, Depth and Height of all Cubicles shall be 800 mm, 800 mm and 2200 mm respectively.

The interior of each cubicle shall be finished with a mat light coloured surface and an interior lamp suitable for the local LVAC supply and controlled by a door-operating switch, and fitted at the top of each cubicle. Anti-condensation heaters shall also be fitted in each cubicle and each cubicle shall be well ventilated top and bottom through vermin proof louvers fitted with brass gauze screens. Each protection cubicle shall also be equipped with a built in AC supply socket out let of single phase, three wire rated 13 A at 230 V, 50 Hz.

The cubicles shall be of the self-standing, floor-mounted type and shall be provided with ways and means for floor fixing and anchoring devices. They shall be supplied completely with their fixing and lifting racks and eyebolts. Equipment and terminals shall be readily accessible and shall require a minimum of disturbance of associated adjacent equipment for access. The arrangement of panel wiring and multicore cable terminal boards shall be in accordance with the relevant Clauses of Chapter 3 of this Specification.

Enclosures shall be provided for bottom entry of power and multi core cables via gland plates.

Removable gland plates shall be located within the cubicles so as to provide adequate working clearance for terminating the cables.

Where relay movements and other sensitive equipment are mounted on hinged front panels, these shall be designed to minimize shock and wiring shall be so arranged as to impose no strain on terminations. No equipment whatsoever shall be mounted on rear access doors.

All sections of a composite cubicle shall be suitably labelled in accordance with the Specification and labels at the rear shall also readily identify each section or panel with the access doors either opens or close.

Each control & protection relay panel shall be of the swing rack type including 19" swing frame and a front cover door equipped with a glass window.

Indoor cubicles and panels shall be of at least IP 41 protection class, and all outdoor local control cubicles shall be of IP54 with sun/rain shades of adequate size.

Each door shall be fitted with suitable earth straps of at least 16mm<sup>2</sup> highly flexible stranded copper wire with an insulation in green-yellow colour.

Doors are to be arranged so that every individual door or frame can be opened without moving doors of adjacent cubicles. Doors shall be of 2 mm thick sheet steel, equipped with 120° concealed hinges, with foamed-in seal and shall be provided with a stable, bolted, rectangular tube frame, with pre-punched holes at 25 mm pitch for fixing channels, covers, cable harnesses, wiring plan pockets and etc. In each outdoor cubicle at least one door shall be equipped with a sheet steel wiring plan pocket. If required, cross rails shall be fixed additionally. The doorstopper at the end of the throw shall be provided.

Doors shall be handled by smooth action locking bars with rollers and security lock system, prepared for insert lengths of 40 or 50 mm. The inserts shall be provided in accordance with the master key system of the Employer, for which details shall be forwarded to the Contractor on request.

The Contractor shall perform a calculation for the heat dissipation for enclosures with the maximum installed heat-losses and shall propose a suitable temperature control method. However the method has to be approved by the Engineer.

Control and relay cubicles and -cabinets are to be installed in totally air-conditioned control rooms.

Cubicles provided as extensions or for erection in the same room with existing cubicles shall be of similar appearance

All enclosures and accessories, such as swing frames shall be corrosion protected by electrophoresis-dip-coat primers and final coats by an approved procedure as to suit the surrounding conditions at Site.

The arrangement and mounting of all indicating devices, control switches, relays and other apparatus shall be to the approval of the Engineer. The exterior and interior finish and colour of all cubicles shall be to the approval of the Engineer.

### **5.3 CABLING, WIRING AND TERMINAL BLOCKS**

In selecting cable and wire sizes, due regard shall be paid to the appropriate de-rating factors in relation to the climatic conditions at site. All cables and wires shall continuously carry their rated currents under the worst temperature conditions, and shall also withstand maximum fault currents without damage or deterioration.

All secondary copper wiring within panels, racks, boards, etc. shall be in accordance with the pertaining IEC, it shall be carried out for the fully rated distribution voltage (2 kV AC/ 1 min. test voltage), and shall consist of copper wires. The bare ends of stranded wires shall be provided with squeezed sleeves.

The minimum cross-section of each copper wire shall be at least as given below:

- 4.0 mm<sup>2</sup> for current transformer circuits and heavy power consumers up to 20 A
- 2.5 mm<sup>2</sup> for voltage transformer circuits
- 2.5 mm<sup>2</sup> for all power consumers such as motors, heaters, lighting, etc. up to 10A
- 1.5 mm<sup>2</sup> for all instrument and control wiring, however, the maximum permissible voltage drop is < 5 % for the furthest point at full load.
- 0.6 mm<sup>2</sup> for all telephones wiring.

Wiring shall be neatly run in PVC rigid plastic wire-ways, clear of any metal panels and filled not more than 70% or bundles with no bunch containing more than 12 wires. All power and control cables used for less than 60 V DC shall be laid and terminated separately. Where power and control cables cannot be laid separately, suitable metallic barriers shall be provided.

Both ends of every wire core and all secondary panel wiring above 60 V (at the screwed terminal side for external connection as well as at the screwed device sides in the panel) shall be fitted with numbered slip-on ferrules of moisture and oil-resisting insulation material having a glossy finish, and with their identification numbers clearly engraved, each being the same as for the relevant terminal.

Ferrules, of white colour with black letters, shall be fitted in such a way that they cannot become detached when the wire is removed from the terminal. (i.e. end crimps shall be provided).

All secondary wiring to be performed at Site shall enter the terminal block at one side only. The panel wiring shall terminate in one or more terminal blocks accommodated at the side or bottom of each panel.

Internal wiring between instruments or other devices not using the terminal block shall be permitted within the same cubicle only.

Whenever required and necessary, armoured and shielded cables and/or groups of cores shall be provided for control, protection and supervisory equipment.

Cables with spiral wrap designed shield shall be used for the current transformer circuits and voltage transformer circuits. The shield shall be grounded at both ends of the cable.

Generally, for wiring, the cable tails shall be so bound that each wire may be traced back to its associated cable without difficulty. Cores in pairs or groups shall be terminated together.

All incoming control cables shall contain minimum 20 % spare cores and be connected to terminal blocks, with 20 % spare terminals of each type. Any further spare cores shall be numbered included in the list of cable table, and shall be sealed in further spare terminals.

**Terminal blocks** shall be numbered consecutively in both sides, preferably beginning with 1, from left to right or top to bottom.

Terminal blocks shall consist of single "insertion" type terminals of non-tracking, non-inflammable synthetic plastic, or ceramic of an approved type, lined up in one row. Polyamide terminal blocks are not acceptable.

All terminals shall have two separate pressure clamping plates suitable for connection of incoming or outgoing stranded or solid conductors, respectively. However, only one wire per terminal will be accepted. Terminals with clamping screws in direct contact with the conductor are not acceptable.

The following minimum categories of terminals shall be used:

- Terminals for power circuits of 10 mm<sup>2</sup>, 6 mm<sup>2</sup> and 2.5 mm<sup>2</sup> size.
- Current transformer Secondary Terminals shall be 4 mm<sup>2</sup> size and shall have -
  - Facility to short circuit the Current Transformer side
  - Facility to isolate the Current transformer secondary side and Relay side by opening link in each terminal
  - Facility to directly plug in probes from test kit without removing wires from the terminal block
- Voltage Transformer Secondary terminals shall be 4 mm<sup>2</sup> size and shall have
  - Facility to isolate the Voltage transformer secondary side and Relay side by opening link in each terminal
  - Facility to directly plug in probes from test kit without removing wires from the terminal block
- DC circuit: It shall be possible to isolate the internal and external wiring using "knife disconnection" mechanism
- Terminals for wiring of 1.5 mm<sup>2</sup> and 0.6 mm<sup>2</sup> size with bridging facilities to the neighbouring terminals.

Terminal blocks shall comply the following IEC standards.

Connection Capacity	: IEC 60947-7-1/-2
Mechanical strength	: IEC 60947-7-1/-2
Bending test	: IEC 60947-7-1/-2
Conductor pull-out test	: IEC 60947-7-1/-2
Tight fit of terminal block	: IEC 60947-7-1/-2
Clearances and creepage distances	: IEC 60947-7-1/UL 1059
Dielectric test	: IEC 60947-7-1/UL 1059
Surge voltage test	: IEC 60947-7-1/-2
Voltage-drop test	: IEC 60947-7-1/-2
Temperature-rise test	: IEC 60947-7-1/-2
Short-time withstand current	: IEC 60947-7-1/-2
Corrosion test	: DIN 50018
Environmental testing methods	: IEC 60068-2-42/43
Shock testing	: IEC 60068-2-27
Vibration test	: IEC 60068-2-6

Test certificates from an independent internationally recognized test laboratory for the above standards shall be provided with the bid.

Insulating barriers shall be provided between each group of power circuit terminals and between the terminal categories, the height and the spacing being such as to give adequate protection to the terminals.

Control and relay circuits, current and voltage transformer secondary circuits, battery and auxiliary power supply wiring, supervisory, alarm and communication circuits shall be protected against conductive, electrostatic and electromagnetic influences.

#### **5.4 LABELS ON INSTRUMENTS AND RELAYS**

Labels shall be as defined in the panel arrangements given under Annexures 8-18. Labels written in English shall be provided for all instruments, relays, control switches, push-buttons, indication lights, breakers, etc.

In the case of instruments, switches and control switches where the function is indicated on the dial plate or on the switch escutcheon plate, no label is required in the front side but backside assembly labelling of those instrument is still required to identify them from inside the panels.

Relays shall be clearly labelled according to their function in the circuits, and to their related equipment, which shall be identical to the designations as used in the circuit manuals. Each label shall be fitted both on relay front and on relay assembly.

Instruction plates in English language showing the sequence diagrams or cautions for maintenance shall be fitted inside of the front door of the electrical switchboards.

Sample of writings shall be submitted for approval to the Engineer.

#### **5.5 TEST AND EARTHING FACILITIES**

##### **5.5.1 Earthing facilities**

Each control or relay panel shall be provided with a copper earth bar of not less than 80 sq.mm cross-section and arranged so that the bars of adjacent panels can be joined together to form a common bus.

The common earthing bus bar of control and relay panels shall be connected to the main station earthing system via a copper earthing connection of not less than 80 sq.mm.

Each current transformer secondary circuit shall be earthed through a removable link at one point only inside the control or relay panel.

##### **5.5.2 Test facilities.**

Since IED testing would be performed using the terminal blocks they shall be mounted inside the panel where they are clearly visible and easily accessible. Terminal blocks as stated in clause 5.3 shall be available to plug in test kits for testing of IEDs.

#### **5.6 PROTECTION DEVICES**

Protection equipment shall be designed and applied to provide maximum discrimination between faulty and healthy circuits. All equipment are to remain inoperative during transient phenomena, which may arise during switching or other disturbances to the system except power system faults.

The performance of the protection system and the performed coordination with the current transformer design shall be ensured. The Contractor shall submit a comprehensive technical report, which shall ensure that current transformer's and relays are designed saturation free under both transient and steady state fault conditions. Typical X/R ratios of 10 and 15 shall be considered for 220 kV and 132 kV systems respectively.

Prices quoted for the protection system shall include, whether explicitly indicated or not, all the necessary elements to coordinate and assure the approved and correct functioning of the protection system, new and existing, in accordance with the requirements of these Specifications.

Current transformers, where possible, are to be located so as to include the associated circuit breaker within the protected zone and shall be located generally as indicated on schematic drawings.

## 5.7 RELAYS

The protection Relay manufacturer should have a minimum of fifteen (15) years successful experience in the manufacturing of equipment in rated voltage and capacity, comparable to the equipment offered under the contract. In addition, a minimum of ten (10) years of experience shall be in manufacturing for orders from outside the country of the manufacturer. Furthermore, the offered model shall be in successful operation in substations for at least three years.

If the equipment is manufactured under a license, the experience (as given above) of equipment manufactured by the parent company shall not be counted as service experience of the licensee equipment manufacturer. Bidder shall provide adequate evidence of compliance to the above requirement to the satisfaction of the Buyer.

The Engineer will reject any design he considers unsatisfactory or having insufficient experience.

Protection equipment shall be of unit / standalone (and modular design shall be capable of replacing modules inside the relay such as power supply, processor and input-output modules) design with the possibility to add input/output cards and fibre optic communication interface if necessary. The offered IEDs shall be a standard product of the manufacturer.

The protection relays, shall be located in specified panels and shall be flush-mounted in dust and moisture proof cases with protection class IP54 and of the draw out type with rear connections. The protection class of the cover for all relays, or protection systems, in which the modules are mounted in 19" racks shall be IP41 or better. The relays shall be able to withstand a harsh environment, so the conformal coating shall be provided.

Relays shall be of approved construction and shall be arranged so that adjustments, testing and replacement can be effected with the minimum of time and labour. Relays of the hand reset type shall be capable of being reset without opening the case.

Electrical protective relays shall be only of numerical type. The relays shall have a warranty period of at least 10 years from the date of operational acceptance of the facility.

Numerical protection shall be designed in such a way that in case of a failure of DC auxiliary in feed, the full information need to be maintained at least 48 hrs. After a recovery of DC auxiliary in feed the last information and alarms will be displayed and the alarm "failure of DC auxiliary in feed" released. The relay reset shall not erase the relay memory.

The protection functions shall be in the form of software such that additional or different functions, application specific logic etc. can be readily implemented without changes to the existing hardware.

All the relays shall be provided with pc based software with following features.

The user program shall be compatible with Microsoft Windows® 10 64bit and 32 bit versions, Microsoft Windows® 8 64bit and 32 bit versions, Windows® 7 64bit and 32 bit versions and Windows® XP 64bit and 32 bit version environment. The user interface program shall contain a user-friendly graphical user interface thereby reducing the need of referring to the operator's manual.

It shall offer the following facilities:

- Ability to create setting template files relevant to the devices, edit and check parameters, off-line. I.e. without establishing a connection to the protection equipment.
- Ability to save and read parameters after establishing a connection with the relay
- Ability to download parameter sets through the Man Machine Configurator(MMC) to the relay
- Selection/adding of protection functions from a pre-defined library.
- Setting of parameters
- Configuration of user defined functional logics
- Configuration of the device to communicate through IEC 61850 standard
- In the case of Bus Bar Protection Configuration software, offered product shall be capable of adding new bays
- Display of actual measured and derived values (U, I, P, Q, f, etc.)
- Extraction of events.
- Extraction of disturbance records and ability to export them in COMTRADE format
- Testing of relay functions
- Facility to add self-explanatory texts with a minimum of coding.
- Ability to save relay data (set files, event lists, etc) in an interpretable format. (eg: pdf or MS Word or Comma separated plain text format)

Knowledge of programming shall not be necessary to operate the MMC programs. The user shall be guided through the functions by menus and windows displayed.

The ability to make changes to parameters, configured logics, binary input output mapping should be limited to users having required access privileges.

Function-specific parameters such as Input channels, pickup values, time delay, definitions of characteristics etc. shall be selectable from menus using the MMC program running on a PC.

If any licensees are required to operate the software to fulfil above described functions the user shall be given 10 licensees. If any third party tool/tools is needed to achieve any of the functions mentioned above, 10 of those licensees shall also be given.

All the numerical type protective relays shall be possible to program / parameterise directly (locally) and remotely by a portable computer (PC). **Five sets of** all other accessories equipment needed to communicate with the relays shall be provided. A backup copy of software (stored in compact diskettes) shall be given for future use. The device shall be connected to the system preferably via an Ethernet (RJ45) interface, Serial RS232 (DB9) interface or an USB interface.

A GPS clock should be utilised to update the relay internal clock. The relay event log, disturbance records should be time tagged and these should be able to retrieve by the PC both locally and remotely through the Optical Ground Wire (OPGW) network available. The accuracy of time tagging shall be within  $\pm 1$  ms.

The relays shall be provided with communication interface for connection to substation automation system and substation monitoring system. Relay shall meet the IEC 61850 standard in every respect and interoperability with other manufactures IEDs and tools should be verified. The bidder shall submit IEC 61850 conformance certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850-10 for the specific device bidder is presenting.

All protection relays shall have disturbance recorder and an event recorder in-built to them. Events shall be time tagged in the order of millisecond accuracy and the capacity shall be at least 8 disturbance records and 100 events. The disturbance recorder shall include at least 8 analogue channels and 32 binary channels and the recording duration shall be at least 5 seconds. The relay event log and disturbance records should be able to be retrieved by the PC both locally and remotely. Additionally, the event log shall be available on the LCD display of the relay.

A liquid crystal display (LCD) as the local human machine interface shall be available which sufficiently large enough to have the bay single line diagram and operate it without any difficulty. And ten programmable light emitting diodes (LED) for several alarms, additional three LEDs for the relay should be available.

In addition to all equipment and components, the Contractor shall supply documents to prove the correct functioning of the equipment, and shall ensure and demonstrate that the setting range of relays and the operating limits of all equipment is suitable for the intended applications.

Any auxiliary supplies needed shall be drawn from the main station batteries and not from separate internal batteries in the protection equipment.

Relays shall utilise a DC-DC converter type regulated power supply to provide transient surge isolation between the station battery and protection equipment.

Each DC supply shall be designed to protect it from high voltage and surge and provide electrically isolated contacts for annunciation.

Relays with provision for manual operation from outside the case, other than for resetting, will not be accepted.

Relays shall be provided with clearly inscribed labels describing their application, version, type, serial number and rating etc. in addition to the general purpose labels.

To minimise the effect of electrolysis, relay coils operating on DC shall be so connected that the coils are not continuously energised from the positive pole of the battery.

Relays shall be suitable for operation on DC systems as specified in Technical Particulars and Guarantees, without the use of voltage dropping resistors. Terminal arrangements shall be to the Engineer's approval.

The protection schemes shall incorporate interface facilities to transform any offered low rated input/output signals of required equipment, to the necessary rated input/output signal.

Unless otherwise specified, tripping shall always be directly from the relevant measuring relay.

If block-close facilities are specified, this relay shall be arranged to prevent the closing of any associated circuit breakers until it has been reset. Local and remote resetting shall be



possible. An operations indicator shall be provided which resets when the block-close relay is reset.

Any tripping relay, which completes the protection relays' initiated tripping of a circuit breaker, shall have an operations indicator. The tripping-contactors' operation must be guaranteed also with 50 % of the rated DC voltage (pick-up at 80 % of DC, self-holding down to 50 % of DC).

Any interruption of the DC supply to relays (internal and external) shall initiate an alarm. Converters and inverters used for feeding relays shall have their outputs monitored and shall initiate an alarm in the event they fail. These devices shall be of short circuit proof design.

All relays shall be adequately protected against damage from incoming surge and shall meet relevant IEC standards.

Type test reports shall be furnished as per IEC60255-1(Edition 1, 2009-08) with all tests summarized in Table11-test overview, according to the requirements given below and operating conditions given elsewhere in chapter 5.7

Temperature tests	Cold - IEC 60068-2-1
	Dry Heat - IEC 60068-2-2
	Operation -10°C to +55°C
	Storage -40°C to +70°C
Humidity	IEC 60068-2-2
Insulation	IEC 60255-27
	Dielectric Test 2kV AC 50Hz, 1min
	Insulation resistance tests 500V DC
	Impulse Voltage Test 5kV, 1.2/50µs, 0.5J
1MHz burst disturbance tests	IEC 60255-22-1, ANSI/IEEE C37, 90.1-1989
Electrostatic discharge tests	IEC 60255-26
	2, 4, 6,8kV contact discharge
	2, 4, 8,15kV air discharge
Fast transient tests (Burst)	IEC 60255-26
	2kV/4kV 5kHz
Power frequency magnetic	IEC 61000-4-9 , 1000 A/m 50Hz permanent field
	Field immunity test Level 5
Radio frequency	IEC 60255-26
Conducted RFI Immunity	10Vrms
Radiated RFI Immunity	10V/m (Unmodulated)
Emission	
CI.A	EN 50081-2(1994)
(Industrial environment)	EN 55011(1992)
	CISPR 11(1990)
	EN 55022(1995)
	CISPR 22(1995)
Seismic Test	IEC 60255-27/ IEC 60255-21-3
	Class 2

The product shall possess test certificates from an independent internationally recognized test laboratory for the above standards. The bidder shall submit the relevant type test certificates.

### 5.7.1 Hardware Requirements

Basic hardware requirement of the different hardware channels are discussed within this chapter. This chapter is common for all types of bays and the number of channels required vary depending on the application. Those specific requirements are discussed in chapters 5.9 – 5.16.

#### 5.7.1.1 Analog Inputs

Operating ranges shall be between +10% and -10% for rated voltage and +5% and -5% with 50Hz rated frequency with the following requirements

##### 5.7.1.1.1 Current Inputs

All the current inputs shall be 1A. If that is not possible the bidder shall provide with necessary current inputs according to the site specific requirement according to the applicable single line representation. All the current inputs shall fulfill following technical rating requirements.

Continuous Thermal Current:	$4 \times I_n$ ( $I_n$ is the nominal current rating of the input which shall be 1A)
1s Thermal Current:	$100 \times I_n$ ( $I_n$ is the nominal current rating of the input which shall be 1A)
10s Thermal Current:	$30 \times I_n$ ( $I_n$ is the nominal current rating of the input which shall be 1A)
Burden:	Shall be less than 0.1VA for 1A input

The input connector type shall be “ring lug” type for the analogue current inputs. There shall be sufficient channels to incorporate all the necessary functions according to chapters 5.9 to 5.16.

##### 5.7.1.1.2 Voltage Inputs

The nominal value of the voltage inputs shall be 110V AC. All the voltage inputs shall fulfill following technical rating requirements.

Operating Range:	0 – 300V AC
10s Thermal Rating:	450V AC
Burden at the nominal value:	Less than 0.1 VA

There shall be at least four voltage inputs. Three of them would be used to measure voltages of phase R, Y, B (A, B, C). Secondary side terminals of three voltage transformers may be connected in star configuration or delta configuration.

There shall be sufficient channels to incorporate all the necessary functions according to chapters 5.9 to 5.16.

##### 5.7.1.1.3 Power Supply

The nominal voltage of the substation DC auxiliary supply would be 110V or 220V DC. The exact nominal voltage depends on the site specification. The protection relay shall be capable of operating between + or – 20% of the nominal voltage of the DC auxiliary supply. It is preferable to have relay that can operate with both 110V DC and 220V DC.

##### 5.7.1.1.4 Output Contacts

All protection relays shall be provided with an adequate number of contacts of suitable rating to carry out the required functions mentioned within this specification. Contacts intended for tripping duty shall be designed such that they initiate the circuit Breaker trip coil directly without the interposition of auxiliary relays or reinforcing contacts. Output contact ratings shall be

compliant to the following minimum requirements. There shall be a watch dog output used for the monitoring of healthy condition of the relay.

Nominal Voltage (V DC)	Breaking Capacity with L/R=40ms (A)	Carry Continuous (A)	Make and Carry for 0.2s (A)
110	0.3 at 125V DC	6	30
220	0.2 at 250 V DC	6	30

**5.7.1.1.5 Binary Inputs**

All the protection relays shall contain the minimum number of binary inputs of suitable voltage rating according to the respective substation specification. The pickup and drop off thresholds shall be defined such that a positive or negative earth fault in an unearthed DC auxiliary power distribution shall not cause the binary inputs to get picked up erroneously. The inputs shall be debounced in order to avoid mal operations caused by bouncy contacts. Debouncing using software is also acceptable.

The pickup and drop off thresholds shall depend on the DC auxiliary supply provided as mentioned below.

Nominal Voltage (V DC)	Pickup Threshold (V DC)	Drop Off Threshold (V DC)
110	88	66
220	176	132

**5.7.1.1.6 Protection Communication Interfaces**

**Line Differential Communication interface (Only for transmission Line Protection Applications)**

For all the relays there shall be two line differential communication interfaces. For three terminal line applications there shall be two identical communication interfaces having following specifications.

Data Interface: Direct fiber  
 Medium: 1550nm single mode fiber  
 Maximum point to point range: 100km

For two terminal line applications there shall be two interfaces with following specification.

**Interface 1**

Data Interface: Direct fiber  
 Medium: 1550nm single mode fiber  
 Maximum point to point range: 100km

**Interface 2**

Data Interface: IEEE C37.94 Compliant  
 Medium: 850nm multi mode fiber  
 Maximum point to point range: 1km

**Station communication interfaces**

All the relays supplied shall comply and support IEC 61850 based station communication. The bidder shall submit IEC 61850 conformance certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850-10 for the specific device bidder is presenting.

#### 5.7.1.1.7 Time Synchronization

The protection system offered should possess the facility to communicate with an external time signal (e.g. GPS), for the purpose of synchronizing the time with a common time base. Since line differential protection with two terminals is expected to work with SONET ring arrangement it is essential that the relay is equipped with a time synchronization device to be able to work with asymmetrical channels which is explained further in chapter 5.9.4.1.

The relay should be able to communicate with any standard time signal format available in the market.

#### 5.7.2 Warranty

Relays shall cover a warranty period of ten (10) years starting from date of Operational Acceptance of the Facility. Warranty shall be issued by the Relay manufacturer only. Warranty issued by parties other than the relay manufacturer is not acceptable. The warranty should cover one to one replacement of Relays. The warranty shall address methods of bug fixing of Relay software too. There should be a 24 hour Online Support Service of the manufacturer to report relays related issues by Email. Warranty certificate shall be submitted with the bid.

### 5.8 CONTROL AND PROTECTION APPLICATION

#### 5.8.1 General

There shall be two control & protection IEDs hereafter known as “Main 1” and “Main 2” to provide required protection and bay switchgear control for line bays, bus couplers/ bus sections and transformers with voltage levels above and including 132kV. Both IEDs shall have identical control & protection functions necessary for the respective bay. For voltage levels below and including 33kV there shall be only one IED providing both control and protection functions (33kV transformer bays, 33kV bus couplers / bus sections and 33kV feeders).

Main 1 and Main 2 IEDs shall operate redundantly based on the following aspects.

- Main 1 and Main 2 IEDs shall be powered by two separate DC circuits drawn through two different MCBs.
- Current inputs to Main 1 and Main 2 IEDs shall be given from two different current transformer cores. Current transformer cores used for Main 1 and Main 2 relays shall be wired in separate cables from the current transformer secondary terminal kiosk to the relay panel.
- Voltage inputs from bay voltage transformer to Main 1 and Main 2 IEDs shall be provided from two different cores. Voltage transformer cores used for Main 1 and Main 2 relays shall be wired in separate cables from the voltage transformer secondary terminal kiosk to the relay panel.
- All the binary inputs taken in to Main 1 and Main 2 IEDs shall be taken directly from the end device without the use of contact multiplication relays as much as possible. Any signal that is multiplied through an auxiliary relay shall be in accordance with chapter 5.9 – 5.17 and any alteration is subjected to Engineer’s approval. All the binary signals shall be taken through different cables for the two different IEDs.
- There shall be separate and redundant communication channels from the local IED to the remote end IED using redundant fiber optic channels. Physical modules used for distance/directional earth fault/breaker failure tele protection commands in the multiplexer equipment shall be capable of operating independently of each other. DC

supply used for tele protection commands in two IEDs shall also be redundant and taken from two different MCB protected circuits.

- Wherever possible the healthy condition of Main 1 shall be monitored by Main 2 relay and vice versa. Bus bar protection bay unit IED healthy conditions shall be monitored by both Main 1 and Main 2 IEDs of the respective bays. Bus section or Bus coupler IED healthy condition shall be monitored by the other IED on the other side of the bus section/bus coupler. Bus section Bus bar protection bay unit healthy condition shall be monitored by both Bus section Control/protection IEDs on either side of bus section. All above shall be done through hard-wired binary outputs and inputs. All 33kV feeder IED healthy condition shall be monitored via parallel wired contact from all IEDs in each Bus/Section. The inbuilt watch dog binary output contact of the IEDs are used for this monitoring.
- There shall be two separate tripping paths wired through trip circuit supervision relays for operation two independent trip coils of the circuit breakers. There shall be two lockout relays 86/1 and 86/2 operating from both Main 1 and Main 2 relays. It shall be possible to reset the lockout relays from the National Control Centre or Substation Automation System through Main 1 and Main 2 IEDs. In addition, there shall be a push button mounted on the panel to reset all lockout relays.

## 5.8.2 Bay Control Applications

### 5.8.2.1 Voltage Levels Including 132kV and above

The user shall be able to control the switchgear in several operational levels based on the location of the equipment in a substation. They are listed below.

Switchgear Local Control Panels

Local Control Panel (Only for GIS)

Protection /Control Panel

Substation automation system

SCADA interface at national control centre through the gateway

#### 5.8.2.1.1 Switchgear Local Control Panels for 132kV and above

Each switchgear shall be capable of being operated either mechanically or electrically from the local control cubicle. The interlocking logic incorporated for electrical operation shall be identical to the interlocking logic associated with any other operational level except in the circuit breaker. The interlocking logic shall be extensively discussed in the coming chapters.

#### 5.8.2.1.2 Local Control Panel (Only for Gas Insulated Substations) 132kV and above

As it was explained at the beginning of chapter 5 for gas insulated substation bays above and including 132kV there shall be two panels to provide control and protection functions. The panel located adjacent/in front of the respective GIS bay shall be equipped with equipment required to provide local control facilities. Hence there shall be discrepancy switches available for each switchgear to operate them electrically. The interlocking logic involved shall be equivalent to the logic required for operation from any remote location. In order to control the switchgear for maintenance work there shall be interlocking bypass facility through a selector switch. Selector switch shall be a lockable type device.

Additionally there shall be a 2-position selector switch in order to select whether to be controlled from the local control cubicle located adjacent to the respective GIS bay or to be

controlled from the protection/control panel located in the relay panel room. The two positions of the selector switch shall be named as “Remote” and “Local”.

#### **5.8.2.1.3 Protection/Control Panel 132kV and above**

Main 1 and Main 2 relay shall contain bay controlling facility and the user shall be able to operate the switchgear using either of them. In addition, there shall be a hardwired backup mimic controllers for each switchgear available in the bay in case neither Main 1 or Main 2 IED can be used for operation for Air Insulated Substation bays. In case of a Gas Insulated Substation this mimic control is not required.

Bay controlling facility can be provided in a separate IED in special cases such as augmentation of existing panels, bay extensions in existing substations etc. under the approval by the Engineer.

##### Bay Controlling Function in IEDs

The IED shall be capable of providing bay controlling function for at least two circuit breakers and eight more other switchgear including isolators and earth switches.

The IED shall be capable of providing bay controlling function from the local human machine interface in the IED and by a Substation Automation System(SAS) through IEC 61850 communication standard. There shall be a simple method of controlling through the available function keys in the relay. The controlling mechanism shall support “Select before Operate” concept.

The state of the switchgear and the controlling for the user shall be depicted on a single line display of the controlled bay. The 3 states of the switchgear known as “Closed”, “Opened” and “Intermediate or status invalid” shall be depicted in a way that the user shall be able to easily distinguish between those statuses.

The user shall be able to create labels on the single line diagram for the bay name, switchgear identifiers according to his nomenclature. There shall be the facility of adding multiple pages to the IED for user defined controls and user defined measurements. There shall be a “Local” and “Remote” selection method through a function key or a symbol on the single line diagram to hand over the control function to a remote mechanism (For the substation automation system). It shall be possible to switch between “Local” and “Remote” statuses through an externally connected selector switch using the binary inputs of the relay as well.

##### Mimic Controllers (only for non GIS substations)

Backup hardwired mimic controller shall be a conventional arrangement comprising of discrepancy switches to control each switchgear in the bay. Discrepancy switches shall contain an indication lamp in case where there is a disparity between the actual switchgear status and the status shown by the discrepancy switch. In addition, there shall be a push button to test the lamps of the discrepancy switches used in the mimic.

#### **5.8.2.1.4 Substation Automation System**

Refer chapter 5.24 for further information.

#### **5.8.2.1.5 SCADA interface at national control center through the gateway**

Refer Chapter 5.24 for further information.

#### **5.8.2.2 Coordination Between Different Operational Levels**

There are several operational levels as explained earlier where each switchgear can be operated by the user. At any given time, a switchgear can only be operated from one level. The operational levels and their respective precedence are tabulated below.

Operational Level	Precedence value
Local Panel of the Switchgear	1
Local Control Panel (Only for GIS)	2
Mimic Controls of the Relay Panel	3
Main 1 IED in Relay Panel	3
Main 2 IED in Relay Panel	3
Substation Automation System	4
SCADA Controls at the System Control Centre	5

The levels which possess the same precedence level shall be selected through a single element such that at a time only one level will be active for controls. The level with lowest precedence value has the highest priority and in order to operate from a higher level all the lower levels should permit the higher level to take the precedence.

There shall be a two-way selector switch installed inside the **switchgear local control cubicle** to toggle between “local” and “Remote” control status. Once the switchgear in local mode the operations remote to the switchgear local control cubicle will be disabled. Once the local remote switch is in “Remote” mode the controls will be handed over to the controlling equipment installed in the **protection/control panel**. In a gas insulated substation there is an operational level in between local control cubicle of the switchgear and the protection/control panel. There will be a **local control panel** with switchgear controls with a mimic diagram representation. Once “Remote” is selected from the **switchgear local control cubicle**, controls will be handed over to the **local control panel**. In the **local control panel** there shall be another two-position switch to toggle between “Local” and “Remote” status. When “Remote” is selected controls will be transferred to the **protection/control panel**.

In order to select the mode of operation at the **protection/control panel** there shall be a 3-way selector switch mounted on the panel such that at a time only one of the three devices (Main 1, Main 2 and the Hard wired Mimic) will be active for controls. Each Protection/Bay controller IED shall be equipped with a mechanism of selecting either “Local” or “Remote” operation level. Once “Local” is selected the operator can operate the switchgear through the single line diagram available in the IED itself. When “Remote” status is selected the operator shall be able to control the switchgear through the substation automation system.

There shall be a software based selection within the substation automation system to transfer the controls to any remotely situated control centre through the gateway. When the human machine interface of the substation automation system is not functional the controls shall be automatically transferred to the national/distribution control centre once the “Remote” status is selected from the Main 1 or Main 2 IED whichever is selected from the 3-way selector switch mounted on the relay panel.

For 33kV and below, operational levels shall be the Local control, Protection/Control IED and SAS and SCADA prioritised in the given order.

### 5.8.2.3 Protection/Control Panel 33kV and below

For voltage levels 33kV and below following operational levels shall be available.

Switchgear Local Control Panel – Refer Clause 5.8.2.1.1

In a 33kV or below Gas Insulated Substation, Protection/Control equipment and switchgear local control equipment are housed in the same panel. But they shall be considered as two different operational levels in this context.

As stated in chapter 5.8.1 there shall be only one IED in all bays at 33kV and below voltage level protection/control panel. That IED shall contain all the necessary protection functions and bay controlling facility such that all the switchgear shall be operable from the single line

representation available in the IED display. Refer “Bay Controlling Function in IEDs” under the chapter 5.8.2.1.3 for further information.

There shall be a hand resettable flag relay visible from panel front side, which is energized when any of the circuit breaker alarms are present.

Hardwired mimic controls are not required for 33kV and below voltage levels.

For Substation Automation System - Refer 5.24

For SCADA interface at national control centre through the gateway - Refer Clause 5.24

### 5.8.3 Interlocking

The interlocking function prevents unsafe operation of circuit breakers, isolators and earthing switches within a bay or substation. The operation of above shall only be possible when certain conditions are fulfilled to ensure safe operation.

Software based interlocking shall be implemented in Main 1 and Main 2 IEDs. Taking the relevant switchgear status and other device status (Trip Lockout Relay, Trip Circuit Supervision Relay etc.) as binary inputs to the IED shall have necessary interlocking through internal software logic functions. The IED shall provide a close/open command through a contact output and that command shall be sent to the relevant switchgear without any additional contacts in the circuit to provide interlocking as much as possible. A hard wiring based interlocking scheme shall be provided for backup mimic operations. Software based interlocking and hardwired scheme shall be connected in parallel. If due to any unavoidable reason this cannot be fulfilled the alternative design shall be subjected to Engineer's approval. Interlocking schemes shall be implemented minimising the use of contact multiplication relays. Most importantly interlocking logic incorporated shall always be “Fail Safe”. Hence a failure of a single element shall not allow or initiate any operation that may be harmful to any personnel or equipment.

Whenever a switchgear status from a different bay is required for interlocking purposes that shall **not be** taken through the communication channel through GOOSE signals. (IEC 61850)

Necessary interlocking schemes for each bay shall be discussed under the respective voltage level and bay type descriptions.

In all bays the circuit breaker closing from the local control cubicle shall only be granted when all the bay isolators are in open condition. This is meant to be done only during maintenance work.

### 5.8.4 Earth Switches

In an air insulated substation operation of the earth switches shall only be allowed from the local control cubicle of the earth switch. The position of the switchgear shall be indicated in the mimic diagram representation of the protection/control panel and Main 1 Main 2 IEDs.

At voltage levels 132kV and above, in a gas insulated substations, operation of the earth switches shall only be allowed from the local control panel explained in chapter 5.8.2.2 with necessary interlocking functions.

At voltage levels 33kV and below, in a Gas Insulated Substations, operation of the earth switches shall be allowed from the switchgear local control panel and also through the protection/control IED. But operation from the substation automation or national control centre shall be prohibited.

At every voltage level, in Gas Insulated Substations, busbar earthing shall be handled by the bus coupler/section bay.



### 5.8.5 Synchronism Check Scheme

Before closing the circuit breaker, it should be verified that two systems at either side of the circuit breaker are in synchronism. This shall be checked during manual closing/auto reclosing (For 132kV/220kV Overhead Line Bays) of the circuit breaker. For manual closing and auto reclosing there shall be two separate check synchronizing functions. Synchronism check is not required in high voltage side of 220kV/132kV:33kV/11kV two winding transformer bays

There shall be independent synchronism check functions in Main 1 and Main 2 IEDs. When the circuit breaker is being closed through either Main 1 or Main 2 IED the internal synchronism check function shall be used. During manual closing of circuit breaker LCD display of IED shall show incoming and running voltage magnitude, voltage difference, phase angle difference, incoming and running frequency, frequency difference, replica of synchroscope.

When the circuit breaker is being closed through the hard wired mimic available in the Protection/Control panel in an AIS and Local Control Cubicle in a GIS a separate synchronism check trolley shall be used. Synchronism check trolley is common to all bays in the substation. Hence in each bay there shall be socket in the Protection/Control panel or Local Control Cubicle where the external trolley can be plugged in.

The synchronism check trolley shall be equipped with following devices.

- Double voltmeter
- Double frequency meter
- Lamp to indicate that two systems are in synchronism
- a synchroscope
- Synchronism check relay
- Push button for manual synchronism check bypass

When the synchronism check trolley is plugged in bus side and line side voltages shall be available in the respective voltmeters and frequency meters. If the synchronism check relay inside the trolley is operated, the respective lamp shall be lit so that operator can issue the close command from the respective discrepancy switch available in the hard wired mimic. If the synchronism check relay is not operated the manual bypassing of synchronism check function shall be facilitated through a push button available in the synchronism check trolley. If the close command of the circuit breaker is given through the discrepancy switch while the push button is being pressed the synchronism check conditions shall be bypassed.

### 5.8.6 Live Bus bar Transfer Scheme

This is only applicable for substations with double bus bar arrangement with a bus coupler bay. During operational conditions to enable the isolation of one energised busbar without disrupting any energised bays this scheme is used. When the bus coupler is in closed position closing of any other opened bus isolator shall be granted in an energised bay. When both bus isolators are in closed position opening of the isolator that connects to the bus that needed to get isolated shall be allowed. Following the same procedure isolating a busbar without disrupting any energised lines can be done.

When both bus isolators are in closed position in any bay tripping and manual opening of the circuit breaker shall be blocked in the bus coupler bay.

### 5.8.7 Protection Functions

At voltage levels 132kV and above all the protection functions included in Main 1 and Main 2 IEDs shall be identical and will be discussed in chapters 5.9 to 5.16. Protection functions in two IEDs shall operate redundantly in all aspects. At Voltage levels 33kV and below there shall be only one protection/control IED. In addition to the things mentioned under the chapter 5.8.1 following conditions shall be fulfilled.

Separate DC circuits shall be used to initiate tripping of the two tripping coils in the circuit breaker.

There shall be two trip lockout relays to provide additional redundancy in circuit breaker tripping circuit and block closure of the circuit breaker after a tripping has occurred. Implementing lockout function in the protection/control IEDs is not acceptable. In 33kV/22kV/11kV outgoing feeder bays and bus section/coupler bays there shall be only one trip lockout relay.

There shall be two separate Trip Circuit Supervision(TCS) relays fulfilling the requirements listed under the chapter 5.18 for all voltage levels. Application of trip circuit supervision function in the protection/control IED/s is not acceptable. Trip circuit shall be supervised both at pre- close and post-close states of the circuit breaker.

Any general requirements mentioned under this chapter will be superseded by any special requirements mentioned under the chapters 5.9-5.14.

### 5.8.8 DC Distribution

The DC distribution of a typical bay shall be designed according to the fundamental conditions mentioned below.

- For a typical line bay- There shall be two separate DC circuits drawn from the main DC distribution board to protection/control panel and marshalling kiosk (in an AIS) /local control cubicle (in a GIS)
- For a typical transformer bay- There shall be four separate DC circuits drawn from the main DC distribution board to protection/control panel, marshalling kiosk (in an AIS) /local control cubicle (in a GIS), marshalling cubicle available in the transformer and AVR panel.
- All switchgear control circuits and motor supply circuits shall be drawn from the bay marshalling kiosk (in an AIS) /local control cubicle (in a GIS).
- Motor supply circuits for different switchgear shall be independent of each other.
- Circuit breaker trip circuit 1 and trip circuit 2 control supplies shall be drawn from independent DC circuits.
- There shall be three independent circuits for Main 1 IED, Main 2 IED and mimic controls in the protection/control panel. The circuits used to energise Main 1 and Main 2 IEDs shall not be drawn outside of the protection/control panel. Hence there shall be two separate DC circuits to get necessary binary inputs to main 1 and main 2 IEDs from equipment external to the protection/control panel.

Accordingly DC circuits shall be available in respective panels as shown below.

**Line Bay Application**

Panel	DC Circuit
Protection/Relay Panel	Main 1 IED, Lockout relay 1 Supply
	Main 2 IED, Lockout relay 2 Supply
	Main 1 IED Binary Input Supply
	Main 2 IED Binary Input Supply
	Bus Bar prot. Bay unit IED, Lockout relay supply
	Bus Bar prot. Bay unit Binary input supply
	Mimic Control Supply (Only for AIS Bays)
Bay Marshalling Kiosk/Local Control Cubicle	Circuit Breaker Trip Circuit 1 and TCS Supply
	Circuit Breaker Trip Circuit 2 and TCS Supply
	Isolator Control Supply
	Circuit Breaker Motor Supply
	Bus 1 Isolator Motor Supply
	Bus 2 Isolator Motor Supply
	Line Isolator Motor Supply
	Line Earth Motor Supply
Mimic Control Supply (Only for GIS Bays)	

**Bus Coupler/Bus section Bay Application**

Panel	DC Circuit
Protection/Relay Panel	Main 1 IED, Lockout relay 1 Supply
	Main 2 IED, Lockout relay 2 Supply
	Main 1 IED Binary Input Supply
	Main 2 IED Binary Input Supply
	Bus bar protection Bay unit 1 IED, lockout relay Supply
	Bus bar protection Bay unit 1 Binary input Supply
	Bus bar protection Bay unit 2 IED, lockout relay Supply
	Bus bar protection Bay unit 2 Binary input Supply
Bay Marshalling Kiosk/Local Control Cubicle	Circuit Breaker Trip Circuit 1 and TCS Supply
	Circuit Breaker Trip Circuit 2 and TCS Supply
	Isolator Control Supply
	Circuit Breaker Motor Supply
	Bus 1 Isolator Motor Supply
	Bus 2 Isolator Motor Supply

**Transformer Bay Application (Two Winding)**

Panel	DC Circuit
HV Side Protection/Relay Panel	HV Main 1 IED, Lockout Relay 1, Busbar Lockout Relay Supply
	HV Main 2 IED, Lockout Relay 2 Supply
	HV Main 1 IED Binary Input Supply
	HV Main 2 IED Binary Input Supply
	Bus Bar prot. Bay unit IED, Lockout relay supply
	Bus Bar prot. Bay unit Binary input supply
	HV Mimic Control Supply (Only for AIS Bays)
HV Side Bay Marshalling Kiosk/Local Control Cubicle	HV Circuit Breaker Trip Circuit 1 and TCS Supply
	HV Circuit Breaker Trip Circuit 2 and TCS Supply
	HV Isolator Control Supply
	HV Circuit Breaker Motor Supply
	HV Bus 1 Isolator Motor Supply
	HV Bus 2 Isolator Motor Supply (Only for Double Busbar Stations)
	HV Line Isolator Motor Supply
	HV Line Earth Motor Supply
HV Mimic Control Supply (Only for GIS Bays)	
LV Side Protection/Control Panel (Only for GIS Bays)	LV Circuit Breaker Trip Circuit 1 and TCS Supply
	LV Circuit Breaker Trip Circuit 2 and TCS Supply
	LV Isolator Control Supply
	LV Circuit Breaker Motor Supply
	LV Bus 1 Isolator/Earth Switch Motor Supply
	LV Bus 2 Isolator Motor Supply (Only for Double Busbar Stations)
	LV Protection/Control IED, Lockout Relay 1 & 2 Supply
	LV Mimic Control Supply
LV Side Bay Marshalling Kiosk (Only for AIS Bays)	LV Circuit Breaker Trip Circuit 1 and TCS Supply
	LV Circuit Breaker Trip Circuit 2 and TCS Supply
	LV Isolator Control Supply
	LV Circuit Breaker Motor Supply
	LV Bus 1 Isolator/Earth Switch Motor Supply
	LV Bus 2 Isolator Motor Supply (Only for Double Busbar Stations)
LV Side Protection/Control Panel (Only for AIS Bays)	LV Protection/Control IED, Lockout Relay 1&2 Supply
	LV Mimic Control Supply
Transformer Marshalling Kiosk	OLTC Control DC Supply
AVR Panel	AVR DC Supply <sup>1</sup>
	Mechanical Protection DC Supply <sup>2</sup>
	Input/output Module DC Supply (Only for Single Phase Transformers)

1 – For a substation with 220kV/132kV:33kV/11kV two winding transformers all the AVRs will be housed in one panel. Those AVR relay auxiliary supplies shall be taken from different MCB protected circuits.

2 - For a substation with 220kV/132kV:33kV/11kV two winding transformers all the mechanical protection flag relays may be housed in one panel. There shall be different MCB protection circuits for each transformer.

### 5.8.9 Station Alarms

Any alarms/indications taken from the equipment that does not belong to a specific bay is considered as a station alarm. Those alarms shall be conveyed to the substation automation system and the national control centre through an IEC 61850 compatible input module. In addition, there shall be an alarm annunciation device for those station alarms which operates independently from the IEC 61850 compatible input module. Both devices shall be mounted in the high voltage side bus bar protection panel. If there are two high voltage levels, the equipment shall be mounted in the bus bar protection panel of highest voltage level. Please refer chapter 2.20 for detailed description.

### 5.8.10 Metering Equipment

At every voltage level there shall be a metering equipment for the operating personnel to acquire measurements. Current to be measured shall be provided through a metering core having an accuracy class of 0.2 from the line current transformers. Voltage shall be provided through a metering core of the line voltage transformer. Current/voltage transformer circuits shall be directly connected to the measuring device without any additional switching equipment.

It shall be a three-phase device capable of calculating and representing at least the following measurands to the operating personnel.

- Current magnitudes in all three phases
- Voltage magnitudes in all three phases
- Active Power
- Reactive Power
- Apparent Power
- Power Factor
- Frequency

User shall be able to navigate through the HMI of the metering equipment conveniently and get the required measurement values.

At 33kV and below voltage levels the metering equipment shall be mounted in the protection/control panel.

In Air Insulated Substations at 132kV and above voltage levels metering equipment shall be mounted in the protection/control panel.

In Gas Insulated Substations at 132kV and above voltage levels metering equipment shall be mounted in the local control cubicle.

### 5.8.11 33kV/11kV Breaker Failure Scheme

Breaker failure function shall be included in protection/control IED of each bay at voltage levels of 33kV or below. The functional description is available in chapter 5.11.4.4.

There shall be a bus wiring in between panels in order to route the timer two tripping initiated by the bay where the breaker has failed. In each bay there shall be an auxiliary relay which will be driven by the trip bus wiring drawn between the panels. Once breaker failure timer 2 has operated in any bay the trip bus relevant to that bus section shall be energised. The breakers in un-faulted bays shall be directly tripped through the auxiliary relay without causing lockout relay to operate.

There shall be separate bus wiring tripping circuit for each bus section. The DC supply for the respective bus section shall be taken from the bus section panel and be separated out through

two MCBs. In case of a three-bus section busbar arrangement, DC supply bus section 1 and bus section 2 shall be taken from bus section 1 protection/control panel and DC supply for bus section 3 shall be taken from bus section 2 protection/control panel. Hence in the bus section/coupler panel there shall be two auxiliary tripping relays for two bus sections.

## **5.9 OVERHEAD TRANSMISSION LINE PROTECTION AND CONTROL FOR 220kV/132kV**

Please refer Single line diagram in [Annexure 1](#)

### **5.9.1 General Requirements**

There shall be two IEDs known as Main 1 and Main 2 with 100% redundancy to provide protection/control functions for a typical 220kV line bay as explained in the previous chapter. Main 1 and Main 2 IEDs shall have two independent current transformer inputs and fiber optic communication channels. Each shall have their tripping commands wired to both trip coils in the Circuit breaker. Each IED shall contain following protection, control and supervision functions.

#### **Functions of Main 1 & Main 2 IEDs:**

1. Line differential protection.
2. Distance protection
3. Distance protection with Tele Protection
4. Directional Earth Fault protection with communication acceleration
5. Backup Over Current and Earth Fault protection
6. Over/Under Voltage Protection
7. Thermal Overload Protection
8. Broken Conductor Protection
9. Stub Protection
10. Auto reclosing (AR) (Single Pole and Three Pole)
11. Circuit Breaker Failure (CBF)
12. Switch On to Fault (SOTF)
13. Power swing blocking
14. Voltage and current supervision functions (VTS, CTS)
15. Synchronism Check Function
16. Bay Controller Function with Interlocking
17. Monitoring of 86-1, 86-2 lockout relays

The respective functions are explained in detail under the chapters 5.9.4

### **5.9.2 220 kV lines**

Additional to the content discussed under chapter 5.9.1 features discussed within this chapter would be required.

Main 1 and Main 2 IEDs shall be from two different manufacturers. Single pole operation shall be applied for 220kV line bays and hence single pole tripping and autoreclosing functions shall be available.

Communication Mode used

F01- Direct Fiber

F02- Fiber link through multiplexers.

In addition to the tripping contacts mentioned in the aforementioned trip matrix sufficient amount of binary outputs as discussed in chapter 5.9.2.1.2 shall be available. The operating time (to initiate a trip command) for the line protection systems shall not exceed 30 ms.

**5.9.2.1 General Circuit Requirements**

The hardware requirements for transmission line protection applications in addition to those in chapter 5.7 are discussed within this chapter.

**5.9.2.1.1 Analog Circuits**

**Current Circuits**

The line current transformer secondaries shall be connected in “Holmgren” connection and connected to the relay in the following manner.

Channel 1	R Phase Current
Channel 2	Y Phase Current
Channel 3	B Phase Current
Channel 4	Summation Current of the Three Phases

Current transformer line protection core which is located closest to the circuit breaker (Busbar side) shall be connected to the Main 1 IED and the next line protection core shall be connected to the Main 2 IED. Core connected to Main 1 IED shall not be used for any other device in the substation. Disturbance recorder shall share the same core with the Main 2 IED and the circuit shall be arranged in such a way that it first comes in to the Main 2 IED and terminated in the disturbance recorder panel. Current transformer circuit earthing in both cores shall be done at the relay panel.

**Voltage Circuits**

Line voltage transformers shall be connected in star configuration and connected to the first three inputs of the relay. Busbar voltage between R and Y phases shall be connected to the fourth input. If the substation is a double busbar station, busbar 2 voltage between R and Y phases shall be connected to the fifth voltage input. Voltage transformer secondary circuit shall be protected by a 3-pole MCB located in the marshalling kiosk and 2-pole MCB located in respective phase voltage transformer secondary terminal boxes. Main 1 and Main 2 IEDs shall be connected to two different cores.

**5.9.2.1.2 Binary Circuits**

**Binary Inputs**

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced. The binary input requirement will increase for gas insulated substations and they are separately listed below.

Index	Binary Inputs	Remarks
	Control and Interlocking	
1	Q9 Opened	Line isolator opened status directly from the isolator auxiliary contacts
2	Q9 Closed	Line isolator closed status directly from the isolator auxiliary contacts

3	Q8 Closed	Line earth switch closed status directly from the earth switch auxiliary contacts
4	Q8 Opened	Line earth switch opened status directly from the earth switch auxiliary contacts
5	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
6	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
7	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
8	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
9	Control in Mimic	Mimic status of the selector switch mounted on the relay panel
10	Control in Main 1	Main 1 status of the selector switch mounted on the relay panel. In the case of Main 2 IED Main 2 status of the selector switch shall be provided.
11	Lockout Relay 1 Operated	N/C contact from the lockout relay 1. In the case of Main 2 IED N/C contact from Lockout relay 2 shall be provided.
12	Busbar Lockout Relay Operated	N/C contact from the busbar lockout relay
13	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high. In the case of Main 2 IED trip circuit supervision relay 2 direct contact shall be provided.
<b>For a Double Busbar Station</b>		
14	Bus Coupler Closed	Bus coupler closed signal from the bus coupler bay. A series connection of auxiliary contacts from the bus coupler circuit breaker and two isolators. This shall be taken through an auxiliary relay. Auxiliary relay shall be energized when the bus coupler is closed.
15	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts. Only for double busbar stations.
16	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts. Only for double busbar stations.
<b>For GIS Applications</b>		
17	Q51 Closed	Q51 earth switch closed status directly from the earth switch auxiliary contacts.
18	Q51 Opened	Q51 earth switch opened status directly from the earth switch auxiliary contacts.
19	Q52 Closed	Q52 earth switch closed status directly from the earth switch auxiliary contacts.
20	Q52 Opened	Q52 earth switch opened status directly from the earth switch auxiliary contacts.
21	Q53 Closed	Q53 earth switch closed status directly from the earth switch auxiliary contacts.
22	Q53 Opened	Q53 earth switch opened status directly from the earth switch auxiliary contacts.
23	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
24	Bus 1 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 1 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
25	Bus 2 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 2 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.



26	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Protection and AR</b>		
27	Line VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the marshalling kiosk and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
28	Bus 1 VT MCB Healthy	This shall be taken from the bus coupler bay through a bus wiring among all panels. This may be taken from an auxiliary relay installed in the protection panel. Signal shall be logically high when all the MCBs in the circuit are closed
29	Bus 2 VT MCB Healthy	Only applicable for a double busbar station. This shall be taken from the bus coupler bay through a bus wiring among all panels. This may be taken from an auxiliary relay installed in the protection panel. Signal shall be logically high when all the MCBs in the circuit are closed
30	AR function off	Selection of "AR Off" from the AR function selector switch mounted on the relay panel.
31	AR Main 1	Selection of "Main 1" from the AR function selector switch mounted on the relay panel.
32	AR Main 2	Selection of "Main 2" from the AR function selector switch mounted on the relay panel.
33	Manual Close Command	Taken from the auxiliary relay/contactors used to send the manual close command to the circuit breaker.
34	General Pickup from Main 1/2	This is only required if the relay has a AR function that operates based on the action time principle.
35	AR single pole only	Selection of "Single Pole Only" from the AR Mode selector switch.
36	AR three pole only	Selection of "Three Pole Only" from the AR Mode selector switch.
37	AR single pole and three pole	Selection of "Single Pole and Three Pole" from the AR Mode selector switch.
38	AR Start single phase from Main 1/2	Single pole trip signal to initiate single pole AR function from the other IED. Input shall be logically high when the AR initiating functions are operated according to chapter 5.9.5.1.
39	AR Start three phase from Main 1/2	3 phase trip signal to initiate single pole AR function from the other IED. Input shall be logically high when the AR initiating functions are operated according to chapter 5.9.5.1.
40	Single Pole AR permitted Main 1/2	Single pole AR ready status from the other relay. This shall be logically high once AR function is selected to other IED and it is ready to perform a single pole autoreclose cycle.
41	Main 1/Main 2 Protection Relay Fail	This input shall be logically high when the other IED is in operation without any complication.
<b>Alarming</b>		
42	Relay Panel DC or AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
43	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC and AC MCBs installed in the Marshalling Kiosk. Signal shall be logically high when all the MCBs are switched on.

44	Circuit Breaker Gas Pressure Low Alarm	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
45	Circuit Breaker Gas Pressure Lockout	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
46	Isolators are in Local Mode	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
47	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
48	CB in Local Mode	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
49	Synchroscope Plugged In	This signal is taken through the syncrocheck console once it is plugged in.
<b>Distance Tele Protection</b>		
50	Communication Healthy	This signal shall be taken directly from the multiplexer equipment. Signal shall be high if communication channel is healthy.
51	Carrier Receive (Distance)	Permissive/Blocking carrier receive from the remote end distance protection function.
52	Carrier Receive (DEF)	Permissive/Blocking carrier receive from the remote end directional earth fault protection function.
53	Carrier Receive (DIT)	Direct inter trip received from the remote end breaker failure and end fault protection functions.

### Binary Output Circuits

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Signal	Remarks
1	General CB Trip R TC 1	General Trip R Phase. This shall include the manual opening of the circuit breaker from the IED as well.
2	General CB Trip R TC 2	General Trip R Phase. This shall include the manual opening of the circuit breaker from the IED as well.
3	General CB Trip Y TC 1	General Trip Y Phase. This shall include the manual opening of the circuit breaker from the IED as well.
4	General CB Trip Y TC 2	General Trip Y Phase. This shall include the manual opening of the circuit breaker from the IED as well.
5	General CB Trip B TC 1	General Trip B Phase. This shall include the manual opening of the circuit breaker from the IED as well.
6	General CB Trip B TC 2	General Trip B Phase. This shall include the manual opening of the circuit breaker from the IED as well.
7	AR Lockout Trip 86/1	AR definitive trip and any trip that does not initiate auto reclosing.
8	AR Lockout Trip 86/2	AR definitive trip and any trip that does not initiate auto reclosing.

9	Start Breaker Failure R Phase	General Trip R Phase to initiate single phase breaker failure function
10	Start Breaker Failure Y Phase	General Trip Y Phase to initiate single phase breaker failure function
11	Start Breaker Failure B Phase	General Trip B Phase to initiate single phase breaker failure function
12	Q1 Isolator Close	Close Command to the bus 1 isolator
13	Q1 Isolator Open	Open Command to the bus 1 isolator
14	Q2 Isolator Close	Close Command to the bus 2 isolator
15	Q2 Isolator Open	Open Command to the bus 2 isolator
16	Q9 Isolator Close	Close Command to the line isolator
17	Q9 Isolator Open	Open Command to the line isolator
18	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
19	86/1 Reset	Contact to reset 86/1 through NCC/SAS
20	AR Start Three Phase	AR Start 3 Pole to other IED. This shall be closed through any tripping command that is intended to initiate 3 pole AR function.
21	AR Start Single Phase	AR Start R phase to other IED. This shall be closed through any tripping command that is intended to initiate single pole AR function.
22	General Pickup	This is required only if the other IED has an AR function which operates in the basis of action time. General pickup of any protection function will activate this output.
23	Distance Carrier Send	Distance permissive or blocking tele protection command sent to the other end
24	DEF Carrier Send	Directional earth fault permissive or blocking tele protection command sent to the other end
25	86/2 Reset	Contact to reset 86/2 through NCC/SAS
26	Single Pole AR Permitted	Single Pole AR Permitted to the Other Relay
<b>Fault Recorder</b>		
27	Differential Trip	Line differential trip to trigger/record in the disturbance recorder
28	Distance Trip	Line distance trip to trigger/record in the disturbance recorder
29	DEF Trip	Directional earth fault trip to trigger/record in the disturbance recorder
30	Over Current and Earth Fault Trip	Over current or earth fault trip to trigger/record in the disturbance recorder
31	AR Close	AR close command to trigger/record in the disturbance recorder

**5.9.2.2. Trip Matrix**

	DC	TC1				TC2				86-1	86-2	Tele-Protection		FO1-	FO2	Auto	Start CBF to BB Prot. (50BF)
		R	Y	B	all	R	Y	B	all			Perm	DTT				
<b>Main 1</b>	1																
87L		X	X	X	X	X	X	X	X					X	X	X	X
21 Z1		X	X	X	X	X	X	X	X							X	X
21 Z2					X				X	X	X						X
21 Z3					X				X	X	X						X
21 Z4					X				X	X	X						X
21 aided		X	X	X	X	X	X	X	X			X		X	X	X	X
49					X				X	X	X						X
59/27					X				X	X	X						
67N		X	X	X	X	X	X	X	X			X		X	X	X	X
51/51N					X				X	X	X						X
AR Lockout					X				X	X	X						
86/1	1				X				X								
<b>Main 2</b>	2																
87L		X	X	X	X	X	X	X	X					X	X	X	X
21 Z1		X	X	X	X	X	X	X	X							X	X
21 Z2					X				X	X	X						X
21 Z3					X				X	X	X						X
21 Z4					X				X	X	X						X
21 aided		X	X	X	X	X	X	X	X			X		X	X	X	X
49					X				X	X	X						X
59/27					X				X	X	X						
67N		X	X	X	X	X	X	X	X			X		X	X	X	X
51/51N					X				X	X	X						X
AR Lockout					X				X	X	X						
86/2	2				X				X								
86BB,87BB	3				X				X								

**5.9.3 132 kV lines**

There shall be two IEDs know as Main 1 and Main 2 with 100% redundancy. Same protection/control and monitoring functions listed under chapter 5.9.1 shall be included in each IED used in 132kV line protection. Main 1 and Main 2 IEDs need not to be from different manufacturers.

The trip matrix for 132kV lines shall be as given below. Any alteration is subjected to the Engineer’s approval during the design stage. Only three pole auto reclosing shall be implemented in 132kV voltage level.

### 5.9.3.1 General Circuit Requirements

As it was discussed in chapter 5.7.1 the hardware requirements of the IED change depending on it's application. The hardware requirement for transmission line protection applications are discussed within this chapter.

#### 5.9.3.1.1 Analog Circuits

Analog circuit connections shall be identical to that of 220kV line control/protection applications as explained in chapter 5.9.2.1.1.

#### 5.9.3.1.2 Binary Circuits

##### Binary Inputs

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced. The binary input requirement will increase for gas insulated substations and they are separately listed below.

Index	Binary Inputs	Remarks
	Control and Interlocking	
1	Q9 Opened	Line isolator opened status directly from the isolator auxiliary contacts
2	Q9 Closed	Line isolator closed status directly from the isolator auxiliary contacts
3	Q8 Closed	Line earth switch closed status directly from the earth switch auxiliary contacts
4	Q8 Opened	Line earth switch opened status directly from the earth switch auxiliary contacts
5	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
6	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
7	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
8	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
9	Control in Mimic	Mimic status of the selector switch mounted on the relay panel
10	Control in Main 1	Main 1 status of the selector switch mounted on the relay panel. In the case of Main 2 IED Main 2 status of the selector switch shall be provided.
11	Lockout Relay 1 Operated	N/C contact from the lockout relay 1. In the case of Main 2 IED N/C contact from Lockout relay 2 shall be provided.
12	Busbar Lockout Relay Operated	N/C contact from the busbar lockout relay
13	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high. In the case of Main 2 IED trip circuit supervision relay 2 direct contact shall be provided.
	<b>For a Double Bus bar Station</b>	
14	Bus Coupler Closed	Bus coupler closed signal from the bus coupler bay. A series connection of auxiliary contacts from the bus coupler circuit breaker and two isolators. This shall be taken through an auxiliary relay.

15	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts. Only for double busbar stations.
16	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts. Only for double busbar stations.
<b>For GIS Applications</b>		
17	Q51 Closed	Q51 earth switch closed status directly from the isolator auxiliary contacts.
18	Q51 Opened	Q51 earth switch opened status directly from the isolator auxiliary contacts.
19	Q52 Closed	Q52 earth switch closed status directly from the isolator auxiliary contacts.
20	Q52 Opened	Q52 earth switch opened status directly from the isolator auxiliary contacts.
21	Q53 Closed	Q53 earth switch closed status directly from the isolator auxiliary contacts.
22	Q53 Opened	Q53 earth switch opened status directly from the isolator auxiliary contacts.
23	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
24	Bus 1 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 1 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
25	Bus 2 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 2 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
26	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Protection and AR</b>		
27	Line VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the marshalling kiosk and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
28	Bus 1 VT MCB Healthy	This shall be taken from the bus coupler bay through a bus wiring among all panels. This may be taken from an auxiliary relay installed in the protection panel. Signal shall be logically high when all the MCBs in the circuit are closed
29	Bus 2 VT MCB Healthy	Only applicable for a double busbar station. This shall be taken from the bus coupler bay through a bus wiring among all panels. This may be taken from an auxiliary relay installed in the protection panel. Signal shall be logically high when all the MCBs in the circuit are closed
30	AR function off	Selection of "AR Off" from the AR function selector switch mounted on the relay panel.
31	AR Main 1	Selection of "Main 1" from the AR function selector selector switch mounted on the relay panel.
32	AR Main 2	Selection of "Main 2" from the AR function selector selector switch mounted on the relay panel.
33	Manual Close Command	Taken from the auxiliary relay/contactor used to send the manual close command to the circuit breaker.
34	General Pickup from Main 1/2	This is only required if the relay has a AR function that operates based on the action time principle.
35	AR Start from Main 1/2	3 phase trip signal to initiate single pole AR function from the other IED. Input shall be logically high when the AR initiating functions are operated according to chapter 5.9.5.1.

36	Main 1/Main 2 Protection Relay Fail	This input shall be logically high when the other IED is in operation without any complication.
<b>Alarming</b>		
37	Relay Panel DC/AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
38	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in the Marshalling Kiosk. Signal shall be logically high when all the MCBs are switched on.
39	Circuit Breaker Gas Pressure Low Alarm	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
40	Circuit Breaker Gas Pressure Lockout	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
41	Isolators are in Local Mode	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
42	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
43	CB in Local Mode	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
44	Synchroscope Plugged In	This signal is taken through the syncrocheck console once it is plugged in.
<b>Distance Tele Protection</b>		
45	Communication Healthy	This signal shall be taken directly from the multiplexer equipment. Signal shall be high if communication channel is healthy.
46	Carrier Receive (Distance)	Permissive/Blocking carrier receive from the remote end distance protection function.
47	Carrier Receive (DEF)	Permissive/Blocking carrier receive from the remote end directional earth fault protection function.
48	Carrier Receive (DIT)	Direct inter trip received from the remote end breaker failure and end fault protection functions.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip

3	AR Lockout Trip 86/1	AR definitive trip and any trip that does not initiate auto reclosing.
4	AR Lockout Trip 86/2	AR definitive trip and any trip that does not initiate auto reclosing.
5	Start Breaker Failure 3 Phase	General Trip 3 Phase to initiate 3 phase breaker failure function
6	Q1 Isolator Close	Close Command to the bus 1 isolator
7	Q1 Isolator Open	Open Command to the bus 1 isolator
8	Q2 Isolator Close	Close Command to the bus 2 isolator
9	Q2 Isolator Open	Open Command to the bus 2 isolator
10	Q9 Isolator Close	Close Command to the line isolator
11	Q9 Isolator Open	Open Command to the line isolator
12	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
13	86/1 Reset	Contact to reset 86/1 through NCC/SAS
14	AR Start	AR Start signal to other IED. This shall be closed through any tripping command that is intended to initiate 3 pole AR function.
15	General Pickup	This is required only if the other IED has an AR function which operates in the basis of action time. General pickup of any protection function will activate this output.
16	Distance Carrier Send	Distance permissive or blocking tele protection command sent to the other end
17	DEF Carrier Send	Directional earth fault permissive or blocking tele protection command sent to the other end
18	86/2 Reset	Contact to reset 86/2 through NCC/SAS
<b>Fault Recorder</b>		
19	Differential Trip	Line differential trip to trigger/record in the disturbance recorder
20	Distance Trip	Line distance trip to trigger/record in the disturbance recorder
21	DEF Trip	Directional earth fault trip to trigger/record in the disturbance recorder
22	Over Current and Earth Fault Trip	Over current or earth fault trip to trigger/record in the disturbance recorder
23	Distance/DEF Carrier Send	Distance/DEF carrier send to trigger/record in the disturbance recorder
24	AR Close	AR close command to trigger/record in the disturbance recorder
25	Distance/DEF Carrier Received	Distance/DEF carrier receive from remote end to trigger/record in the disturbance recorder



**5.9.3.2 Trip Matrix**

Only three pole auto reclosing shall be implemented in 132kV voltage level.

	DC	TC1	TC2	86-1	86-2	Tele-Protection		FO1	FO2	AR	Start CBF to BB Prot.(50BF)
						Perm	DTT				
<b>Main 1</b>	1	all	all								
87L		X	X					X	X	X	X
21 Z1		X	X							X	X
21 Z2		X	X	X	X						X
21 Z3		X	X	X	X						X
21 Z4		X	X	X	X						X
21 aided		X	X			X		X	X	X	X
49		X	X	X	X						X
59/27		X	X	X	X						
67N		X	X			X		X	X	X	X
51/51N		X	X	X	X						X
AR Lockout		X	X	X	X						
86/1	1										
<b>Main 2</b>	2										
87L		X	X					X	X	X	X
21 Z1		X	X							X	X
21 Z2		X	X	X	X						X
21 Z3		X	X	X	X						X
21 Z4		X	X	X	X						X
21 aided		X	X			X		X	X	X	X
49		X	X	X	X						X
59/27		X	X	X	X						
67N		X	X			X		X	X	X	X
51/51N		X	X	X	X						X
AR Lockout		X	X	X	X						
86/2	2										
86BB,87BB	3	x	x								

**5.9.4 Protection Functions Required in Line Protection Applications**

**5.9.4.1 Differential Protection**

Differential protection shall be capable of protecting 100% of the total line length in the transmission line to be protected for three phase faults, phase to phase faults, phase to earth faults and high impedance faults within one cycle. (Not including the time taken to trip the circuit breaker) The protection shall be immune to inrush currents caused by transformer energization, current transformer saturation due to heavy external faults, data synchronization

errors, higher frequency components during energization of overhead transmission lines or cables, noise in communication channels, difference between current transformer ratio errors and phase errors at different ends. In addition the protection shall not mal operate during sudden loss of communication, analog acquisition unit failure in local or remote relay, internal failure of local or remote relay. The line differential relay shall be phase segregated thereby facilitating faulted phase selection function.

The relay shall have at least two dedicated, independent serial links for line differential protection related data communication between the local and remote end relays. For three terminal line protection applications there shall be two identical serial interfaces facilitating communication through 1550nm single mode fiber links. For two terminal lines there shall be two interfaces where the first one is 1550nm single mode fiber link facilitating relay to relay direct communication and the second interface shall be a IEEE C37.94 compliant interface facilitating communication through a multiplexer.

For differential protection communication link, armoured fibre optic cables shall be used from protection panel to multiplexer panel and patch panel to avoid physical damages caused by rodents, insects etc. Inside the protection cubicles, protected fibre optic cables shall be used to give added protection to the communication link.

The relay shall include a secure integral inter-tripping facility, which can be used as inter-tripping path by external breaker fail protection. Also, it shall be possible to transfer/receive up to eight binary signals to/from relays at remote ends. The relay shall perform this inter-tripping/binary signal transfer via both interfaces. i.e. (1) direct fibre (2) multiplexer

The line differential protection relay shall be connected to individual phase currents in 1 ½ breaker and multi-breaker arrangements without external summation for improved through fault stability.

The relay shall be capable of protecting two terminal or three terminal transmission line segments with all the relays functioning in the “master” mode if both available serial communication links between the relays are in order. (In master mode all the relays in the differential scheme will calculate differential and restraint currents and operate independently of each other while sending trip commands to the remote ends when fault detection has occurred)

In the case of a two terminal line protection application the two serial links shall function in hot-standby mode. If the link currently being used for communication is failed the protection shall be routed automatically through the standby link without any interference or mal operation of the protection. Blocking or desensitizing of differential protection during the transition period shall be acceptable.

In three terminal application without any link failure the scheme should operate with all the relays in “master” mode. When one of the links between two relays fail the scheme should be reverted in to a “master – slave” mode. The relay with both links intact and is able to receive all the currents from remote ends will act as the master performing the differential calculation and sending trip commands to the remote ends. The relays in the slave mode does not perform any differential calculation and it only reports the locally measured currents to the remote end and trip it's local breaker when direct inter trip command is received.

#### Time Synchronizing

For symmetrical serial links (if channel delays in both send and receive directions are similar) between the relays the time synchronization between the relays shall be performed without any external time synchronization devices. If the link is deemed asymmetrical the use of external time synchronizing sources shall be facilitated. Hence the relays shall be capable of functioning without any interference with “SONET Ring” arrangement facilitated by external time sources. When the application uses external sources for time synchronization the

differential scheme shall be secured when an external time source to at least one relay is degraded.

#### Charging Current Compensation

It is preferable to have the charging current compensated by a calculated value based on the instantaneous voltage measured by the line or bus side connected voltage transformers and the user inserted susceptance value. The voltage used for compensation shall be monitored by a "Voltage transformer fuse failure" element and if the voltage is deemed unhealthy an indication shall be given that can be used in logic configuration tool to utilize in the logics according to the user's desired configuration. (For an instance switch setting groups) The charging current shall be compensated by any other algorithm mentioned above to increase the sensitivity of the differential protection for faulty conditions.

#### Open CT detection

It is preferable to have open current transformer secondary circuit detection incorporated in to the differential element or as a separate module. The user shall have the option of disabling the current differential protection when current transformer secondary circuit is open based on his protection philosophy.

Upon detection of a communications channel failure and following a time delay of less than 1 seconds, an alarm shall be given.

#### **5.9.4.2 Line Distance Protection**

In addition to line current differential protection there shall be the facility of enabling distance protection to detect three phase faults, phase to phase faults, phase to earth faults and high impedance faults within one cycle independently of each other. (Not including the time taken to trip the circuit breaker) The relay shall provide "full scheme" or in other words "non-switched" distance protection having separate measuring systems to detect different fault types without switching in to a measuring system after determining the faulted phase using starters.

The distance protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and inrush currents caused by transformer energization. The user shall have the provision to configure and apply settings independently to phase distance protection and ground distance protection. There shall be at least five zones of protection for each phase and ground distance element. The user shall have the facility to configure at least two zones as reverse looking elements. Zone timing used in the operation shall be based on the "common zone timing" principle. There shall be at least two separate settings for "zero sequence compensation" factor separately for zone one and other zones to compensate for the error of impedance measurement caused by the presence of zero sequence impedance in the protected line.

Faulted phase selection is considered very important even in the case of three pole tripping and hence there shall be a mechanism within the algorithm to accurately determine the faulted phase and represent it to the user. In the case of single pole auto reclosure the phase selection algorithm shall trip the faulted phase and initiate auto reclosure. During a line – line – ground fault, three fault loops will be picked up. Two line to ground loops and one line to line loop and depending on the location of the fault impedances line to ground loops can over reach. (Leading faulted loop tend to over reach when there is a fault resistance between phase to ground and lagging element tend to over reach when there's an impedance between phases) This shall be detected and during a line to line to ground fault individual line to ground loops shall be blocked appropriately without causing malfunction.

Memory voltage or healthy phase voltages shall be used for directional determination at least in the case of insufficient faulted phase voltage. The use of memory voltage shall not hamper the directional determination as the time elapses after the fault inception and hence shall not operate for a close in reverse faults for a forward looking zone as the time increases.

The user shall have the facility to determine the characteristic to be used for phase distance and ground distance separately out of “Mho” characteristic and “Quadrilateral” characteristic. For quadrilateral characteristic, the user shall be able to enter following settings separately for phase distance and ground distance protection which explains the dimensions of the characteristic.

Reactance reach

Right blinder resistive reach

Angles with respect to the R-axis and X-axis which governs the directional decision

Tilt angle of the reactance line

Line characteristic angle

Operating delay

The user shall have the liberty to change the tilt angle of the reactance line of the quadrilateral characteristic to take the pre fault load conditions into account and minimize the error in impedance calculation caused by that.

For Mho characteristic the user shall be able to enter following settings separately for phase distance and ground distance protection which explains the dimensions of the characteristic.

Impedance Reach

Line characteristic angle

Operating delay

Reverse Offset

The Mho characteristic shall be memory or cross polarized to increase the resistive coverage of the zone setting and improve directional security.

There shall be the facility of blocking distance protection during the following scenarios. The user shall have the liberty of blocking or not blocking according to this protection philosophy.

- Power Swing Detection

Power swing blocking module shall be capable of detecting power swing conditions in the power system by analyzing the positive sequence impedance loci. An element without additional user defined settings would be preferred and an element functioning according to the conventional method of analyzing the timing between inner and outer characteristics would also be acceptable. The user shall have the facility to block or trip during power swing conditions according to protection philosophy.

- Voltage transformer secondary circuit failure

Voltage transformer secondary circuit failure shall be provided. The user shall have the facility to block or operate distance during voltage transformer secondary circuit failure.

- Load encroachment

The distance protection shall not mal operate during heavily loaded condition of the protected transmission line. The phase distance element will be blocked when the load encroachment is detected hence even though the impedance loci operates within a distance zone of protection when the line is heavily loaded without a faulty condition in the line the distance function will not mal function.

- Fault Locator

The fault locator function shall calculate the fault location with the measured values of both line ends. For the transmission of the measured values between the line ends, the communication channel available for differential protection function shall be used. The results of the fault locator shall be recorded in relay event list, displayed on relay LCD display and in station computer. This information shall include the following.

1. Distance to fault
2. Fault Current

If end to end communication is not possible the calculation shall be carried out based on locally available information.

#### 5.9.4.3 Tele Protection for Distance Protection

Since distance protection in the local end cannot protect the whole transmission line without jeopardizing the security and maintaining selectivity, the facility to implement following conventional tele protection schemes shall be available. All the tele protection schemes shall be compatible to use with lines having three terminals and hence the system shall be designed accordingly. i.e. Tele Protection signals generated at one terminal shall be transmitted to all remote ends.

- Permissive Under reach transfer trip scheme (PUTT)

When the fault is detected in zone 1 (under reaching zone) the relay trip instantaneously (if zone 1 time setting is 0s) and send a tele protection permissive signal to the remote end. Relay will be operated instantaneously if the overreaching zone is picked up and the permissive signal is received from the remote end.

- Permissive Over Reach Transfer Trip scheme (POTT)

When a fault is detected inside the overreaching zone a permissive signal will be sent to remote ends. Relay will be operated instantaneously if the overreaching zone is picked up and the permissive signal is received from the remote end.

Additionally the scheme shall be secured for current reversal conditions that can occur during fault clearance in the parallel line.

Weak infeed logic shall be incorporated with the permissive over reach transfer trip scheme or as a separate module. Weak infeed module shall detect pole open conditions or weak infeed conditions and echo the signal received from the remote end in order to accelerate the tripping for an internal fault. The scheme should be secured against reverse faults at the weak infeed end. It is preferable if a phase to phase or residual voltage supervision is available for at the weak infeed end to determine that there's an actual fault in the line.

- Directional Comparison Blocking (DCB)

Instantaneous distance over reaching zone shall be operated if the blocking signal is not received from the remote end. The blocking signal is transmitted to the remote end once a reverse fault is detected in the local end.

The scheme shall be secured against for current reversal conditions that can occur during fault clearance in the parallel line.

Additionally there shall be timers to coordinate with blocking signal getting delay due to communication channel delays.

The function shall be capable of working with three terminal lines hence there shall be separate inputs to block instantaneous tripping when the blocking signal is received from either end in a three-terminal application.

#### 5.9.4.4 Directional Earth Fault Protection

The relay shall contain a directional earth fault function operated by the zero sequence current calculated from the phase current transformers inputs. If the current transformers are connected in the “Holmgren” connection and the zero sequence current is available as a measurement that measured current shall be used as the operating quantity.

The directional earth fault protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and inrush currents caused by transformer energization. It is preferable to have faulted phase selection for the directional earth fault protection.

The user shall have the facility of selecting one option from the following Measurement as the polarizing quantity.

- Zero sequence voltage calculated from the three phase to neutral voltages connected.
- Negative sequence voltage calculated from the three phase to neutral voltages connected
- Zero sequence current from a neutral current transformer of a power transformer in the substation.

The directional earth fault function shall support tripping based on the following inverse definite minimum time curves.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time

Additionally the directional earth fault function shall support delayed or instantaneous tripping with the assistance of tele protection.

- Permissive Over Reach Transfer Trip scheme (POTT)

When the pickup value of the directional earth fault function is exceeded and the direction is towards the transmission line a permissive signal will be sent to remote ends. Relay will be operated instantaneously if the local end directional earth fault function is picked up, the fault direction is detected towards the transmission line and the permissive signal is received from the remote end.

Additionally the scheme shall be secured for current reversal conditions that can occur during fault clearance in the parallel line.

Weak infeed logic shall be incorporated with the permissive over reach transfer trip scheme or as a separate module. Weak infeed module shall detect pole open conditions or weak infeed conditions and echo the signal received from the remote end in order to accelerate the tripping for an internal fault. The scheme should be secured against reverse faults at the weak infeed end.

- Directional Comparison Blocking (DCB)

When the directional earth fault function is picked up local end the function shall be operated if the blocking signal is not received from the remote end. The blocking signal is transmitted to the remote end once a reverse fault is detected in the local end.

The scheme shall be secured against for current reversal conditions that can occur during fault clearance in the parallel line.

Additionally there shall be timers to coordinate with blocking signal getting delayed due to communication channel delays.

The function shall be capable of working with three terminal lines hence there shall be separate inputs to block instantaneous tripping when the blocking signal is received from either end in a three-terminal application.

The user shall have the option of blocking the directional element if the voltage transformer fuse failure function has operated or the voltage transformer secondary circuit MCB is tripped.

If the directional earth fault function does not contain a phase selection algorithm it is preferable to have the facility for the user to block the directional earth fault function in case either distance protection zone 1 or line differential protection is picked up.

Integral weak in-feed and open terminal signal echo logic shall allow fast tripping in the event of low or zero fault current infeed at one line terminal.

The residual over current starter shall be adjustable between 5% and 100% of rated current. The characteristic angle of the directional control element shall offer an adequate range of adjustment for a solidly earthed power system.

When the signalling channel is lost DEF tripping shall be blocked.

#### **5.9.4.5 Directional/Non Directional Over Current (50,51,67)**

There shall be directional and non-directional over current elements to detect faults in any of the three phases. The over current functions shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse

- Very Inverse

- Extremely Inverse

- Long time inverse

- Definite time

Additionally there shall be instantaneously operating elements as well. The over current protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and inrush currents caused by transformer energization and shall not respond to DC component.

The user shall have the option of blocking the directional element if the voltage transformer fuse failure function has operated or the voltage transformer secondary circuit MCB is tripped.

There shall be some degree of memory polarization to make sure directional element directionality is secured under close in three phase faults.

There shall be at least four stages of inverse definite minimum time curve based elements.

The function shall have a reset ratio of 95%.

The user shall have the facility to configure following settings according to his requirement.

- Pickup value of the function

- The desired inverse definite minimum time curve

- Time multiplier setting of the IDMT curve

- Time delay if the selected curve is definite time

Additionally for the directional over current elements following settings shall be available for the user customize according to his need.

- Direction; Forward or Reverse

- Relay characteristic angle

The sector opening of the forward or reverse direction with respect to the characteristic angle.

The over current IDMT elements shall have current ranges from 50% to 200%, adjustable in steps of 1%.

Each over current shall be supplemented with a definite time element having a range 5 to 30 times nominal current. The definite time setting shall be adjustable between zero and ten seconds in steps of 0.01 seconds.

Tripping shall occur from the instantaneous elements in less than 20 ms including main tripping contactor when three times the setting current is flowing.

An earth fault element shall have current ranges from 10% to 80%, adjustable in step of 1%.

The time settings for both over current and earth fault IDMT elements shall be continuously variable from 0 to 1.0 or as an alternative, with steps of at least 0.01 from 0.05 to 1.0

#### **5.9.4.6 Under /Over Voltage Protection (27/59)**

Under voltage and over voltage functions shall be available to detect under voltage or over voltage conditions in any of the three phases of the connected voltage source.

There shall be at least two elements each for under voltage and over voltage protection having a definite time characteristic. Having inverse characteristics in the operating time curve shall be considered as an additional advantage.

The reset ratio shall be 95%.

#### **5.9.4.7 Thermal Over Load (49)**

This particular function is used to detect overloading conditions of the protected transmission line/Transformer based on a thermal model. The thermal model and the operating characteristic shall be based on IEC 60255-8. The thermal model shall be centred on following factors.

Continuous thermal current rating of the object

Time Constant based on the maximum short term current rating

Pre-fault current

#### **5.9.4.8 Broken Conductor (46)**

Broken conductor function is used to detect an open phase condition.

The function shall detect the broken conductor situation by considering the measured negative sequence and positive sequence current magnitudes. The function shall be blocked if the measured positive sequence current is larger than a predefined value (or by any other means) to discriminate between an external fault and an open phase condition.

This function shall immune to operate due to the negative sequence current resulting from a, the full load steady state unbalance arising from CT errors, load unbalance.

#### **5.9.4.9 Stub Protection (50-STB)**

Stub protection shall be provided for busbar arrangements like one and half breaker arrangement or ring busbar arrangements. When the line disconnector in open position in an one and half breaker arrangement the area between the current transformers and the line disconnector will not be protected because the distance protection cannot operate with the line end voltage transformers being installed towards the remote end from the line disconnector. In line differential protection the local current reporting to the remote end shall be blocked in case line disconnector is opened and stub protection is active.



#### 5.9.4.10 Switch on to Fault

Switch on to fault protection function is intended to provide instantaneous tripping if the circuit breaker is manually closed or autoreclosed on to a fault.

The user shall have the facility to use following conditions as a combination to detect that the breaker is closed manually or by autoreclosing function.

- Through a binary input connected to the manual close command
- Through a binary input connected in parallel with the circuit breaker closing path
- Through binary inputs connected circuit breaker status indicating auxiliary contacts

From the measured voltage and current

There shall be a timer which can be set by the user that governs the duration where this function is activated after manual closing of the circuit breaker is detected.

There shall be a timer which can be set by the user that governs the time duration where the circuit breaker should be open to activate this function.

The user shall have the following options to initiate tripping when the circuit breaker is closed on to a fault according to his philosophy.

- Tripping instantaneously by an over reach directional distance protection zone
- Tripping instantaneously by a non-directional distance zone
- Tripping instantaneously by a non-directional over current function

The function shall be immune to in rush currents caused by transformer energization.

### 5.9.5 Control Functions for 220 kV/132kV Lines

#### 5.9.5.1 Auto-Reclosing (AR)Function (79)

Only three pole reclosing will be applied in 132kV transmission network. Both single pole and three pole reclosing shall be applied in 220kV network.

Autoreclosing function shall support high speed and delayed autoreclosing if the relevant conditions (which are discussed below) are met and it is deemed safe to perform a reclosing of the circuit breaker. The relay shall be capable of supporting the function of having an external reclosing equipment as well. The function shall be capable of handling following modes of operation.

- Single pole operation

When the internal phase selection algorithm concluded that the fault is single phase that particular pole should be open and a reclosing cycle should start and close the circuit breaker at the end of the dead time.

If the fault is identified as a double phase or three phase the autoreclose cycle should not start and it should go in 3 pole trip lockout.

- Three pole operation

Whichever the fault occurs three pole autoreclosing will be initiated.

- Both single and three pole operation

When the internal phase selection algorithm concluded that the fault is single phase that particular pole should be open and a reclosing cycle should be initiated and close the circuit breaker at the end of the dead time.

If a fault is detected as a multi-phase fault 3 pole auto-reclosure will be initiated.

- Auto-recloser disabled mode

Auto-recloser will be disabled and will not be initiated for any type of fault.

The user shall be able to select the desirable recloser mode either directly through inserting settings or through an externally connected selector switch. When AR is in disabled mode all the trippings shall initiate both lockout relays.

Auto-reclosing function shall be enabled in both main 1 and main 2 IEDs. But at a given moment only one relay will act as the “Master” unit and perform auto-reclosing function. Once the autorecloser function in the “Master” is blocked due to an external reason, handling of the function of auto-reclosing shall be switched to the other IED automatically. The user shall be able to select the IED that performs auto-reclosing function through an externally wired selector switch or through substation automation system. If the Main 1 IED is performing the auto-recloser function and only main 2 relay tripped due to a fault that shall also initiate the auto-reclosing cycle in main 1 IED.

The reclosing function shall supervise the following conditions and incorporate them within the algorithm.

- Circuit breaker “Ready” status – Supervise whether the circuit breaker is ready to perform a reclosing cycle (For an instance of spring operated SF6 circuit breaker; spring is charged and SF6 gas pressure is sufficient)
- The circuit breaker position to supervise whether it was closed prior to the fault inception.
- Supervising voltages at both sides of the breaker for synchronism conditions or voltage check through an internal “synchronism check” or “Voltage check” function. The synchronism check function features are discussed below. This is valid only for three pole auto reclosing.

If any of the supervising conditions are not fulfilled the function will be driven in to lockout mode resulting in a permanent three pole trip.

#### Auto recloser Initiation and operation

Please note that the operation discussed here is for single shot operation.

The function shall be capable of taking external trip commands from other relays to initiate auto reclosing. The user shall have the facility to select the respective protection functions to be used to initiate auto reclosing. The relay shall have the facility of having a separate binary input to detect the manual close command to the breaker and block auto reclosing for a user definable time period.

Once the function is initiated and the “dead time” will start when the protection function caused the tripping is reset or the breaker is regarded to be open depending on the current and breaker status taken from the auxiliary contacts of the breaker. The dead time is the duration that the breaker will be left open and the user shall be able to change that according to his philosophy. Once the dead time is elapsed and the previously mentioned supervision conditions are met, the relay will issue a close command to the breaker. Again, the function shall supervise whether the breaker is actually closed depending on the current and breaker status taken from the auxiliary contacts of the breaker. If the breaker status is not plausible a permanent trip shall be issued. If the breaker status is plausible a timer known as “Reclaim time” shall start and if there’s another fault within the reclaim time the relay shall issue a permanent trip. Reclaim time shall be user definable. After the reclaim timer has elapsed the relay shall be ready for another reclosing cycle if the other supervising conditions are met. Once a reclosing cycle is performed and the reclaim timer has elapsed it is considered that the reclosing cycle is successful.

In the case of single pole auto reclosing, if there’s an evolving fault occurring during a single pole dead time the relay shall either start three pole reclosing or perform three pole permanent trip depending on the user definable settings.

The relay shall provide dead time extension until the synchronism conditions are met which shall be defined by the user.

Following protection function shall be used to initiate auto reclosing function.

- Line differential protection – single pole and three pole
- Line distance zone 1 instantaneous element – single pole and three pole
- Line distance zone 1 extension instantaneous element – single pole and three pole
- Carrier aided distance element–single pole and three pole
- Carrier aided directional earth fault element–single pole and three pole

#### **5.9.5.2 Synchronism check Function (25)**

There are basically two parts in the synchronism check function.

Voltage Check

Synchronism Check

These two functions could be handled separately by two functions or can be incorporated in the same function.

A synchronism function that include both functions will be used in the following discussion.

The “Synchronism check” function shall use the voltages either side of the breaker. All three phase of the line side voltages will be supplied to the relay and only one phase or line voltage from the bus side will be provided. The user shall have the facility of using any line voltage or phase voltage as the bus side voltage according to his philosophy. In the case of a “double bus bar” configuration user will provide one phase or line voltage from each bus bar and depending on the bus isolators’ position relay shall select the required bus voltage for the function.

At least the following setting parameters shall be available for the user to customize according to his requirements.

Maximum Voltage level above which the bus side or line side is deemed “Live”

Minimum Voltage level below which the bus side or line side is deemed “Dead”

Maximum allowable voltage magnitude difference between bus side voltage and line side voltage below which the two voltages are considered in synchronism

Maximum allowable voltage angle difference between bus side voltage and line side voltage below which the two voltages are considered in synchronism

Maximum allowable frequency difference between bus side voltage and line side voltage below which the two voltages are considered in synchronism

Additionally following conditions shall be supervised to validate the voltage inputs provided to the relay.

#### **Bus side Voltage transformer MCB healthy**

An auxiliary contact of the MCB connected in the bus side voltage transformer secondary circuit will be wired as an input to the relay. The user shall have the facility to block synchronism / voltage check function if MCB is not healthy. In the case of a double bus bar arrangement the user will provide two MCB healthy inputs from each bus bar voltage transformer secondary circuit.

#### **Line side Voltage transformer MCB healthy**

An auxiliary contact of the MCB connected in the line side voltage transformer secondary circuit will be wired as an input to the relay. The user shall have the facility to block synchronism / voltage check function if MCB is not healthy.

#### **Line side voltage transformer fuse failure detection**

The user shall have the option of blocking synchronism / voltage check function if voltage transformer fuse failure detection function has operated. The features of the voltage transformer fuse failure function is discussed in the chapter 5.12.8.

The user shall be able to select the mode of voltage check/synchronism check used for reclosing out of the following factors individually or as a combination.

#### **Synchronism check**

If both line side and bus side voltages are deemed as “Live” this function will determine whether the two systems are in synchronism depending on the maximum allowable difference between voltage magnitude, voltage angle and frequency. If they are within limits permission to close signal will be provided for the autoreclosing function. There shall be a user selectable timer during which synchronism check conditions should be fulfilled and release is initiated subsequently.

- Dead line – live bus

When line side voltage is deemed “Dead” and bus side voltage is deemed “Live” based on the settings voltage check function shall give permission to close for the autorecloser function.

- Dead bus – Live line

When line side voltage is deemed “Live” and bus side voltage is deemed “Dead” based on the settings voltage check function shall give permission to close for the autorecloser function.

- Dead bus – Dead line

When line side voltage is deemed “Dead” and bus side voltage is deemed “Dead” based on the settings voltage check function shall give permission to close for the autorecloser function.

#### **5.9.5.3 Line Feeder Circuit Breaker Bypass Switch for 220 kV**

The off load circuit breaker by pass switch shall be provided on all 220 kV line feeder circuits of a Grid Sub Station having a double bus bar arrangement with a bus coupler circuit breaker.

The following shall be achieved on the feeder circuits and on the bus coupler circuit when operating in by pass position.

- Isolate all line feeder and bus bar protection trip circuits from the 220 kV line feeder circuit breaker.
- Isolate all bus coupler trip circuits from the 220 kV bus coupler circuit breaker.
- Transfer all trip circuits from the 220kV line feeder Main and Back up protection to the bus coupler trip circuit.
- Isolate 220 kV line feeder auto-reclose circuits from the line feeder circuit breakers.
- Initiate direct inter-trip signals to the remote end of the by passed line feeder on operation of:
  - bus coupler bus bar protection trip relay of the connected bus.
  - Bus coupler circuit breaker fail relay
- An alarm should be provided to annunciate when the switch is in the by pass position.

#### **5.9.6 Interlocking Logic for Transmission Line Applications**

All the conditions discussed in chapter 5.8.4 shall be included in the interlocking logic. The complete interlocking logic for a typical GIS bay/AIS bay line application consists of two segments. First the overall interlocking for each switchgear is depicted in chapter 5.9.6.1 and the logic involved in synchronism check is depicted in chapter 5.9.6.2. Please refer annexed protection single line diagrams to clarify the abbreviations used in the interlocking logic tables.

5.9.6.1 Interlocking Logics

Operation	Operating Location	Switchgear											Other Conditions										
		Q0	Q1	Q2	Q8	Q9	Q51*	Q52*	Q53*	Bus Coupler	Bus 1 ES*	Bus 2 ES*	<U	86/1	86/2	86BB(96)	74/1	74/2	25	Bus VT MCB Healthy	Line VT MCB Healthy	Hand Crank Not inserted	
Q1 Close/Open	Any Location	Open	-	Open	-	-	Open	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
	Any Location	-	-	Close	-	-	Open	Open	Open	Close	Open	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q2 Close/Open	Any Location	Open	Open	-	-	-	Open	Open	Open	-	-	Open	-	-	-	-	-	-	-	-	-	-	Not Inserted
	Any Location	-	Close	-	-	-	Open	Open	Open	Close	-	Open	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q0 Close	CRP,SAS,NCC	-			-		-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	Permit to Close	Healthy	Healthy	Not Inserted	
	Local Control Panel	-	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q9 Close/Open	Any Location	Open	-	-	Open	-	Open	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q8 Close/Open	Only from LCP	-	-	-	-	Open	-	-	-	-	-	-	Operated	-	-	-	-	-	-	-	-	Healthy	Not Inserted
Q51,Q52,Q53 Close/Open	Only from LCP	-	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted

\* - Only Available in GIS  
I - Not Intermediate

Notes:

1. Bus Coupler close signal shall be the series connection of N/O contacts in two isolators and the circuit breaker in the bus coupler bay. Signal will be logically high when the bus coupler bay is closed.
2. <U signal shall be the series connection of three per phase voltage supervision relay contacts installed in the local control panel Signal shall be logically high when the voltage measured in all three phases are less than 10% of the nominal voltage.
3. Synchronism check shall be done according to the chapter 5.9.6.2.
4. Bus 1 earth switch status and Bus 2 earth switch status shall be taken to individual bays through a bus wiring from the bus coupler bay. Signal shall be logically high when the earth switches are in open condition.

Shortened Term	Description
LCP	Local Control Panel; Refer Clause 5.8.2.1 and 5.8.2.2
CRP	Protection/Control Panel; Refer Clause 5.8.2.3
SAS	Substation Automation System; Refer Clause 5.8.2.4
NCC	National Control Center; Refer Clause 5.8.2.5

5.9.6.2 Synchronism Check

Operation	VT MCB Healthy			Switchgear Status		Synchronism Conditions						
	Line VT MCB	Bus 1 VT MCB	Bus 2 VT MCB	Q1	Q2	$V_{Bus} < 10\% V_N,$ $V_{Line} > 75\% V_N$	$V_{Bus} > 75\% V_N,$ $V_{Line} < 10\% V_N$	$V_{Bus} < 10\% V_N,$ $V_{Line} < 10\% V_N$	$V_{Bus} > 75\% V_N,$ $V_{Line} > 75\% V_N$	$V_{Diff} < 10\% V_N$	$Ang_{Diff} < 20^\circ$	$F_{Diff} < 0.1Hz$
Permit to Close	Healthy	Healthy	-	Close	Open	Operated	-	-	-	-	-	-
	Healthy	Healthy	-	Close	Open	-	Operated	-	-	-	-	-
	Healthy	Healthy	-	Close	Open	-	-	Operated	-	-	-	-
	Healthy	Healthy	-	Close	Open	-	-	-	Operated	Operated	Operated	Operated
	Healthy	-	Healthy	Open	Close	Operated	-	-	-	-	-	-
	Healthy	-	Healthy	Open	Close	-	Operated	-	-	-	-	-
	Healthy	-	Healthy	Open	Close	-	-	Operated	-	-	-	-
	Healthy	-	Healthy	Open	Close	-	-	-	Operated	Operated	Operated	Operated

## 5.10 220kV/132kV CABLE PROTECTION AND CONTROL

Protection and control functions and concepts incorporated in cable applications shall be identical to the content discussed under the chapter 5.9. However, auto reclosing function is not required and hence all hardware except the IEDs necessitated for auto reclosing shall be excluded. In order to maintain a common standard for IEDs they shall be identical to the IEDs used in 220kV/132kV overhead line protection and control.

Protection signal line shall also be identical to the SLD in 220kV/132kV overhead line protection and control (Annexure 1) except the illustrations relevant to auto reclosing function.

## 5.11 33KV/11KV FEEDER PROTECTION AND CONTROL

### 5.11.1 General Requirements

Following bays are classified under the category of 33kV/11kV feeders.

- Overhead lines
- Underground Cables

There shall be only one IED in each bay which includes the protection/control functions mentioned below and bay controlling function as it was discussed in chapter 5.8.2.

- Non Directional/Directional Over Current Protection
- Non Directional/Directional/Sensitive Earth Fault Protection
- Negative sequence
- Over/Under Voltage
- Breaker Failure Protection
- Under Frequency Load Shedding Protection
- Over Frequency, Under Frequency and ROCOF Protection
- Auto reclosing function
- Synchronism Check Function
- Fault Locator

The hardware requirements for 33kV protection applications in addition to those in chapter 5.7 are discussed within this chapter.

### 5.11.2 Analog Circuits

#### Current Circuits

The protection core of line current transformer secondaries shall be connected in “Holmgren” connection and connected to the relay in the following manner.

Channel 1	R Phase Current
Channel 2	Y Phase Current
Channel 3	B Phase Current
Channel 4	Summation Current of the Three Phases
Channel 5	Neutral current of measuring CT for SEF

#### Voltage Circuits

Line voltage transformers shall be connected in star configuration and connected to the first three inputs of the relay. Busbar voltage between R and Y phases shall be

connected to the fourth input. If the substation is a double busbar station, busbar 2 voltage between R and Y phases shall be connected to the fifth voltage input. Voltage transformer secondary circuit shall be protected by a 3-pole MCB located in the protection/control panel and 2-pole MCB located in respective phase voltage transformer secondary terminal boxes.

Channel 6	R Phase Voltage
Channel 7	Y Phase Voltage
Channel 8	B Phase Voltage
Channel 9	R-Y Busbar Voltage-BB1
Channel 10	R-Y Busbar Voltage-BB2

### 5.11.3 Binary Circuits

#### Binary Inputs

The binary inputs mentioned in the table below shall be wired to the IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Binary Inputs	Remarks
	Control and Interlocking	
1	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts
4	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts
5	Q5 Opened	Line earth switch opened status directly from auxiliary contacts of earth switch
6	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
7	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
8	Lockout Relay Operated	N/C contact from the lockout relay.
9	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.
10	Trip Circuit 2 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.
11	Breaker Failure Inter trip	Breaker failure trip received from a bay connected to the same bus section.
<b>For GIS Applications</b>		
12	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
13	Bus 1 Earth Switch Opened	Bus 1 earth switch opened status directly from the earth switch.
14	Bus 2 Earth Switch Opened	Bus 2 earth switch opened status directly from the earth switch.
15	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle

<b>Protection and AR</b>		
16	Bus 1 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
17	Bus 2 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position. (For stations with double busbar)
18	Feeder VT MCB Healthy	From auxiliary contacts of the voltage transformer secondary circuit of the feeder
19	Gas Pressure OK in CB Cubicle	Direct contact from the pressure gauge installed in the circuit breaker chamber. Signal shall be logically high when the gas pressure is healthy.
20	Gas Pressure OK in Busbar Cubicle	Direct contact from the pressure gauge installed in the circuit busbar chamber. Signal shall be logically high when the gas pressure is healthy.
<b>Alarming</b>		
21	Relay Panel DC or AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
22	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC and AC MCBs installed in Marshalling Kiosk. Signal shall be logically high when all the MCBs are switched on.
23	Circuit Breaker Gas Pressure Low Alarm (Only for SF6 Breakers)	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
24	Circuit Breaker Gas Pressure Lockout (Only for SF6 Breakers)	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
25	Isolators are in Local Mode (Only for AIS)	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
26	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
27	CB in Local Mode (Only for AIS)	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced. In Gas Insulated Substations additional contacts may be required depending on manufacturers recommendations. And also, some outputs might not be required since in certain case Q1 and Q5 are operated using a single mechanism. Those may be introduced with the approval of the ENGINEER.



Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip
3	Lockout Trip 86	Tripping that initiates the lockout according to the trip matrix
4	Q1 Isolator Close	Close Command to the bus 1 isolator
5	Q1 Isolator Open	Open Command to the bus 1 isolator
6	Q2 Isolator Close	Close Command to the bus 2 isolator
7	Q2 Isolator Open	Open Command to the bus 2 isolator
8	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
9	86 Reset	Contact to reset 86 through NCC/SAS
10	Q5 Earth Switch Close	Close Command to Q5 Earth Switch
11	Q5 Earth Switch Open	Open Command to Q5 Earth Switch
12	Breaker Failure Timer 2 Trip	Trip command to other bays when breaker failure timer 2 has operated.

#### 5.11.4 Protection/Control Functions Required in 11kV/33kV Feeder Protection

Please refer Single line diagram in [Annexure 7](#)

##### 5.11.4.1 Directional/Non-Directional Earth Fault Protection (51N,50N,67N)

The relay shall contain a directional earth fault function operated by the zero sequence current calculated from the phase current transformers inputs. If the current transformers are connected in the “Holmgren” connection and the zero sequence current is available as a measurement that measured current shall be used as the operating quantity.

The directional earth fault protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and inrush currents caused by transformer energization. The function shall be polarized by the zero sequence voltage calculated from the three phase to neutral voltages connected. The user shall have the facility of configuring three directional elements and three non-directional elements at the same time. The directional earth fault function shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time

The user shall have the facility to configure following settings according to his requirement.

- Pickup value of the function
- The desired inverse definite minimum time curve
- Time multiplier setting of the IDMT curve
- Time delay if the selected curve is definite time

- Whether the function is directional or non-directional – Having two different functions for directional and non-directional earth fault is also acceptable and in that case this setting is not required.

Additionally, for the directional earth fault elements following settings shall be available for the user customize according to his need.

- Direction; Forward or Reverse
- Relay characteristic angle
- The sector opening of the forward or reverse direction with respect to the characteristic angle.

#### **5.11.4.2 Directional/Non-Directional, Negative sequence Over Current Protection (51,50,67,46)**

There shall be directional and non-directional over current elements to detect faults in any of the three phases. The over current functions shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time

Additionally there shall be instantaneously operating elements as well. The over current protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and inrush currents caused by reactor energization and shall not respond to DC component.

The user shall have the option of blocking the directional element if voltage transformer fuse failure function has operated or the voltage transformer secondary circuit MCB is tripped. The directional element shall be polarized by healthy phase voltages. There shall be some degree of memory polarization to make sure directional element directionality is secured under close in three phase faults. The user shall have the facility of configuring three directional elements and three non-directional elements at the same time. The function shall have a reset ratio of 95%.

The user shall have the facility to configure following settings according to his requirement.

- Pickup value of the function
- The desired inverse definite minimum time curve
- Time multiplier setting of the IDMT curve
- Time delay if the selected curve is definite time
- Whether the function is directional or non-directional – Having two different functions for directional and non-directional earth fault is also acceptable and in that case this setting is not required.

Additionally, for the directional over current elements following settings shall be available for the user customize according to his need.

- Direction; Forward or Reverse
- Relay characteristic angle
- The sector opening of the forward or reverse direction with respect to the characteristic angle

#### 5.11.4.3 Under Frequency Load Shedding Function (81U and 81R)

Dedicated under frequency and rate of change of frequency load shedding functions shall be available in each bay protection/control IED. There shall be at least five stages that operates based on the frequency and one stage that operates based on the rate of change of frequency. Rate of change frequency stage shall be supervised by a user definable frequency value. User shall have the capability of setting the rate of change of frequency stage in "Freq< AND df/dt" and "Freq< OR df/dt" mode. Rate of change of frequency function shall be capable of discriminating positive and negative change in frequency. All stages shall operate with a definite time delay which shall be settable by the user.

The function shall not mal-operate during transient low voltage conditions. Operating stage selection shall be performed through the Bay Control Unit (BCU) Human Machine Interface (HMI) or the substation automation system user interface Function keys in Control & Protection IED shall be programmed in each 33 and 11 kV Feeder to control load shedding status ON or OFF.

#### 5.11.4.4 Breaker Failure (50BF)

A circuit breaker failure shall be incorporated in protection/control IED in each bay which is initiated by each internal and external tripping commands and supervised by current detectors in each phase. The current detector shall have a very fast reset time in order to achieve an overall reset function of the CBF system in less than 15 ms. They shall be sensitive to detect from 0.1 to 2.0 times the rated feeder current, adjustable in steps of less than or equal to 0.1 times this current. A separate residual current supervision function shall also be available having the same sensitivity.

The breaker failure function shall be initiated by all other protection device tripping commands to the circuit breaker and also by any remote tripping signal, which shall initiate tripping of that breaker. The information of the initiation shall be taken separately from the relays that operate the trip coil 1 and the trip coil 2 via potential free contacts.

If a trip command fails to open the circuit breaker, after a period of delay (called T1 and shall be adjustable between 50 to 300 ms continuously or in steps smaller than 10 ms) the breaker failure relay shall give a "first step" tripping command to both trip coils of the respective circuit breaker.

If the operation of the "first step" of the CBF has no effect, the CBF protection system shall give a different tripping command, after a second period of delay (called T2 and adjustable between 50 to 500 ms continuously or in steps smaller than 10 ms) the tripping shall be routed to all the bays connected to the specific bus section where the breaker failure occurred bay is connected. The wiring/tripping scheme is further explained in chapter 5.8.11.

#### 5.11.4.5 Auto-reclosing Function (79)

A reclosing function with only 3 pole operation shall be available with at least three shots of operation. Auto-reclosing function shall support high speed and delayed auto-reclosing if the relevant conditions (which are discussed below) are met and it is deemed safe to perform a reclosing of the circuit breaker.

Function keys in Control & Protection IED shall be programmed to control Auto Reclosing status ON or OFF. The reclosing function shall supervise the following conditions and incorporate them within the algorithm.

- Circuit breaker “Ready” status – Supervise whether the circuit breaker is ready to perform a reclosing cycle (For an instance of spring operated SF6 circuit breaker; spring is charged and SF6 gas pressure is sufficient)
- The circuit breaker position to supervise whether it was closed prior to the fault inception.
- Supervising voltages at both sides of the breaker for synchronism conditions or voltage check through an internal “Voltage check” function. The voltage check function will be explained in the next chapter.

If any of the supervising conditions are not fulfilled the function will be driven in to lockout mode resulting in a permanent three pole trip.

The user shall be able to select following parameters in relevant to the auto-reclosing function.

- Number of Shots
- Dead time for each shot
- The functions that initiates auto-reclosing
- Reclaim Time

Reclosing function shall be blocked for a user definable time duration after manual closure of the circuit breaker.

#### **5.11.4.6 Synchronism Check Function (25)**

For auto-reclosing and manual closing of the circuit breaker a release signal from synchronism is required to ensure that the feeder is energised only if the two systems on either side the circuit breaker is in synchronism. Refer chapter 5.9.5.2 for further information about the requirements of synchronism check function.

#### **5.11.4.7 Over Frequency, Under Frequency and ROCOF Protection (81O,81U and 81R)**

Dedicated Over Frequency, Under Frequency and ROCOF Protection functions shall be made available in bay protection/control IED as feeder could be connected to embedded generators in the network.

#### **5.11.4.8 Over Voltage and Under Voltage Protection (27 and 59)**

Dedicated Over Voltage and Under Voltage Protection functions shall be made available in bay protection/control IED as feeder could be connected to embedded generators in the network.

#### **5.11.4.9 Fault Locator (21FL)**

The integrated fault locator shall calculate the fault impedance and the distance-to-fault. The following results shall be displayed on LCD display.

- Fault Impedance
- Distance to fault
- Fault Current (Phase and Magnitude)

The results of the fault locator shall also be recorded in relay event list and in station computer.

**5.11.4.10 Basic Power Quality Measurements**

Feeder Protection Relay shall be able to record following Basic Power Quality Measurements. Voltage unbalance; voltage changes: overvoltage, dip, interruption; TDD (Total Demand Distortion), THD (Total Harmonic Distortion), and harmonics.

**5.11.5 Trip Matrix**

	DC1	DC from Bus Section Bay	TC1	TC2	Initiate 50BF	Initiate AR	86	BFP Auxiliary Relay	Trip to Other Bays
			all	all	all				
<b>BCU</b>	X								
51			X	X	X	X			
50			X	X	X	X			
51N			X	X	X	X			
50N			X	X	X	X			
46			X	X	X				
59/27			-	-	-	-			
67			X	X	X	X			
67N			X	X	X	X			
81L			X	X					
81R			X	X					
AR Definitive Trip			X	X	X		X		
50BF Re-trip			X	X	X		X		
50BF Timer 2 Trip									X
External BFP Trip Received from Other Bays								X	
86	X		X	X					
BFP Auxiliary Relay		X	X	X					

There shall be a hand resettable flag relay each energized when any of the following alarms are present.

- Circuit Breaker Spring Uncharged
- Circuit Breaker Gas Pressure Low (Not applicable for vacuum interrupters)
- Circuit Breaker Gas Pressure Lockout (Not applicable for vacuum interrupters)

**5.11.6 Interlocking**

Operation	Operating Location	Switchgear							Other Conditions							
		Q0	Q1	Q2	Q5	Bus Coupler	Bus 1 ES*	Bus 2 ES*	<U	86	74/1	74/2	25	Bus VT MCB Healthy	Line VT MCB Healthy	Hand Crank Not inserted
Q1 Close/Open	Any Location	Open	-	Open	-	-	Open		-	-	-	-	-	-	-	Not Inserted
	Any Location	-	-	Close	-	Close	Open		-	-	-	-	-	-	-	Not Inserted
Q2 Close/Open	Any Location	Open	Open	-	-	-		Open	-	-	-	-	-	-	-	Not Inserted
	Any Location	-	Close	-	-	Close		Open	-	-	-	-	-	-	-	Not Inserted
Q0 Close	Any Location	-	I	I	Open	-	-	-	-	Not Operated	Not Operated	Not Operated	Permit to Close	Healthy	Healthy	Not Inserted
	CRP,LCP	-	I	I	Close	-	-	-	Operated	-	Not Operated	Not Operated	-	-	Healthy	Not Inserted
Q5 Close/Open	CRP,LCP	-	Open	Open	-	-	-	-	Operated	-	-	-	-	-	Healthy	Not Inserted

Shortened Term	Description
LCP	Local Control Panel; Refer Clause 5.8.2.1 and 5.8.2.2
CRP	Protection/Control Panel; Refer Clause 5.8.2.3
SAS	Substation Automation System; Refer Clause 5.8.2.4
NCC	National Control Centre; Refer Clause 5.8.2.5

\* - Only Available in GIS

I - Not Intermediate

Notes:

1. Bus Coupler close signal shall be the series connection of N/O contacts in two isolators and the circuit breaker in the bus coupler bay. Signal will be logically high when the bus coupler bay is closed.
2. <U signal shall be the series connection of three per phase voltage supervision relay contacts installed in the local control panel Signal shall be logically high when the voltage measured in all three phases are less than 10% of the nominal voltage.
3. Synchronism check shall be done according to "Synchronism Check" Work Sheet
4. Bus 1 earth switch status and Bus 2 earth switch status shall be taken to individual bays through a bus wiring from the bus coupler bay. Signal shall be logically high when the earth switches are in open condition.
5. Bus VT MCB Healthy status will depend on the bus isolator closed at the moment of breaker closing. If Q1 is closed bus 1 VT MCB shall be checked and if Q2 is closed bus 2 VT MCB shall be checked. Bus VT MCB status shall be wired from the bus coupler panel as a bus wiring.

## 5.12 TRANSFORMER PROTECTION AND CONTROL (INCLUDING EARTHING & AUXILIARY TRANSFORMERS)

Please refer Single line diagram in [Annexure 2,3 &4](#)

### 5.12.1 General Requirements

Power transformers shall be protected by the usually applied gas- and oil-surge and pressure detectors, oil- and winding-temperature monitoring devices, including the monitoring and protection of the tap changer and/or the cable connection chambers in a similar manner, all as specified in the preceding chapters of this Specification.

Beside these protection systems as built into or mounted on the power transformers, at least the following electrical protection/control functions shall be provided, but shall not be limited to the functions mentioned below.

There are basically two types of transformers in relevant to the scope of this specification.

- Power transformers with two voltage levels

Hereafter within this specification the high voltage winding of a two-winding transformer shall be known as HV winding and the other winding shall be known as LV winding. HV winding can either be at 220kV or 132kV voltage. LV winding can either be at 33kV, 22kV or 11kV levels.

- Power transformers with three voltage levels

Hereafter within this specification winding at the highest voltage shall be known as HV winding. The winding at the lowest voltage would be known as LV winding and the other would be MV winding. Two HV and MV voltage levels may share the same physical winding as a Y connected 3 phase Auto Transformer. But within this specification they may be considered as two separate windings. The LV winding shall be a  $\Delta$  connected tertiary.

### Basic Panel Arrangement

There shall be separate protection/control panels for each voltage level. Additionally to house the contact multiplications relays and input module (to report the alarms to the substation automation system and the gateway) required for the mechanical tripping and alarming signals there shall be a separate panel. Automatic voltage regulators shall also be housed in this panel. If possible, this panel shall be shared by all the available transformers in the substations. In a three-voltage level transformer two automatic voltage regulators might be needed and one panel might not be sufficient to house all the required equipment for each transformer available in the substation. In that scenario there shall be one panel for each transformer bay.

### HV Control and Protection Panel

To provide protection for the system comprises of the main transformer, earthing transformer and the auxiliary transformer and control for the high voltage winding two separate IEDs are required as Main 1 and Main 2 protection with 100% redundancy mounted in the HV protection/control panel. The two IEDs shall consist of all the protection functions mentioned below and they shall provide identical protection schemes inside the relays and tripping logics.

For All Transformers:

- Transformer differential protection
- Restricted earth fault protection for HV side
- Restricted earth fault protection for LV side
- Over excitation protection
- Directional and Non-directional Over current protection for HV side
- Over current protection for HV side

- Non-directional Over current protection for LV side
- Directional and Non-directional Over current protection for HV side
- Residual Earth fault protection for HV side
- Non-directional Residual Earth fault protection for LV side
- Stand by earth fault protection for HV side
- Stand by earth fault protection for LV side
- Over voltage protection
- Under voltage protection
- BCU function for HV side
- Thermal Overload Function (Refer Section 5.9.4.7)
- Monitoring of Lockout relays
- Synchronism check for HV side required only for transformers connecting two transmission voltage levels

#### MV Protection/Control Panel (Only for three voltage level transformer)

There shall be two IEDs with 100% redundancy mounted on the MV protection and control panel providing the following protection/control functions for a three voltage level transformer.

##### Transformer Backup protection

- Directional and Non-directional Over current protection for MV side
- Directional and Non-directional Residual Earth fault protection for MV side
- BCU function for MV side
- Synchronism Check function for the MV side
- Monitoring of Lockout relay

#### LV Side Protection/Control Panel

Except in the cases where the LV winding is unused in a three-voltage level transformer there shall be one IED mounted on the LV control/protection functions for a three winding or two winding transformer providing the following functions.

##### Low Voltage level

- Directional and Non-directional Over current protection for LV side
- Directional and Non-directional Residual Earth fault protection for LV side
- BCU function for LV side
- Synchronism Check function for the LV side
- Monitoring of Lockout relay
- Breaker failure

#### Mechanical Protection and Control Panel

Mechanical protection flag relays, transformer tap changer AVR IED and any associated input modules for Mechanical relays shall be mounted in this panel

To provide the mechanical protection tripping and alarms there shall be hand reset flag type contact multiplication relays for each signal to initiate tripping, alarming and lockout functions. In order to send the mechanical protection alarms and tripping operations to the substation automation system there shall be an input module which can communicate with the Substation Automation System(SAS) via IEC 61850.

For a transformer comprising of three single phase transformer banks (three voltage level) there shall be flag type relays for mechanical tripping and alarms for each phase The required number of inputs depends on the number of mechanical tripping and alarms to be recorded.



To regulate the voltage and control the on-load tap changer there shall be an automatic voltage regulator relay. For a transformer with two on load tap changers there shall be two AVR relays. Further information regarding the AVR relay is available in chapter 5.24. For transformer protection applications there shall be one additional panel to house flag type mechanical tripping and alarming relays, AVR relay/relays and input module to report alarms to the SAS.

## **5.12.2 HV/LV Two Winding Transformer Protection and Control (220kV/33kV, 132kV/33kV, 220kV/11kV and 132kV/11kV)**

### **5.12.2.1 HV Side Protection IED**

#### **5.12.2.1.1 General Requirements**

Please refer chapter 5.7 for specifications for the IEDs. It has been discussed in chapter 5.7.1 that hardware requirements of the IED shall change depending on its application. The hardware requirement for HV side of HV/LV two winding transformer protection applications are discussed within this chapter. Refer [Annexure 2](#) for Single line diagram

#### **5.12.2.1.2 Analog Circuits**

##### **Current Circuits**

##### **HV Side Current Channels**

HV side transformer bay current transformer secondaries shall be connected in “Holmgren” connection and connected to the first three analog inputs of the IED.

Current transformer protection core which is located closest to the circuit breaker (Busbar side) shall be connected to the Main 1 IED and the next line protection core shall be connected to the Main 2 IED. Core connected to Main 1 IED shall not be used for any other device in the substation. Disturbance recorder shall share the same core with the Main 2 IED and the circuit shall be arranged in a such a way that it first comes in to the Main 2 IED and terminated in the disturbance recorder panel. Current transformer circuit earthing in both cores shall be done at the relay panel.

HV side neutral current transformer protection core located towards the earthing side shall be connected directly to the Main 1 IED. The other core shall be shared between the Main 2 IED and disturbance recorder panel if available. Earthing of secondary circuit of both cores shall be done at the HV protection/control panel.

##### **LV Side Current Channels**

LV side current transformer secondaries shall be connected in Holmgren connection and transformer protection core that is placed towards the LV busbar side with respect to other cores shall be connected to Main 1 IED at the HV control/protection panel. The other protection core shall be shared among the control/protection IED at the LV protection/control panel, automatic voltage regulator panel, HV protection/control panel and disturbance recorder panel if available. Only “Y” phase shall be connected to the AVR relay. Earthing of all the secondary circuits of phase current transformers shall be done at the LV protection/control panel.

LV side neutral current transformer core located towards the grounded side shall be directly connected to the Main 1 IED. The other core shall be shared by the disturbance recorder panel and the Main 2 IED. The secondary circuit shall be terminated at the disturbance recorder panel and earthed at the HV protection/control panel.

Current channel allocation of Main 1 and Main 2 IEDs shall be as follows.

Channel 1	HV R Phase Current
Channel 2	HV Y Phase Current
Channel 3	HV B Phase Current
Channel 4	HV Neutral CT
Channel 5	LV R Phase Current
Channel 6	LV Y Phase Current
Channel 7	LV B Phase Current
Channel 8	LV Neutral CT

### Voltage Circuits

Core 1 of LV side voltage transformers shall be connected in star configuration and connected to Main 1 relay and Core 2 shall be shared between LV protection/control IED, AVR relay, disturbance recorder and the Main 2 IED in HV protection/control panel. Hence both Main 1 and Main 2 IEDs shall be equipped with four voltage channels.

Channel 9	R Phase Voltage
Channel 10	Y Phase Voltage
Channel 11	B Phase Voltage
Channel 12	

### 5.12.2.1.3 Binary Circuits

#### Binary Inputs

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced. The binary input requirement will increase for gas insulated substations and they are separately listed below.

Index	Binary Inputs	Remarks
	<b>Control and Interlocking</b>	
1	Bus 1 isolator Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Bus 1 Isolator Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Circuit Breaker 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
4	Circuit Breaker 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
5	Control in Mimic	Mimic status of the selector switch mounted on the relay panel
6	Control in Main 1	Main 1 status of the selector switch mounted on the relay panel. In the case of Main 2 IED Main 2 status of the selector switch shall be provided.
7	Lockout Relay 1 Operated	N/C contact from the lockout relay 1. In the case of Main 2 IED N/C contact from lockout relay 2 shall be provided.
8	Busbar Lockout Relay Operated	N/C contact from the busbar lockout relay

9	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high. In the case of Main 2 IED a contact from trip circuit 2 supervision relay shall be provided.
10	LV Bus 1 Isolator Opened	A direct contact from the LV side bus isolator.
11	LV Bus 2 Isolator Opened	Only applicable if LV side is in double busbar arrangement. A direct contact from the LV side bus 2 isolator.
12	LV Earth Switch Open (Only for LV GIS)	A direct contact from LV side earth switch.
13	Line VT MCB Healthy	Direct Contact from Live VT MCB auxiliary contact.
14	Bus 1 VT MCB Healthy	From Bus 1 VT MCB auxiliary contact.
<b>For a Double Busbar Station</b>		
15	Bus 2 VT MCB Healthy	From Bus 2 VT MCB auxiliary contact.
16	Bus Coupler Closed	Bus coupler closed signal from the bus coupler bay. A series connection of auxiliary contacts from the bus coupler circuit breaker and two isolators. This shall be taken through an auxiliary relay.
17	Bus 2 isolator Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts. Only for double busbar stations.
18	Bus 2 Isolator Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts. Only for double busbar stations.
<b>For GIS Applications</b>		
19	Line Isolator Opened	Line isolator opened status directly from the isolator auxiliary contacts
20	Line Isolator Closed	Line isolator closed status directly from the isolator auxiliary contacts
21	Line Earth Switch Closed	Line earth switch closed status directly from the earth switch auxiliary contacts
22	Line Earth Switch Opened	Line earth switch opened status directly from the earth switch auxiliary contacts
23	Q51 Earth Switch Closed	Q51 earth switch closed status directly from the earth switch auxiliary contacts
24	Q51 Earth Switch Opened	Q51 earth switch opened status directly from the earth switch auxiliary contacts
25	Q52 Earth Switch Closed	Q52 earth switch closed status directly from the earth switch auxiliary contacts. Only for double busbar stations.
26	Q52 Earth Switch Opened	Q52 earth switch opened status directly from the earth switch auxiliary contacts. Only for double busbar stations.
27	Q8 Earth Switch Closed	Q8 earth switch closed status directly from the earth switch auxiliary contacts
28	Q8 Earth Switch Opened	Q8 earth switch opened status directly from the earth switch auxiliary contacts
29	Hand Crank Not Inserted	Hand crank not inserted in any of the switchgear.
30	Bus 1 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 1 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
31	Bus 2 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 2 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.

32	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Alarms</b>		
33	Relay Panel DC/AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
34	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
35	Circuit Breaker Gas Pressure Low Alarm	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
36	Circuit Breaker Gas Pressure Lockout	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
37	Isolators are in Local Mode	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
38	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
39	CB in Local Mode	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
40	Main 1/Main 2 Relay Healthy	This input shall be logically high when Main 2 (Input to Main 1) IED is operating without any internal failure.
41	Busbar Bay Unit Healthy	This input shall be logically high when busbar bay unit IED is operating without any internal failure.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Signal	Remarks
1	General Trip 220kV or 132kV TC1	General Trip including all electrical protection trips except 33kV or 11kV over current and earth fault trips.
2	General Trip 220kV or 132kV TC2	General Trip including all electrical protection trips except 33kV or 11kV over current and earth fault trips.
3	Lockout Trip 220kV or 132kV 86/1	General Trip including all electrical protection trips except 33kV or 11kV over current and earth fault trips.
4	Lockout Trip 220kV or 132kV 86/2	General Trip including all electrical protection trips except 33kV or 11kV over current and earth fault trips.
5	General Trip 33kV or 11kV TC1	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.
6	General Trip 33kV or 11kV TC2	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.
7	Lockout Trip 33kV or 11kV 86/1	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.

8	Lockout Trip 33kV or 11kV 86/2	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.
<b>Controls</b>		
9	Q1 Close	Close Command to the bus 1 isolator
10	Q1 Open	Open Command to the bus 1 isolator
11	Q2 Close	Close Command to the bus 2 isolator
12	Q2 Open	Open Command to the bus 2 isolator
13	86/1 Reset	Contact to reset 86/1 through NCC/SAS
14	86/2 Reset	Contact to reset 86/2 through NCC/SAS
15	Q0 Close	Close Command to the Circuit Breaker
<b>DDR Signals</b>		
16	Differential Protection Operated	Transformer differential trip to trigger/record in the disturbance recorder
17	220kV or 132kV REF Operated	Transformer 220kV or 132kVREF trip to trigger/record in the disturbance recorder
18	33kV or 11kV REF Operated	Transformer 33kV or 11kV REF trip to trigger/record in the disturbance recorder
19	220kV or 132kV OC/EF Operated	Transformer 220kV or 132kV over current and earth fault trip to trigger/record in the disturbance recorder
20	33kV or 11kV OC/EF Operated	Transformer 33kV or 11kV over current and earth fault trip to trigger/record in the disturbance recorder
21	Over Fluxing Protection Operated	Transformer over fluxing trip to trigger/record in the disturbance recorder
22	Over Voltage Protection Operated	Transformer over voltage trip to trigger/record in the disturbance recorder
23	Thermal Overload Operated	Transformer thermal overload trip to trigger/record in the disturbance recorder

### 5.12.2.2 LV Side Protection IED

#### 5.12.2.2.1 General Requirements

Please refer chapter 5.7 for specifications for the IEDs. It has been discussed in chapter 5.7.1 that hardware requirements of the IED shall change depending on it's application. The hardware requirement for LV side of HV/LV two winding transformer protection applications are discussed within this chapter. Refer [Annexure 2](#) for Single line diagram

#### 5.12.2.2.2 Analog Circuits

##### Current Circuits

LV side current transformer secondaries shall be connected in Holmgren connection and transformer protection core that is placed towards the LV busbar side with respect to other cores shall be connected to Main 1 IED at the HV control/protection panel. The other protection core shall be shared among the control/protection IED at the LV protection/control panel, automatic voltage regulator panel, HV protection/control panel and disturbance recorder panel if available. Only “Y” phase shall be connected to the AVR relay. Earthing of all the secondary circuits of phase current transformers shall be done at the LV protection/control panel.

Current channel allocation shall be as follows.

Channel 1	LV R Phase Current
Channel 2	LV Y Phase Current
Channel 3	LV B Phase Current
Channel 4	Summation of LV side RYB phase currents

### Voltage Circuits

Core 1 of LV side voltage transformers shall be connected in star configuration and connected to Main 1 relay and Core 2 shall be shared between LV protection/control IED, AVR relay, disturbance recorder and the Main 2 IED in HV protection/control panel.

LV IED shall be equipped with five voltage channels. Line voltage transformers shall be connected in star configuration and connected to the first three inputs of the relay. Busbar voltage between R and Y phases shall be connected to the fourth input. If the substation is a double busbar station, busbar 2 voltage between R and Y phases shall be connected to the fifth voltage input. Voltage transformer secondary circuit shall be protected by a 3-pole MCB located in the protection/control panel and 2-pole MCB located in respective phase voltage transformer secondary terminal boxes.

Channel 7	R Phase Voltage
Channel 8	Y Phase Voltage
Channel 9	B Phase Voltage
Channel 10	R-Y Busbar Voltage-BB1
Channel 11	R-Y Busbar Voltage-BB2

### 5.12.2.2.3 Binary Circuits

#### Binary Inputs

The binary inputs mentioned in the table shall be implemented. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Binary Inputs	Remarks
	Control and Interlocking	
1	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts
4	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts
5	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
6	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
7	Lockout Relay Operated	N/C contact from the lockout relay. (Series contact of 86-1 & 86-2)
8	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.

9	Trip Circuit 2 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.
10	Breaker Failure Inter trip	Breaker failure trip received from a bay connected to the same bus section at LV side.
11	Breaker Failure Initiation from HV Side	Signal received from HV side to initiate LV breaker failure function.
12	HV Side Q1 Open	HV side Bus 1 isolator opened status directly from the isolator auxiliary contacts
13	HV Side Q2 Open	HV side Bus 2 isolator opened status directly from the isolator auxiliary contacts
14	HV Side Q0 Close	HV side circuit breaker closed status directly from the circuit breaker auxiliary contacts
15	HV Side Q51 Open (Only if HV side is GIS)	HV side Q51 earth switch opened status directly from the earth switch auxiliary contacts
16	HV Side Q52 Open (Only if HV side is GIS)	HV side Q52 earth switch opened status directly from the earth switch auxiliary contacts
17	HV Side Q8 Open (Only if HV side is GIS)	HV side Q8 earth switch opened status directly from the earth switch auxiliary contacts
<b>For GIS Applications</b>		
18	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
19	Bus 1 Earth Switch Opened	Bus 1 earth switch opened status directly from the earth switch.
20	Bus 2 Earth Switch Opened	Bus 2 earth switch opened status directly from the earth switch.
21	Q5 Earth Switch Opened	Q5 earth switch opened status directly from the isolator auxiliary contacts
22	Q5 Earth Switch Closed	Q5 earth switch closed status directly from the isolator auxiliary contacts
23	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Synchronism Check</b>		
24	Bus 1 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
25	Bus 2 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
26	Line VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
<b>Alarming</b>		
27	Gas Pressure OK in CB Cubicle	Direct contact from the pressure gauge installed in the circuit breaker chamber. Signal shall be logically high when the gas pressure is healthy.
28	Gas Pressure OK in Busbar Cubicle	Direct contact from the pressure gauge installed in the circuit busbar chamber. Signal shall be logically high when the gas pressure is healthy.

29	Relay Panel DC or AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
30	Marshalling Kiosk DC/AC MCB Fail (Only for AIS)	A series connection of the auxiliary contacts in the DC and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
31	Circuit Breaker Gas Pressure Low Alarm (Only for SF6 Breakers)	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
32	Circuit Breaker Gas Pressure Lockout (Only for SF6 Breakers)	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
33	Isolators are in Local Mode (Only for AIS)	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
34	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
35	CB in Local Mode (Only for AIS)	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
36	Mechanical Protection Trip	Output from each mechanical protection flag relay shall be connected in parallel and wired to this inout.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced. In Gas Insulated Substations additional contacts may be required depending on manufacturers recommendations. And also, some outputs might not be required since in certain case Q1 and Q5 are operated using a single mechanism. Those may be introduced with the approval of the ENGINEER.

Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip
3	Lockout Trip 86_1	Tripping that initiates the lockout according to the trip matrix
4	Lockout Trip 86 2	Tripping that initiates the lockout according to the trip matrix
5	Trip to HV side TC1	DEF and DOC trip HV side
6	Trip to HV side TC2	DEF and DOC trip HV side
7	Trip to HV side 86/1	DEF and DOC trip HV side
8	Trip to HV side 86/2	DEF and DOC trip HV side



9	Breaker failure initiation to HV side	DEF and DOC trip HV side to initiate breaker failure
10	Q1 Isolator Close	Close Command to the bus 1 isolator
11	Q1 Isolator Open	Open Command to the bus 1 isolator
12	Q2 Isolator Close	Close Command to the bus 2 isolator
13	Q2 Isolator Open	Open Command to the bus 2 isolator
14	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
15	86/1 Reset	Contact to reset 86/1 through NCC/SAS
16	Q5 Earth Switch Close	Close Command to Q5 Earth Switch
17	Q5 Earth Switch Open	Open Command to Q5 Earth Switch
18	Breaker Failure Timer 2 Trip	Trip command to other bays when breaker failure timer 2 has operated.
19	86/2 Reset	Contact to reset 86/2 through NCC/SAS

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**5.12.2.3 Trip Matrix- HV/LV 2Wdg Transformer**

Relay	Protection Function	ANSI No	DC	HV CB					LV CB					
				TC1	TC2	861	862	Start CBF (50BF)	TC1	TC2	861	862	Start CBF (50BF)	
Main 1			1											
	Transformer Differential	87T		x	x	x	x	x	x	x	x	x	x	x
	Restricted Earth fault (HV)	87NH		x	x	x	x	x	x	x	x	x	x	x
	Restricted Earth fault (LV)	87NL		x	x	x	x	x	x	x	x	x	x	x
	Over Excitation (V/f)	24		x	x	x	x	x	x	x	x	x	x	x
	HV Phase Over Current	50/51 HV		x	x	x	x	x	x	x	x	x	x	x
	HV Residual Earth fault	51N/ 50N HV		x	x	x	x	x	x	x	x	x	x	-
	LV Phase Over Current	50/51 LV							x	x	x	x	x	x
	LV Residual Earth Fault	50N/ 51N LV							x	x	x	x	x	x
	LV Stand by Earth fault	51G-LV		x	x	x	x	x	x	x	x	x	x	x
	Over Voltage	59		x	x	x	x	x	x	x	x	x	x	x
	Thermal Overload	49		x	x	x	x	x	x	x	x	x	x	x
Main 2			2											
	Transformer Differential	87T		x	x	x	x	x	x	x	x	x	x	x
	Restricted Earth fault (HV)	87NH		x	x	x	x	x	x	x	x	x	x	x
	Restricted Earth fault (LV)	87NL		x	x	x	x	x	x	x	x	x	x	x
	Over Excitation (V/f)	24		x	x	x	x	x	x	x	x	x	x	x
	HV Phase Over Current	50/51 HV		x	x	x	x	x	x	x	x	x	x	x
	HV Residual Earth fault	51N/ 50N HV		x	x	x	x	x	x	x	x	x	x	x
	LV Phase Over Current	50/51 LV							x	x	x	x	x	x
	LV Residual Earth fault	50N/51N LV							x	x	x	x	x	x
	LV Stand by Earth fault	51G-LV		x	x	x	x	x	x	x	x	x	x	x
	Over Voltage	59		x	x	x	x	x	x	x	x	x	x	x
	Thermal Overload	49		x	x	x	x	x	x	x	x	x	x	x
LV			3											
	LV Over Current	51/ 50 LV							x	x	x	x	x	x
	LV Residual Earth fault	51N/ 50N LV							x	x	x	x	x	x
	Directional Over Current	67 LV		x	x	x	x	x	x	x	x	x	x	x
	Directional Earth fault	67N LV		x	x	x	x	x	x	x	x	x	x	x
HV-86-1	Operated		1	x	x			x						
HV-86-2	Operated		2	x	x			x						
LV-86-1	Operated		3						x	x				x
LV-86-2	Operated		3						x	x				x
HV-86BB	Operated		4	x	x								x	
Mechanical	Mechanical Trips (Flag relay)		5			x	x							

**5.12. 2.4 Interlocks for HV/LV Two Winding Transformer Bays**

All the conditions discussed in chapter 5.8.4 shall be included in the interlocking logic.

Operation	Operating Location	Switchgear											Other Conditions						
		HQ0	HQ1	HQ2	LQ1	LQ5	LQ0	HQ8	HQ51*	HQ52*	Bus Coupler	Bus 1 ES*	Bus 2 ES*	86/1	86/2	86BB(96)	74/1	74/2	25
<b>High Voltage Side</b>																			
HQ1 Close/Open	Any Location	Open	-	Open	-	Open	-	Open	Open	Open	-	Open	-	-	-	-	-	-	-
	Any Location	-	-	Close	-	Open	-	Open	Open	Open	Close	Open	-	-	-	-	-	-	-
HQ2 Close/Open	Any Location	Open	Open	-	-	Open	-	Open	Open	Open	-	-	Open	-	-	-	-	-	-
	Any Location	-	Close	-	-	Open	-	Open	Open	Open	Close	-	Open	-	-	-	-	-	-
HQ0 Close	CRP,SAS,NCC	-	I	I	Open	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	-
	Local Control Panel	-	Open	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-
HQ51,HQ52,HQ8	Local Control Panel	-	Open	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Low Voltage Side (GIS with a single busbar)</b>																			
LQ1 Close/Open	Any Location	-	-	-	-	Open	Open	Open	Open	Open	-	-	-	-	-	-	-	-	-
LQ5 Close/Open	Any Location	-	Open	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-
LQ0	Local Control Panel	-	Open	Open	Open	I	-	-	-	-	-	-	-	-	-	-	-	-	-
	CRP,SAS,NCC	Close	-	-	I	-	-	-	-	-	-	-	-	Not Operated	Not Operated	-	Not Operated	Not Operated	Synch OK

\* - Only Available in GIS  
I - Not Intermediate

Shortened Term	Description
LCP	Local Control Panel; Refer Clause 5.8.2.1 and 5.8.2.2
CRP	Protection/Control Panel; Refer Clause 5.8.2.3
SAS	Substation Automation System; Refer Clause 5.8.2.4
NCC	National Control Center; Refer Clause 5.8.2.5

**Notes:-**

1. Bus Coupler close signal shall be the series connection of N/O contacts in two isolators and the circuit breaker in the bus coupler bay. Signal will be logically high when the bus coupler bay is closed.
2. <U signal shall be the series connection of three per phase voltage supervision relay contacts installed in the local control panel Signal shall be logically high when the voltage measured in all three phases are less than 10% of the nominal voltage.
3. Synchronism check shall be done according to the chapter 5.9.6.2.
4. Bus 1 earth switch status and Bus 2 earth switch status shall be taken to individual bays through a bus wiring from the bus coupler bay. Signal shall be logically high when the earth switches are in open condition.

### 5.12.3 HV/MV/LV Three Voltage Level Transformer (220kV/132kV/33kV)

#### 5.12.3.1 HV side Protection

##### 5.12.3.1.1 General Circuit Requirements

Please refer chapter 5.7 for specifications for the IEDs. It was discussed in chapter 5.7.1 hardware requirements of the IED shall change depending on its application. The hardware requirement for HV side of HV/MV/LV three winding transformer protection applications are discussed within this chapter. Refer [Annexure 4](#) for Single Line Diagram.

##### 5.12.3.1.2 Analog Circuits

###### Current Circuits

Current transformer protection core (transformer protection) at 220kV, 132kV and 33kV levels which is located closest to the circuit breaker (Busbar side) shall be connected to the Main 1 IED and the next transformer protection core at 220kV, 132kV and 33kV levels shall be connected to the Main 2 IED of 220kV protection/control panel. Cores at 220kV and 33kV levels connected to Main 1 IED shall not be used for any other device in the substation. Main 1 IED at 132kV shall share current transformer core at 132kV level with 220kV Main 1 IED. Disturbance recorder shall share the same cores at 220kV, 132kV and 33kV levels with the Main 2 IED at the 220kV protection/control panel. In neutral current transformer at 132kV and 33kV level the protection core located towards the earthed side of the neutral CT shall be connected to Main 1 IED and the other core shall be connected to the Main 2 IED. Current transformer circuit earthing in both cores shall be done at the protection/control panel where the current transformer circuit enters first.

Current transformer inputs in each relay shall be wired and configured as shown below.

Current Channel	220kV Main1/2
1	HV side R phase
2	HV side Y phase
3	HV side B phase
4	MV side R phase
5	MV side Y phase
6	MV side B phase
7	LV side R phase
8	LV side Y phase
9	LV side B phase
10	MV side NCT
11	LV side NCT

###### Voltage Channels

Transformer HV side voltage transformers shall be connected in star configuration and connected to the first three inputs of the relay. HV Busbar voltage between R and Y phases shall be connected to the fourth input. If the substation is a double busbar station, busbar 2 voltage between R and Y phases shall be connected to the fifth voltage input. Voltage transformer secondary circuit shall be protected by a 3-pole MCB located in the marshalling kiosk and 2-pole MCB located in respective phase voltage transformer secondary terminal boxes. Main 1 and Main 2 IEDs shall be connected to two different cores.

Channel 12	HV R Phase Voltage
------------	--------------------

Channel 13	HV Y Phase Voltage
Channel 14	HV B Phase Voltage
Channel 15	R-Y Busbar Voltage-BB1
Channel 16	R-Y Busbar Voltage-BB2

### 5.12.3.1.3 Binary Circuits

#### Binary Input Circuits

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced. The binary input requirement will increase for gas insulated substations and they are separately listed below. In single phase transformer banks mechanical protection trippings and alarms will be available per phase. Same trip alarms in all three transformers shall be paralleled and wired in to single input in Main 1 and Main 2 IED.

Index	Binary Inputs	Remarks
<b>Control and Interlocking</b>		
1	Bus 1 isolator Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Bus 1 Isolator Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Circuit Breaker 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
4	Circuit Breaker 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
5	Control in Mimic	Mimic status of the selector switch mounted on the relay panel
6	Control in Main 1	Main 1 status of the selector switch mounted on the relay panel. In the case of Main 2 IED Main 2 status of the selector switch shall be provided.
7	Lockout Relay 1 Operated	N/C contact from the lockout relay 1. In the case of Main 2 IED N/C contact from lockout relay 2 shall be provided.
8	Busbar Lockout Relay Operated	N/C contact from the busbar lockout relay
9	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high. In the case of Main 2 IED a contact from trip circuit 2 supervision relay shall be provided.
10	LV Bus 1 Isolator Opened	A direct contact from the LV side bus isolator.
11	LV Bus 2 Isolator Opened	Only applicable if LV side is in double busbar arrangement. A direct contact from the LV side bus 2 isolator.
12	MV Bus 1 Isolator Opened	A direct contact from the MV side bus isolator.
13	MV Bus 2 Isolator Opened	Only applicable if MV side is in double busbar arrangement. A direct contact from the MV side bus 2 isolator.

14	LV Earth Switch Open (Only for LV GIS)	A direct contact from LV side earth switch.
15	MV Side Q51 Open (Only if MV side is GIS)	MV side Q51 earth switch opened status directly from the earth switch auxiliary contacts
16	MV Side Q52 Open (Only if MV side is GIS)	MV side Q52 earth switch opened status directly from the earth switch auxiliary contacts
17	MV Side Q8 Open (Only if MV side is GIS)	MV side Q8 earth switch opened status directly from the earth switch auxiliary contacts
18	Line VT MCB Healthy	Direct Contact from Line VT MCB auxiliary contact.
19	Bus 1 VT MCB Healthy	From Bus 1 VT MCB auxiliary contact.
<b>For a Double Busbar Station</b>		
20	Bus 2 VT MCB Healthy	From Bus 2 VT MCB auxiliary contact.
21	Bus Coupler Closed	Bus coupler closed signal from the bus coupler bay. A series connection of auxiliary contacts from the bus coupler circuit breaker and two isolators. This shall be taken through an auxiliary relay.
22	Bus 2 isolator Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts. Only for double busbar stations.
23	Bus 2 Isolator Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts. Only for double busbar stations.
<b>For GIS Applications</b>		
24	Line Isolator Opened	Line isolator opened status directly from the isolator auxiliary contacts
25	Line Isolator Closed	Line isolator closed status directly from the isolator auxiliary contacts
26	Line Earth Switch Closed	Line earth switch closed status directly from the earth switch auxiliary contacts
27	Line Earth Switch Opened	Line earth switch opened status directly from the earth switch auxiliary contacts
28	Q51 Earth Switch Closed	Q51 earth switch closed status directly from the earth switch auxiliary contacts
29	Q51 Earth Switch Opened	Q51 earth switch opened status directly from the earth switch auxiliary contacts
30	Q52 Earth Switch Closed	Q52 earth switch closed status directly from the earth switch auxiliary contacts. Only for double busbar stations.
31	Q52 Earth Switch Opened	Q52 earth switch opened status directly from the earth switch auxiliary contacts. Only for double busbar stations.
32	Q8 Earth Switch Closed	Q8 earth switch closed status directly from the earth switch auxiliary contacts
33	Q8 Earth Switch Opened	Q8 earth switch opened status directly from the earth switch auxiliary contacts
34	Hand Crank Not Inserted	Hand crank not inserted in any of the switchgear.
35	Bus 1 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 1 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
36	Bus 2 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 2 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.

37	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Alarms</b>		
38	Relay Panel DC/AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
39	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in MK. Signal shall be logically high when all the MCBs are switched on.
40	Circuit Breaker Gas Pressure Low Alarm	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
41	Circuit Breaker Gas Pressure Lockout	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
42	Isolators are in Local Mode	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
43	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
44	CB in Local Mode	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
45	Synchroscope Plugged In	This signal is taken through the syncrocheck console once it is plugged in.
46	Main 1/Main 2 Relay Healthy	This input shall be logically high when Main 2 (Input to Main 1) IED is operating without any internal failure.
47	Busbar Bay Unit Healthy	This input shall be logically high when busbar bay unit IED is operating without any internal failure.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Signal	Remarks
1	General Trip HV CB TC1	General Trip including all electrical protection trips except MV, LV over current and earth fault trips.
2	General Trip HV CB TC2	General Trip including all electrical protection trips except MV, LV over current and earth fault trips.
3	Lockout Trip HV 86/1/2	General Trip including all electrical protection trips except MV, LV over current and earth fault trips. Main 1 shall trip Lockout 1 and Main 2 Lockout 2.
4	General Trip MV CB TC1	General Trip including all electrical protection trips except LV over current and earth fault trips.
5	General Trip MV CB TC2	General Trip including all electrical protection trips except LV over current and earth fault trips.

6	Lockout Trip MV 86/1/2	General Trip including all electrical protection trips except LV over current and earth fault trips. Main 1 shall trip Lockout 1 and Main 2 Lockout 2.
7	General Trip LV CB TC1	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.
8	General Trip LV CB TC2	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.
9	Lockout Trip LV 86	General Trip including all electrical protection trips and mechanical trips that is taken as input to the relay.
<b>Controls</b>		
10	Q1 Close	Close Command to the bus 1 isolator
11	Q1 Open	Open Command to the bus 1 isolator
12	Q2 Close	Close Command to the bus 2 isolator
13	Q2 Open	Open Command to the bus 2 isolator
14	Q0 Close	Close Command to the Circuit Breaker
15	86/1 Reset	Contact to reset 86/1 through NCC/SAS
16	86/2 Reset	Contact to reset 86/2 through NCC/SAS
<b>DDR Signals</b>		
17	Differential Protection Operated	Transformer differential trip to trigger/record in the disturbance recorder
18	HV/MV REF Operated	Transformer HV/MV REF trip to trigger/record in the disturbance recorder
19	LV REF Operated	Transformer LV REF trip to trigger/record in the disturbance recorder
20	HV OC/EF Operated	Transformer HV over current and earth fault trip to trigger/record in the disturbance recorder
21	MV OC/EF Operated	Transformer MV over current and earth fault trip to trigger/record in the disturbance recorder
22	LV OC/EF Operated	Transformer LV over current and earth fault trip to trigger/record in the disturbance recorder
23	Over Fluxing Protection Operated	Transformer over fluxing trip to trigger/record in the disturbance recorder
24	Thermal Overload Protection Operated	Transformer thermal overload trip to trigger/record in the disturbance recorder
25	Over Voltage Protection Operated	Transformer over voltage trip to trigger/record in the disturbance recorder

### 5.12.3.2 MV side Protection

#### 5.12.3.2.1 General Circuit Requirements

Please refer chapter 5.7 for specifications for the IEDs. It was discussed in chapter 5.7.1 hardware requirements of the IED shall change depending on its application. The hardware requirement MV side of a HV/MV/LV three winding transformer protection applications are discussed within this chapter. Refer [Annexure 4](#) for Single Line Diagram.



### 5.12.3.2.2 Analog Circuits

#### Current Circuits

Current transformer protection core (transformer protection) at HV, MV and LV levels which is located closest to the circuit breaker (Busbar side) shall be connected to the Main 1 IED and the next transformer protection core at HV, MV and LV levels shall be connected to the Main 2 IED of HV protection/control panel. Cores at HV and LV levels connected to Main 1 IED shall not be used for any other device in the substation. Main 1 IED at 132kV shall share current transformer core at MV level with HV Main 1 IED. Disturbance recorder shall share the same cores at HV, MV and LV levels with the Main 2 IED at the HV protection/control panel. In neutral current transformer at MV and LV level the protection core located towards the earthed side of the neutral CT shall be connected to Main 1 IED and the other core shall be connected to the Main 2 IED. Current transformer circuit earthing in both cores shall be done at the protection/control panel where the current transformer circuit enters first. Current transformer inputs in each relay shall be wired and configured as shown below.

Current Channel	MV Main 1/2
1	MV side R phase
2	MV side Y phase
3	MV side B phase
4	Current summation of R,Y,B

#### Voltage Channels

Transformer MV side voltage transformers shall be connected in star configuration and connected to the first three inputs of the relay. MV Busbar voltage between R and Y phases shall be connected to the fourth input. If the substation is a double busbar station, busbar 2 voltage between R and Y phases shall be connected to the fifth voltage input. Voltage transformer secondary circuit shall be protected by a 3-pole MCB located in the marshalling kiosk and 2-pole MCB located in respective phase voltage transformer secondary terminal boxes. Main 1 and Main 2 IEDs shall be connected to two different cores.

Channel 5	MV R-E Voltage
Channel 6	MV Y-E Voltage
Channel 7	MV B-E Voltage
Channel 8	Busbar 1 R-Y Voltage
Channel 9	Busbar 2 R-Y Voltage

### 5.12.3.2.3 Binary Circuits

#### Binary Input Circuits

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Binary Inputs	Remarks
	Control and Interlocking	

1	Bus 1 isolator Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Bus 1 Isolator Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Circuit Breaker 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
4	Circuit Breaker 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
5	Control in Mimic	Mimic status of the selector switch mounted on the relay panel
6	Control in Main 1	Main 1 status of the selector switch mounted on the relay panel. In the case of Main 2 IED Main 2 status of the selector switch shall be provided.
7	Lockout Relay 1 Operated	N/C contact from the lockout relay 1. In the case of Main 2 IED N/C contact from lockout relay 2 shall be provided.
8	Busbar Lockout Relay Operated	N/C contact from the busbar lockout relay
9	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high. In the case of Main 2 IED a contact from trip circuit 2 supervision relay shall be provided.
10	LV Bus 1 Isolator Opened	A direct contact from the LV side bus isolator.
11	LV Bus 2 Isolator Opened	Only applicable if LV side is in double busbar arrangement. A direct contact from the LV side bus 2 isolator.
12	HV Bus 1 Isolator Opened	A direct contact from the HV side bus isolator.
13	HV Bus 2 Isolator Opened	Only applicable if HV side is in double busbar arrangement. A direct contact from the HV side bus 2 isolator.
14	LV Earth Switch Open (Only for LV GIS)	A direct contact from LV side earth switch.
15	HV Side Q51 Open (Only if MV side is GIS)	HV side Q51 earth switch opened status directly from the earth switch auxiliary contacts
16	HV Side Q52 Open (Only if MV side is GIS)	HV side Q52 earth switch opened status directly from the earth switch auxiliary contacts
17	HV Side Q8 Open (Only if MV side is GIS)	HV side Q8 earth switch opened status directly from the earth switch auxiliary contacts
18	Line VT MCB Healthy	Direct Contact from Live VT MCB auxiliary contact.
19	Bus 1 VT MCB Healthy	From Bus 1 VT MCB auxiliary contact.
<b>For a Double Busbar Station</b>		
20	Bus 2 VT MCB Healthy	From Bus 2 VT MCB auxiliary contact.
21	Bus Coupler Closed	Bus coupler closed signal from the bus coupler bay. A series connection of auxiliary contacts from the bus coupler circuit breaker and two isolators. This shall be taken through an auxiliary relay.
22	Bus 2 isolator Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts. Only for double busbar stations.
23	Bus 2 Isolator Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts. Only for double busbar stations.
<b>For GIS Applications</b>		
24	Line Isolator Opened	Line isolator opened status directly from the isolator auxiliary contacts

25	Line Isolator Closed	Line isolator closed status directly from the isolator auxiliary contacts
26	Line Earth Switch Closed	Line earth switch closed status directly from the earth switch auxiliary contacts
27	Line Earth Switch Opened	Line earth switch opened status directly from the earth switch auxiliary contacts
28	Q51 Earth Switch Closed	Q51 earth switch closed status directly from the earth switch auxiliary contacts
29	Q51 Earth Switch Opened	Q51 earth switch opened status directly from the earth switch auxiliary contacts
30	Q52 Earth Switch Closed	Q52 earth switch closed status directly from the earth switch auxiliary contacts. Only for double busbar stations.
31	Q52 Earth Switch Opened	Q52 earth switch opened status directly from the earth switch auxiliary contacts. Only for double busbar stations.
32	Q8 Earth Switch Closed	Q8 earth switch closed status directly from the earth switch auxiliary contacts
33	Q8 Earth Switch Opened	Q8 earth switch opened status directly from the earth switch auxiliary contacts
34	Hand Crank Not Inserted	Hand crank not inserted in any of the switchgear.
35	Bus 1 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 1 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
36	Bus 2 Earth Switch Opened	This shall be taken from the bus coupler panel through a bus wiring among all the panels. This shall be taken through an auxiliary relay driven by the bus 2 earth switch open auxiliary contact. Signal shall be logically high when the earth switch is in open state.
37	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Alarms</b>		
38	Relay Panel DC/AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
39	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in MK panel. Signal shall be logically high when all the MCBs are switched on.
40	Circuit Breaker Gas Pressure Low Alarm	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
41	Circuit Breaker Gas Pressure Lockout	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lock out alarm is generated.
42	Isolators are in Local Mode	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
43	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.

44	CB in Local Mode	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
45	Synchroscope Plugged In	This signal is taken through the syncrocheck console once it is plugged in.
46	Main 1/Main 2 Relay Healthy	This input shall be logically high when Main 2 (Input to Main 1) IED is operating without any internal failure.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced. In Gas Insulated Substations additional contacts may be required depending on manufacturers recommendations. And also, some outputs might not be required since in certain case Q1 and Q5 are operated using a single mechanism. Those may be introduced after the approval from the ENGINEER

Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip
3	Lockout Trip 86/1	Tripping that initiates the lockout according to the trip matrix
4	Lockout Trip 86/2	Tripping that initiates the lockout according to the trip matrix
5	Q1 Isolator Close	Close Command to the bus 1 isolator
6	Q1 Isolator Open	Open Command to the bus 1 isolator
7	Q2 Isolator Close	Close Command to the bus 2 isolator
8	Q2 Isolator Open	Open Command to the bus 2 isolator
9	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
10	86/1 Reset	Contact to reset 86/1 through NCC/SAS
11	Breaker Failure Initiation	Breaker failure initiation to MV busbar protection IED.
12	86/2 Reset	Contact to reset 86/2 through NCC/SAS

### 5.12.3.3 LV Side IED

#### 5.12.3.3.1 General Circuit Requirements

It was discussed in chapter 5.7.1 that hardware requirements of the IED shall change depending on it's application. The hardware requirement for a LV side IED of a HV/MV/LV three winding transformer protection applications are discussed within this chapter.

#### 5.12.3.3.2 Analog Circuits

### Current Circuits

#### LV Side Current Channels

As it was mentioned in chapter 5.12.3.1 the other protection core shall be shared among the control/protection IED at the LV protection/control panel, automatic voltage regulator panel, HV protection/control panel and disturbance recorder panel if available. Earthing of all the secondary circuits of phase current transformers shall be done at the LV protection/control panel. Current channel allocation of LV side IED shall be as follows.

Channel 1	LV R Phase Current
Channel 2	LV Y Phase Current
Channel 3	LV B Phase Current
Channel 4	Summation of LV side R,Y,B Phase Currents

### LV Side Voltage Circuits

Core 2 of LV side voltage transformer shall be connected in star configuration to LV Side IED. The same core shall be shared between other devices as discussed in chapter 5.12.2.1.1. Busbar voltage between R and Y phases shall be connected to the fourth input. If the substation is a double busbar station, busbar 2 voltage between R and Y phases shall be connected to the fifth voltage input.

Channel 6	LV R-E Voltage
Channel 7	LV Y-E Voltage
Channel 8	LV B-E Voltage
Channel 9	Busbar 1 R-Y Voltage
Channel 10	Busbar 2 R-Y Voltage

### 5.12.3.3.3 Binary Circuits

#### Binary Inputs

The binary inputs mentioned in the table below shall be wired to Protection and Control IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Binary Inputs	Remarks
	<b>Control and Interlocking</b>	
1	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts
4	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts
5	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
6	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
7	Lockout Relay Operated	N/C contact from the lockout relay.
8	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.
9	Trip Circuit 2 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.

10	Breaker Failure Inter trip	Breaker failure trip received from a bay connected to the same bus section at LV side.
11	Breaker Failure Initiation from HV Side	Signal received from HV side to initiate LV breaker failure function.
12	HV Side Q1 Open	HV side Bus 1 isolator opened status directly from the isolator auxiliary contacts
13	HV Side Q2 Open	HV side Bus 2 isolator opened status directly from the isolator auxiliary contacts
14	HV Side Q0 Open	HV side circuit breaker opened status directly from the circuit breaker auxiliary contacts
15	HV Side Q51 Open (Only if HV side is GIS)	HV side Q51 earth switch opened status directly from the earth switch auxiliary contacts
16	HV Side Q52 Open (Only if HV side is GIS)	HV side Q52 earth switch opened status directly from the earth switch auxiliary contacts
17	HV Side Q8 Open (Only if HV side is GIS)	HV side Q8 earth switch opened status directly from the earth switch auxiliary contacts
18	MV Side Q1 Open	MV side Bus 1 isolator opened status directly from the isolator auxiliary contacts
19	MV Side Q2 Open	MV side Bus 2 isolator opened status directly from the isolator auxiliary contacts
20	MV Side Q0 Close	MV side circuit breaker closed status directly from the circuit breaker auxiliary contacts
21	MV Side Q51 Open (Only if HV side is GIS)	MV side Q51 earth switch opened status directly from the earth switch auxiliary contacts
22	MV Side Q52 Open (Only if HV side is GIS)	MV side Q52 earth switch opened status directly from the earth switch auxiliary contacts
23	MV Side Q8 Open (Only if HV side is GIS)	MV side Q8 earth switch opened status directly from the earth switch auxiliary contacts
<b>For GIS Applications</b>		
24	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
25	Bus 1 Earth Switch Opened	Bus 1 earth switch opened status directly from the earth switch.
26	Bus 2 Earth Switch Opened	Bus 2 earth switch opened status directly from the earth switch.
27	Q5 Earth Switch Opened	Q5 earth switch opened status directly from the isolator auxiliary contacts
28	Q5 Earth Switch Closed	Q5 earth switch closed status directly from the isolator auxiliary contacts
29	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Synchronism Check</b>		
30	Bus 1 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
31	Bus 2 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.

32	Line VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
<b>Alarming</b>		
33	Gas Pressure OK in CB Cubicle	Direct contact from the pressure gauge installed in the circuit breaker chamber. Signal shall be logically high when the gas pressure is healthy.
34	Gas Pressure OK in Busbar Cubicle	Direct contact from the pressure gauge installed in the circuit busbar chamber. Signal shall be logically high when the gas pressure is healthy.
35	Relay Panel DC or AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
36	Marshalling Kiosk DC/AC MCB Fail (Only for AIS)	A series connection of the auxiliary contacts in the DC and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
37	Circuit Breaker Gas Pressure Low Alarm (Only for SF6 Breakers)	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
38	Circuit Breaker Gas Pressure Lockout (Only for SF6 Breakers)	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
39	Isolators are in Local Mode (Only for AIS)	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
40	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
41	CB in Local Mode (Only for AIS)	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
42	Mechanical Protection Trip	Output from each mechanical protection flag relay shall be connected in parallel and wired to this inout.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced. In Gas Insulated Substations additional contacts may be required depending on manufacturers recommendations. And also, some outputs might not be required since in certain case Q1

and Q5 are operated using a single mechanism. Those may be introduced with the approval of the ENGINEER.

Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip
3	Lockout Trip 86	Tripping that initiates the lockout according to the trip matrix
4	Trip to HV side TC1	DEF and DOC trip HV side
5	Trip to HV side TC2	DEF and DOC trip HV side
6	Trip to HV side 86/1	DEF and DOC trip HV side
7	Trip to HV side 86/2	DEF and DOC trip HV side
8	Breaker failure initiation to HV side	DEF and DOC trip HV side to initiate breaker failure
4	Trip to MV side TC1	DEF and DOC trip MV side
5	Trip to MV side TC2	DEF and DOC trip MV side
6	Trip to MV side 86/1	DEF and DOC trip HV side
7	Trip to MV side 86/2	DEF and DOC trip HV side
8	Breaker failure initiation to HV side	DEF and DOC trip HV side to initiate breaker failure
9	Q1 Isolator Close	Close Command to the bus 1 isolator
10	Q1 Isolator Open	Open Command to the bus 1 isolator
11	Q2 Isolator Close	Close Command to the bus 2 isolator
12	Q2 Isolator Open	Open Command to the bus 2 isolator
13	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
14	86/1 Reset	Contact to reset 86/1 through NCC/SAS
15	Q5 Earth Switch Close	Close Command to Q5 Earth Switch
16	Q5 Earth Switch Open	Open Command to Q5 Earth Switch
17	Breaker Failure Timer 2 Trip	Trip command to other bays when breaker failure timer 2 has operated.
18	86/2 Reset	Contact to reset 86/2 through NCC/SAS



### 5.12.3.4 Trip Matrix -HV/MV/LV Three Winding TF

Relay	Protection Function	ANSI No	DC	HV CB					MV CB					LV CB						
				TC1	TC2	86/1	86/2	Start CBF (50BF)	TC1	TC2	86/1	86/2	Start CBF (50BF)	TC1	TC2	86/1	86/2	Start CBF (50BF)		
Main 1	Transformer Differential	87T	1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Restricted Earthfault (HV)	87N-HV		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Restricted Earthfault (LV)	87N-LV		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Over Excitation (V/f)	24		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	HV Phase Over Current	50/51 #1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	HV Residual Earth Fault	50N/51N #1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	HV Directional Over Current	67#1		X	X	X	X	X												
	HV Directional Earth Fault	67N#1		X	X	X	X	X												
	MV Phase Over Current	50/51 #2							X	X	X	X	X	X						
	MV Residual Earth Fault	50N/51N #2							X	X	X	X	X	X						
	LV Phase Over Current	50/51 #3													X	X	X	X	X	
	LV Residual Earth Fault	50N/51N #3													X	X	X	X	X	
	LV Stand by Earthfault	51G-HV			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	LV Stand by Earthfault	51G-LV			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Under Voltage / Over Voltage	27 / 59		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Thermal Overload	49		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Main 2	Transformer Differential	87T	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Restricted Earthfault (HV)	87N-HV		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Restricted Earthfault (LV)	87N-LV		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Over Excitation (V/f)	24		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	HV Phase Over Current	50/51 #1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	HV Residual Earth Fault	50N/51N #1		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	HV Directional Over Current	67#1		X	X	X	X	X												
	HV Directional Earth Fault	67N#1		X	X	X	X	X												
	MV Phase Over Current	50/51 #2							X	X	X	X	X	X						
	MV Residual Earth Fault	50N/51N #2							X	X	X	X	X	X						
	LV Phase Over Current	50/51 #2													X	X	X	X	X	
	LV Residual Earth Fault	50N/51N #2													X	X	X	X	X	
	HV Stand by Earthfault	51G-HV			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	LV Stand by Earthfault	51G-LV			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Under Voltage / Over Voltage	27 / 59		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Thermal Overload	49		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
MV Backup 1	MV Over Current	51#2/ 50#2	3							X	X	X	X	X						
	MV Earth Fault	51N#2/ 50N#2								X	X	X	X	X						
	MV Directional Over Current	67#2								X	X	X	X	X						
	MV Directional Earth Fault	67N#2								X	X	X	X	X						
MV Backup 2	MV Over Current	51#2/ 50#2	4							X	X	X	X	X						
	MV Earth Fault	51N#2/ 50N#2								X	X	X	X	X						
	MV Directional Over Current	67#2								X	X	X	X	X						
	MV Directional Earth Fault	67N#2								X	X	X	X	X						
LV Backup	LV Over Current	51#3/ 50#3	5												X	X	X	X	X	
	LV Earth Fault	51N#3/ 50N#3													X	X	X	X	X	
	Directional Over Current	67#3			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	Directional Earth Fault	67N#3			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
HV – 86/1	Operated		1	X	X		X													
HV – 86/2	Operated		2	X	X		X													
MV – 86/1	Operated		3						X	X		X								
MV – 86/2	Operated		4						X	X		X								
LV – 86/1	Operated		5										X	X			X			
LV – 86/2	Operated		5										X	X			X			
HV-86BB	Operated		6	X	X															
MV-86BB	Operated		7						X	X										
	Each Mechanical Trip		8			X	X				X	X			X					

**5.12.3.6 Interlocks for HV/LV Three Winding Transformer Bays**

All the conditions discussed in chapter 5.8.4 shall be included in the interlocking logic.

Operation	High Voltage Side																																	
	Operating Location	Switchgear																Other Conditions																
		HQ0	HQ1	HQ2	MQ1	MQ2	MQ0	LQ1	LQ5	LQ0	HQ8	HQ5 1*	HQ5 2*	MQ8	MQ5 1*	MQ5 2*	HV Bus Coupler	MV Bus Coupler	HV Bus 1 ES*	HV Bus 2 ES*	MV Bus 1 ES*	MV Bus 2 ES*	86/1	86/2	86BB (96)	74/1	74/2	HV <U	MV <U	L V < U	25			
HQ1 Close/Open	1,2,3,4	Open	-	Open	-	-	-	-	Open	-	Open	Open	Open	Open	Open	Open	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	1,2,3,4	-	-	Close	-	-	-	-	Open	-	Open	Open	Open	Open	Open	Open	Close	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
HQ2 Close/Open	1,2,3,4	Open	Open	-	-	-	-	-	Open	-	Open	Open	Open	Open	Open	Open	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	1,2,3,4	-	Close	-	-	-	-	-	Open	-	Open	Open	Open	Open	Open	Open	Close	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
HQ0 Close	1	-	Open	Open	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	2,3,4	-			Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	Line Dead	-	-	-	Line Dead OK		
	2,3,4	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	Line Live	-	-	-	Sync h OK		
HQ51,HQ52, HQ8	1	-	Open	Open	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Medium Voltage Side																																		
MQ1 Close/Open	1,2,3,4	-	-	-	-	Open	Open	-	Open	-	Open	Open	Open	Open	Open	Open	-	-	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-
	1,2,3,4	-	-	-	-	Close	-	-	Open	-	Open	Open	Open	Open	Open	Open	-	Close	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-
MQ2 Close/Open	1,2,3,4	-	-	-	Open	-	Open	-	Open	-	Open	Open	Open	Open	Open	Open	-	-	-	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-
	1,2,3,4	-	-	-	Close	-	-	-	Open	-	Open	Open	Open	Open	Open	Open	-	Close	-	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-
MQ0 Close	1	-	Open	Open	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2,3,4	-	Open	Open			-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	Line Dead	-	-	-	Line Dead OK		
	2,3,4	-	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	Line Live	-	-	-	Sync h OK		
HQ51,HQ52, HQ8	1	-	Open	Open	Open	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Low Voltage Side (GIS with a single busbar)																															
Operation	Operating Location	Switchgear																Other Conditions													
		HQ0	HQ1	HQ2	MQ1	MQ2	MQ0	LQ1	LQ5	LQ0	HQ8	HQ51*	HQ52*	MQ8	MQ51*	MQ52*	HV Bus Coupler	MV Bus Coupler	HV Bus 1 ES*	HV Bus 2 ES*	MV Bus 1 ES*	MV Bus 2 ES*	86/1	86/2	74/1	74/2	HV <U	MV <U	LV <U	25	
LQ1 Close/Operation	1,2,3,4	-	-	-	-	-	-	Open	Open	Open	Open	Open	Open	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
LQ5 Close/Operation	1,2,3,4	-	Open	Open	Open	Open	-	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
LQ0	2,3,4	-	Open	Open	Open	Open	-	Open	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		-	-	-	-	-	Close	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	-	-	Line Live	Synch OK/Deaded Bus OK
	2,3,4	Close	-	-	-	-	-	I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	-	-	Line Live	Synch OK/Deaded Bus OK

Operating Locations	Index
Switchgear Local Control Cubicle	1
Protection/Control Panel	2
SAS	3
NCC	4

\* - Only Available in GIS

I - Not Intermediate

Notes:

1. Bus Coupler close signal shall be the series connection of N/O contacts in two isolators and the circuit breaker in the bus coupler bay. Signal will be logically high when the bus coupler bay is closed.
2. <U signal shall be the series connection of three per phase voltage supervision relay contacts installed in the local control panel. Signal shall be logically high when the voltage measured in all three phases are less than 10% of the nominal voltage.
3. Synchronism check shall be done according to "Synchronism Check" Worksheet
4. Bus 1 earth switch status and Bus 2 earth switch status shall be taken to individual bays through a bus wiring from the bus coupler bay. Signal shall be logically high when the earth switches are in open condition.

## 5.12.4 HV/MV Transformer with a Buried Delta Winding (220kV/132kV/33kV)

### 5.12.4.1 General Requirements

Three winding transformers with a buried delta winding shall be considered as a three voltage level transformer and hence a three winding differential protection scheme shall be implemented.

One current transformer located within the buried delta shall be used to implement three terminal differential between HV, LV sides and the buried delta winding. In addition to that another current transformer shall be located to measure the current in the buried delta winding earthing path.

The protection/control functions required would be identical to that of a HV/LV two winding transformer barring the following changes.

Differential protection shall be a three winding differential function in both Main 1 and Main 2 IEDs.

There shall be a zero sequence protection function in both Main 1 and Main 2 IEDs additionally to measure and operate based on the current in the Delta winding earthing path.

Please refer chapter 5.7 for specifications for the IEDs. It was discussed in chapter 5.7.1 that hardware requirements of the IED shall change depending on it's application. The hardware requirement for a transformer with a buried delta winding protection applications are discussed within this chapter. Refer [Annexure 3](#) for Single Line Diagram

### 5.12.4.2 Analog Circuits

#### Current Circuits

Current channel requirement would be identical to that of a HV/LV two winding transformer apart from the following additional channels.

There shall be three current channels to connect the current transformers installed within the delta winding

One more additional channel shall be available to connect the current transformer installed in the delta winding earthing path.

Refer 5.12.2.2.1 for further information.

#### Voltage Circuits

Voltage channel requirement would be identical to that of a HV/LV two winding transformer.

Refer 5.12.2.2.1 for further information.

### 5.12.4.3 Binary Circuits

Binary circuit requirement shall be identical to that of a HV/LV 2 winding transformer. Refer 5.12.2.2.2 for further information.

**5.12.4.4 Trip Matrix – HV/MV Buried Delta Transformer**

Relay	Protection Function	ANSI No	DC	HV CB					LV CB					
				TC1	TC2	86A	86B	CBF initiation	TC1	TC2	86A	86B	CBF initiation	
Main 1			1											
	Transformer Differential	87T		X	X	X	X	X	X	X	X	X	X	X
	Restricted Earthfault (HV)	87N-HV		X	X	X	X	X	X	X	X	X	X	X
	Restricted Earthfault (LV)	87N-LV		X	X	X	X	X	X	X	X	X	X	X
	Over Excitation (V/f)	24		X	X	X	X	X	X	X	X	X	X	X
	HV Phase Over Current	50/51 #1		X	X	X	X	X	X	X	X	X	X	X
	HV Residual Earth Fault	50N/51N #1		X	X	X	X	X	X	X	X	X	X	X
	LV Phase Over Current	50/51 #2							X	X	X	X	X	X
	LV Residual Earth Fault	50N/51N #2							X	X	X	X	X	X
	LV Stand by Earthfault	51G-LV		X	X	X	X	X	X	X	X	X	X	X
	Under Voltage / Over Voltage	27 / 59		X	X	X	X	X	X	X	X	X	X	X
	Zero Sequence Over Current	50G		X	X	X	X	X	X	X	X	X	X	X
	Thermal Overload	49		X	X	X	X	X	X	X	X	X	X	X
Main 2			2											
	Transformer Differential	87T		X	X	X	X	X	X	X	X	X	X	X
	Restricted Earthfault (HV)	87N-HV		X	X	X	X	X	X	X	X	X	X	X
	Restricted Earthfault (LV)	87N-LV		X	X	X	X	X	X	X	X	X	X	X
	Over Excitation (V/f)	24		X	X	X	X	X	X	X	X	X	X	X
	HV Phase Over Current	50/51 #1		X	X	X	X	X	X	X	X	X	X	X
	HV Residual Earth Fault	50N/51N #1		X	X	X	X	X	X	X	X	X	X	X
	LV Phase Over Current	50/51 #2							X	X	X	X	X	X
	LV Residual Earth Fault	50N/51N #2							X	X	X	X	X	X
	LV Stand by Earthfault	51G-LV		X	X	X	X	X	X	X	X	X	X	X
	Under Voltage / Over Voltage	27 / 59		X	X	X	X	X	X	X	X	X	X	X
	Zero Sequence Over Current	50G		X	X	X	X	X	X	X	X	X	X	X
	Thermal Overload	49		X	X	X	X	X	X	X	X	X	X	X
LV			3											
	LV Over Current	51#2/ 50#2							X	X	X	X	X	X
	LV Residual Earth Fault	51N#2/ 50N#2							X	X	X	X	X	X
	Directional Over Current	67#2		X	X	X	X	X	X	X	X	X	X	X
	Directional Earth Fault	67N#2		X	X	X	X	X	X	X	X	X	X	X
HV - 86A	Operated		1	X	X									
HV - 86B	Operated		2	X	X									
LV - 86A	Operated		3						X	X				
LV - 86B	Operated		3						X	X				
HV- 86BB,87BB	Operated		4	X	X									
	Each Mechanical Trip		5			X	X				X			

#### 5.12.4.5 Interlocking Logic

Interlocking logic for a HV/MV transformer with a buried delta winding shall be identical to the logic discussed under the two winding transformer chapter.

### 5.12.5 Transformer Protection Functions

#### 5.12.5.1 Differential protection

Overall numerical transformer differential protection shall be provided for each power transformer as indicated on the single line diagrams forming part of the contract specification. The protection shall comply with the following requirements:

- a. The protection shall remain stable for effects of tap changing and for all out-of zone. The power transformer protection shall also remain stable for all other transient conditions, such as in-rush currents during energisation and overfluxing following load rejection, which are not due to faults internal to the protected zone. The content of 2<sup>nd</sup> harmonic or other approved methods shall be used to retain stability during inrush conditions. Time delaying methods will not be accepted.
- b. The techniques used for inrush stabilisation shall be guaranteed not to prevent fast tripping for maximum internal short circuit currents occurring during a transformer energization.
- c. The relay operating time shall be < 30ms at an operation level of not less than 5 times the setting (including main tripping relay)
- d. Integral facilities to compensate for current transformers whose ratings are not matched to transformer winding ratings on either side of the power transformer and also to provide winding phase shift compensation.
- e. Differential protection shall internally facilitate the ratio and vector group compensation.

The differential protection relay shall be able to protect two and three winding transformers or auto transformers and tertiary windings from the internal phase and earth faults of the transformer windings. Relays shall offer independent analogue current inputs for each set of CT's involved in the protection scheme, so that a restraining quantity will be produced for all through fault conditions.

The parameterizing of the relay shall be possible by local operation of an integral user interface or using a portable computer. The necessary setting software shall be included with the relay. The differential protection shall trip all the local breakers associated with the transformer.

#### 5.12.5.2 Restricted Earth Fault Protection

Each transformer winding, having its neutral earthed, either through the neutral point in a star winding or through an earthing transformer in a delta winding, shall be separately protected by the restricted earth fault protections (REF). The REF relays shall be of low impedance numerical type and shall have operating times less than 20 ms (including the main tripping contactor).

Low impedance type restricted earth fault (REF) protection shall facilitate internal current transformer ratio compensation.

High stability during through faults even under conditions of current transformer saturation, effects of tap changing and current transformer errors shall be guaranteed. Each REF protection shall trip all the circuit breakers associated with the transformer.

#### 5.12.5.3 Transformer back up protection

Transformer backup protection shall protect each winding of the transformer by four protection functions namely, Directional and Non-directional over current protection and Directional and Non-directional Earth fault functions. The above functions shall be implemented in both Main-1 and Main-2 relays

Backup protection functions of the MV/ LV windings in a three winding transformer shall be implemented in a separate protection IEDs mounted on each bay panel of the respective voltage level. Operation of the directional functions shall trip all the circuit breakers of the transformer whilst non-directional protection functions shall trip only the relevant local breaker. In each case the tripping signal shall be sent to both the trip coils TC-1 and TC-2 of the circuit breaker through direct tripping as well as two lockout relays 86-1 and 86-2.

#### **5.12.5.4 Over current protection**

Three phase directional overcurrent IDMT elements of numerical type shall be provided as per the clause 5.11.4. For back up protection on each and every transformer winding of the transformer. These IDMT elements shall comply with IEC 60255-3 and they shall incorporate a range of standard characteristics. The “Normal Inverse” characteristic (i.e. curve Type A) will be applied in service.

The over current IDMT elements shall have current ranges of at least 50% to 200% rated current, adjustable in steps of 1%. The earth fault elements shall have current ranges of at least 10% to 80% rated

current, adjustable in steps of less than 10%. The time multiplier settings for over current IDMT elements shall be adjustable, with steps of at least 0.05, from 0.05 to 1.0. Each of the IDMT elements shall have separate trip and alarm contacts and separate trip indicators. In addition the protection shall have the necessary contacts for initiating breaker failure protection and the disturbance recorder.

#### **5.12.5.5 Residual Earth fault protection.**

Residual Earth fault elements shall be provided for each and every power transformer winding as per the clause 5.11.4. The earth fault elements shall be connected to the power transformer’s phase current transformers and shall have the same curve specification like the over current elements.

The earth fault elements shall have current ranges from 10 % to 80%, adjustable in steps of 10%. The time settings earth fault IDMT elements shall be continuously variable from 0 to 1.0 or, as an alternative, with steps of at least 0.05 from 0.05 to 1.0. The IDMT elements provided for earth fault protection shall also have separate trip and alarm contacts and separate trip indicators.

#### **5.12.5.6 Standby Earth Fault Protection**

Standby Earth fault elements implemented in Main-1 and Main -2 relays shall be provided for each and every power transformer winding having its neutral earthed. The earth fault element shall be connected to the power transformer’s neutral current transformer and shall have the same curve specification like the over current elements. For Delta winding the neutral current transformer shall be the neutral current transformer of the earthing transformer.

The earth fault elements shall have current ranges from 10 % to 80%, adjustable in steps of 10%. The time settings for both over current and earth fault IDMT elements shall be continuously variable from 0 to 1.0 or, as an alternative, with steps of at least 0.01 from 0.05 to 1.0. The IDMT elements provided for earth fault protection shall also have separate trip and alarm contacts and separate trip indicators.

#### **5.12.5.7 Over Excitation protection.**

Over excitation protection shall be provided and implemented in Main protection relays. LV side voltage transformer connections shall be used for over excitation protection. The function characteristics should follow the transformer manufacturer’s recommendation in the transformer manual.

**5.12.5.8 Over Voltage and Under Voltage protection**

Power transformer shall be protected from all abnormal voltage conditions. For two winding transformer, over voltage and under voltage functions shall be implemented based on low voltage level whilst for three winding transformers the function shall be implemented based on medium voltage level. Over voltage and under voltage protection functions shall be implemented in transformer main protection relays.

**5.12.5.9 Earthing & Auxiliary transformer protection for 220kV/33kV and 132kV/33kV Y-Δ Transformers**

Transformer Delta winding shall be earthed normally via an earthing transformer. This earthing transformer & the auxiliary transformer shall be included in the protection zones of the main transformer differential and the Delta winding REF.

**5.12.6 Mechanical Protection**

This clause shall apply for all mechanical protection trippings of the main transformer, auxiliary transformer and earthing transformer. All necessary flag indications, tripping relays and alarm relays, DDR inputs associated with this protection shall be provided, mounted and connected under this Contract. If the main transformer is having three separate single phase units then the alarm scheme and DDR input’s shall follow phase segregated design. The operation of such protection functions should be monitored using digital inputs of the numerical power transformer protection relay, so that a record of the operation of the devices can be remotely accessed by CEB protection engineers. Mechanical protection shall trip all the circuit breakers of the transformer.

**5.12.6.1 Mechanical Protection Tripping and Alarm Scheme**

**5.12.6.1.1 For Two Voltage level Transformers**

As it was explained there shall be hand reset flag type auxiliary relays to initiate tripping and alarming for mechanical protection operation. There shall be one flag auxiliary relay each for every mechanical tripping and alarming signal. If the transformer consists of single phase banks, there shall be auxiliary relays for each signal on per phase basis.

**Tripping**

Each tripping auxiliary relay shall have N/O contacts and they shall be connected to other equipment as shown below.

Output 1	HV Lockout 1	N/O contacts in all flag tripping relays shall be connected in parallel and connected to HV lockout 1
Output 2	HV Lockout 2	N/O contacts in all flag tripping relays shall be connected in parallel and connected to HV lockout 2
Output 3	LV Lockout	N/O contacts in all flag tripping relays shall be connected in parallel and connected to LV lockout (86-1)
Output 4	LV IED	N/O contacts in all flag tripping relays shall be connected in parallel and connected to LV IED Input
Output 5	IO Box	N/O contacts in each relay shall be separately connected to an input in IO Box
Output 6	DDR	N/O contacts in all flag tripping relays shall be connected in parallel and connected to DDR Input

**Alarming**

Each alarming auxiliary relay shall have N/O contacts and they shall be connected to other equipment as shown below.



Output 1	IO Box	N/O contacts in each relay shall be separately connected to an input in IO Box
Output 2	DDR	N/O contacts in all flag tripping relays shall be connected in parallel and connected to DDR Input

**5.12.6.1.2 For Three Voltage level Transformers**

As it was explained there shall be hand reset flag type auxiliary relays to initiate tripping and alarming for mechanical protection operation. There shall be one flag auxiliary relay each for every mechanical tripping and alarming signal. If the transformer consists of single phase banks, there shall be auxiliary relays for each signal on per phase basis.

**Tripping**

Each tripping auxiliary relay shall have N/O contacts and they shall be connected to other equipment as shown below.

Output 1	HV Lockout 1	N/O contacts in all flag tripping relays shall be connected in parallel and connected to HV lockout 1
Output 2	HV Lockout 2	N/O contacts in all flag tripping relays shall be connected in parallel and connected to HV lockout 2
Output 3	MV Lockout 1	N/O contacts in all flag tripping relays shall be connected in parallel and connected to MV lockout 1
Output 4	Auxiliary Relay	There shall be one auxiliary relay driven 4 <sup>th</sup> output connected in parallel in all mechanical tripping flag relays. There shall at least 3 N/O contacts in the auxiliary relay which are connected as shown in the table below.
Output 5	LV Lockout	N/O contacts in all flag tripping relays shall be connected in parallel and connected to LV lockout (86-1)
Output 6	IO BOX	N/O contacts in each relay shall be separately connected to an input in IO Box of SAS

Auxiliary relay connected to 4<sup>th</sup> output of each mechanical tripping relay shall contain N/O contact as shown below.

Output 1	MV Lockout 2	N/O contacts in all flag tripping relays shall be connected in parallel and connected to MV lockout 2
Output 2	LV IED	N/O contacts in all flag tripping relays shall be connected in parallel and connected to LV IED Input
Output 3	DDR	N/O contacts in all flag tripping relays shall be connected in parallel and connected to DDR Input

**Alarming**

Each alarming auxiliary relay shall have N/O contacts and they shall be connected to other equipment as shown below.

Output 1	IO Box	N/O contacts in each relay shall be separately connected to an input in IO Box
Output 2	DDR	N/O contacts in all flag tripping relays shall be connected in parallel and connected to DDR Input

**5.12.6.2 Buchholz protection**

Power transformers and earthing transformers shall be fitted with Buchholz devices of the two element type giving operation under gassing and under surge conditions. The Buchholz relay shall be equipped with gas sampling and testing devices to be operated from the ground level at a convenient height.

**5.12.6.3 Oil and winding temperature**

Transformers will be provided with oil and winding temperature protection. These will be of the two stage type with adjustable settings giving alarm and trip facilities. All necessary flag indication, tripping relays and alarm relays associated with this protection shall be supplied and connected up under this Contract.

**5.12.6.4 Input Module for Transformer Alarms**

In order to route the mechanical alarms and trippings to the substation automation system, an input module is required. The specifications for the required hardware of the input module shall fulfil the requirements mentioned in chapter 5.7 (please note that the input module shall not have any analog channels). The input module shall contain the minimum number of binary inputs as mentioned within this chapter of suitable voltage rating according to the respective substation specification. The pickup and drop off thresholds shall be defined such that a positive or negative earth fault in an unearthed DC auxiliary power distribution shall not cause the binary inputs to get picked up erroneously. The inputs shall be debounced in order to avoid mal operations caused by bouncy contacts. Debouncing using software is also acceptable. The pickup and drop off thresholds shall depend on the DC auxiliary supply provided as mentioned below.

Nominal Voltage (V DC)	Pickup Threshold (V DC)	Drop Off Threshold (V DC)
110	88	66
220	176	132

The input module shall contain an IEC 61850 interface so that it can be directly connected to the substation automation system without any additional equipment in between. The bidder shall submit IEC 61850 conformance certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850-10 for the specific device bidder is presenting.

All the mechanical alarms available in the transformer shall be routed to the input module through respective flag relays. For single phase transformer banks alarms and trippings shall be available per phase basis. Following signals shall be available. (List is for a three phase transformer bank)

1	Main Transformer Buchholz Trip
2	HV Winding Temperature Trip
3	LV Winding Temperature Trip
4	Oil Temperature Trip
5	Buchholz Gas Trip
6	Tap Changer Oil Level Trip
7	Tap Changer Oil Pressure Surge Trip
8	Tap Changer Buchholz Trip

9	Main Transformer PRV Trip
10	Main Transformer Oil Level Minimum Trip
11	Tap Changer PRV Trip
12	Main Transformer Buchholz Alarm
13	HV Winding Temperature Alarm
14	LV Winding Temperature Alarm
15	Oil Temperature Alarm
16	Tap Changer Oil Level Alarm
17	Main Transformer Oil Level Minimum Alarm
18	Tap Changer Buchholz Alarm
19	Cooling Fan Motor MCB Trip
20	Cooling Fan Motor Thermal Overload
21	Cooling Fan Switched On
22	Cooling Fan Switched Off
23	OLTC Motor MCB Trip
24	Tap Change Incomplete
25	OLTC in Local
26	OLTC Motor Thermal Overload
27	Earthing Transformer Buchholz Trip
28	Earthing Transformer PRV Trip

#### 5.12.6.5 Blocking of automatic voltage regulator

The Automatic Voltage Regulator shall block on conditions of over current or under voltage of 70% of nominal operating voltage.

### 5.13 SHUNT REACTOR PROTECTION

Please refer Single line diagram in [Annexure 5](#)

#### 5.13.1 General Requirements

Reactors shall be protected by the usually applied gas- and oil-surge and pressure detectors, oil- and winding-temperature monitoring devices, including the monitoring and protection of the tap changer and/or the cable connection chambers in the similar manner, all as specified below of this Specification.

Beside these protection systems as built into or mounted on the reactor, at least the following electrical protection/control IEDs shall be provided, but shall not be limited to the functions mentioned below. Two separate IEDs are required as Main 1 and Main 2 protection with 100% redundancy mounted in the HV protection/control panel. The two relays shall consists of all the protection functions mentioned below and they shall provide identical protection schemes inside the relays and tripping logics.

Shunt Reactor Main 1 and Main 2 protection

Reactor differential protection

Restricted earth fault protection for the reactor winding

Directional / Non directional Over Current Function

Directional / Non directional earth fault function (Residual current calculated by the summation of phase CTs)

Directional / Non Directional zero sequence function (Zero sequence current measured by the neutral current transformer)

Over Fluxing Protection

Over Voltage and Under Voltage Function  
Reactor Thermal Overload Function  
Bay controller function for the reactor bay

The protection relays shall be of numerical type with extensive self-monitoring and analogue / digital conversion of all input quantities. All the electrical protection relays shall have sufficient number of contacts for signalling, alarms and the disturbance recorder.

There shall be direct tripping contacts for both trip coils and two lockout relays from both Main 1 and Main 2 IEDs. Please refer chapter 5.7 for specifications for the IEDs.

Pole discrepancy protection for single pole operated circuit breakers with controlled switching shall be provided.

### 5.13.2 Protection Functions

#### 5.13.2.1 Differential Protection (87P)

Reactor differential protection shall be provided with bus side phase current transformers and neutral side phase segregated current transformers. The function shall protect the reactor from internal phase to phase faults, internal phase to earth faults. Relay operating time shall not exceed 30ms without considering the time taken for the circuit breaker to open. The protection shall be immune to severe inrush currents caused by reactor energization and current transformer saturation. To avoid mal operations caused by inrush current 2<sup>nd</sup> harmonic based blocking method or any other acceptable method can be used. Desensitizing or blocking of the function to avoid mal operation to reactor energization or current transformer saturation shall not prevent the relay from initiating a trip command to an actual fault condition.

Due to the extreme X/R ratios the current transformers may get saturated very quickly even for an internal fault. This shall be considered for the operation of this function.

The differential function shall contain a biased characteristic or any other acceptable means of taking care of current transformer inequalities creating a false differential current.

#### 5.13.2.2 Restricted Earth Fault Protection (87N)

A low impedance restricted earth fault scheme shall be implemented using the bus side phase current transformers and the neutral current transformer. The function shall protect the reactor from internal phase to earth faults. . The protection shall be immune to severe inrush currents caused by reactor energization and current transformer saturation. Due to the extreme X/R ratios the current transformers may get saturated very quickly even for an internal fault. This shall be considered for the operation of this function.

The relay shall be capable of internally compensating for different current transformer ratios.

#### 5.13.2.3 Directional/Non Directional Over Current Function (50,51,67)

There shall be directional and non-directional over current elements to detect faults in any of the three phases. The over current functions shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time

Additionally there shall be instantaneously operating elements as well. The over current protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and in rush currents caused by reactor energization and shall not respond to DC component.

The user shall have the option of blocking the directional element if there voltage transformer fuse failure function has operated or the voltage transformer secondary circuit MCB is tripped. There shall be some degree of memory polarization to make sure directional element directionality is secured under close in three phase faults.

There shall be at least four stages of inverse definite minimum time curve based elements. The function shall have a reset ratio of 95%.

The user shall have the facility to configure following settings according to his requirement.

- Pickup value of the function
- The desired inverse definite minimum time curve
- Time multiplier setting of the IDMT curve
- Time delay if the selected curve is definite time

Additionally for the directional over current elements following settings shall be available for the user customize according to his need.

- Direction; Forward or Reverse
- Relay characteristic angle
- The sector opening of the forward or reverse direction with respect to the characteristic angle.

#### **5.13.2.4 Directional/Non Directional Earth Fault Function (50N,51N,67N)**

The relay shall contain a directional earth fault function operated by the zero sequence current calculated from the phase current transformers inputs. If the current transformers are connected in the "Holmgren" connection and the zero sequence current is available as a measurement that measured current shall be used as the operating quantity.

The directional earth fault protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and in rush currents caused by transformer energization.

The user shall have the facility of selecting one option from the following Measurement as the polarizing quantity.

- Zero sequence voltage calculated from the three phase to neutral voltages connected.
- Negative sequence voltage calculated from the three phase to neutral voltages connected
- Zero sequence current from a neutral current transformer of a power transformer in the substation.

The directional earth fault function shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time

The user shall have the facility to configure following settings according to his requirement.

- Pickup value of the function
- The desired inverse definite minimum time curve
- Time multiplier setting of the IDMT curve
- Time delay if the selected curve is definite time

Additionally for the directional earth fault elements following settings shall be available for the user customize according to his need.

- Direction; Forward or Reverse
- Relay characteristic angle

The sector opening of the forward or reverse direction with respect to the characteristic angle.

#### **5.13.2.5 Directional / Non Directional zero sequence function (50G, 51G, 67G)**

The operating quantity of this function shall be the current measured by the neutral current transformer. The function shall be immune to capacitive voltage transformer transients. The directional zero sequence function shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time

The user shall have the facility to configure following settings according to his requirement.  
Pickup value of the function

Pickup value ranging from 0.05A – 1A with a minimum step of 0.01A.

- The desired inverse definite minimum time curve
- Time multiplier setting of the IDMT curve
- Time delay if the selected curve is definite time

Additionally for the directional earth fault elements following settings shall be available for the user customize according to his need.

- Direction; Forward or Reverse
- Relay characteristic angle

The sector opening of the forward or reverse direction with respect to the characteristic angle.

#### **5.13.2.6 Over Fluxing Protection (24)**

Over fluxing function shall operate based on the ratio of measured line voltage and its frequency. The function shall work based on per unit values calculated from the nominal voltage and nominal frequency of the protected object.

The user shall be able to specify the pickup value and the cooling time constant to take memory action in to account.

#### **5.13.2.7 Over Voltage and Under Voltage Function (29, 57)**

Under voltage and over voltage functions shall be available to detect under voltage or over voltage conditions in any of the three phases of the connected voltage source.

There shall be at least two elements each for under voltage and over voltage protection having a definite time characteristic. Having inverse characteristics in the operating time curve shall be considered as an additional advantage.

The reset ratio shall be 95%.

#### **5.13.2.8 Reactor Thermal Overload Function (49)**

This particular function is used to detect overloading conditions of the protected transmission line/Transformer/Reactor based on a thermal model. The thermal model and the operating characteristic shall be based on IEC 60255-8. The thermal model shall be centred on following factors.

Continuous thermal current rating of the object

Time Constant based on the maximum short term current rating

Pre fault current

### 5.13.2.9 Bay Controller Function

Refer clause 5.8.2.3.

### 5.13.3 Mechanical Protection

This clause shall apply for all mechanical protection tripping of the shunt reactors. All necessary flag indications, tripping relays and alarm relays, DDR inputs associated with this protection shall be provided, mounted and connected under this Contract. If the shunt reactor is having three separate single phase units then the alarm scheme and DDR inputs shall follow phase segregated design. The operation of such protection functions should be monitored using digital inputs of the numerical shunt reactor protection relay, so that a record of the operation of the devices can be remotely accessed by CEB protection engineers.

#### 5.13.3.1 Buchholz Protection

Shunt Reactors shall be fitted with Buchholz devices of the two element type giving operation under gassing and under surge conditions. The Buchholz relay shall be equipped with gas sampling and testing devices to be operated from the ground level at a convenient height.

#### 5.13.3.2 Oil and Winding Temperature

Reactors will be provided with oil and winding temperature protection. These will be of the two stage type with adjustable settings giving alarm and trip facilities. All necessary flag indication, tripping relays and alarm relays associated with this protection shall be supplied and connected up under this Contract.

### 5.13.4 Tripping and blocking scheme

#### 5.13.4.1 Blocking of Variable Shunt Reactor Controller

The Variable Shunt Reactor Controller shall block on conditions of over current or under voltage of 70% of nominal operating voltage.

#### 5.13.4.2 Tap Changer Blocking

A tap changer blocking scheme to prevent operating of the tap changer during system fault conditions, which result in fault current passing through the reactor, shall be incorporated in the tap changer control system.

#### 5.13.4.3 Tripping Scheme

All mechanical and electrical protection scheme of the shunt reactors shall be operated through lockout tripping scheme with relevant manual resetting. Mechanical tripping contacts shall initiate the flag relays directly. Additionally direct contacts from the flag relays shall initiate both trip lockout relays and inputs from each flag relay shall be taken as inputs to Main 1 and Main 2 relays.

## 5.14 BUS BAR PROTECTION FOR 220 kV / 132 kV SCHEMES

### 5.14.1 General Requirements

Numerical type de-centralized bus bar protection scheme to detect all inter-phase and phase-to-earth faults is required. Bay unit IEDs shall be installed within bay protection panels of the respective bays and the central unit shall be installed in a separate panel where the station alarm devices shall also be mounted. Please refer chapter 5.7 for specifications for the IEDs. The additional hardware requirements are discussed in this chapter. Please see [Annexure 18](#) for panel arrangement.

For the protection of Bus Bars of 220kV or higher voltages, a redundant and fully independent numerical type centralized or de-centralized bus bar protection scheme is required to detect all inter-phase and phase-to-earth faults. This redundant busbar protection IEDs shall be mounted in a separate panel(s) with independent DC and a separate CT core shall be used.

Redundant busbar protection scheme which hereafter referred to as BBP Main 2 should be from a different manufacturer.

The Bus bar protection shall incorporate the following protection functions

- Decentralised Bus Bar protection (Not applicable for BBP Main 2)
- Stub(T zone) protection for 1 ½ breaker Bus bar system
- End Fault Protection by Bay unit
- Circuit Breaker failure
- Back up Over Current Protection by bay units (Not applicable for BBP Main 2)
- Backup Earth Fault Function by bay units (Not applicable for BBP Main 2)

To enhance security, the protection scheme shall use at least two independent criteria for detecting an in-zone fault and shall initiate a trip signal only if all criteria are securely satisfied. The extension of bus bar protection cubicle(s) shall be possible also for any future feeders and/or bus bar configuration by adding additional cubicle(s). Thus, later on, the respective prints, modules or parts for extensions can easily be fitted to the protection system and no cubicle wiring at Site shall be necessary. The DC supply of bus bar protection equipment shall be fed from the independent DC buses.

The Contractor prior to commissioning shall submit the calculation for stability of bus bar protection during the 125 % normal over load conditions and maximum through fault conditions.

**Tripping:** The protection trip command for each feeder shall be given directly to both of the circuit breaker trip coil systems and the tripping function of the bus bar protection shall block the close-circuits of all circuit breakers concerned. The bus bar protection scheme shall have an operating time of less than one cycle (including tripping relays).

Provision shall be made such that any bus bar trip signal from the protection system shall result in a self-holding function. A defined action shall be required for the reset-function to be activated locally.

In addition to the tripping contacts the protection shall have where necessary contacts for initiating disturbance recorder, signalling and alarms.

Fault indicators must be provided which clearly show which zones and phases have faulted.

**Monitoring:** There shall be continuous and independent monitoring of current transformer-circuits, bus bar isolator auxiliary circuits and circuit breaker auxiliary contacts; latter in opened and closed position. If an error is detected the protection system shall be blocked and an alarm shall be given.

Built-in continuous self monitoring function shall test the complete bus bar protection function automatically. The test equipment's functions shall include tests of all logic circuits, trip routings, blocking functions, essential time delays and measuring circuits. Bus bar protection equipment of feeders, which are switched off, shall also be tested. The test starting time shall be easily adjustable. It shall also be possible to start the test sequence manually, even if the bus bar is not energized.



During automatic test cycles the remote signalling shall be given only in the case of faults, however, the test equipment must activate the fault recorder.

This self monitoring function shall enable personnel to find every individual defective module in a very short time and the manuals of the test equipment shall be easily legible and shall contain full descriptions of the complete system.

**Blocking:** Each zone of the bus bar protection shall be provided with functions to block the protection manually by external on / off switch (key operated). This facility shall be available for individual bays and the scheme shall be properly work even if any of the bays are manually switched off for maintenance. When the relay is blocked it shall be indicated locally as well as at station computer. Under this condition, the tripping functions of the bus bar protection shall be blocked for all feeders. However, the measuring of the bus bar protection should remain in service for monitoring purposes.

**Current Transformers:** Current transformer secondaries of each bay shall be connected to each bus bar protection bay unit IEDs. The bus bar protection shall be able to operate on current transformers having a wide range of different ratios. The bus bar protection shall internally facilitate ratio compensation. Full selectivity shall be achieved for every bus bar zone, hence the replica of every feeder isolator (in 1 ½ breaker system), bus isolator, circuit breaker and/or bus bar sectionaliser in each bay shall be incorporated.

The current transformer secondary circuits shall not be switched via auxiliary contacts of the bus bar isolators directly. Under no circumstances during switching over of feeder isolators, shall voltages be generated in the system, which are higher than the allowable insulation voltage of the wiring. The isolator position and individual phase current shall be visible via LCD display for each bay.

Two sets of current transformers mounted on either side of the bus coupler/sectionaliser shall be connected in an over-lapping arrangement. The bus zones on both sides of the breaker shall operate in the event of a fault between this circuit breaker and one of its current transformers.

Stability for external faults shall be ensured under current transformer saturation of the outgoing circuits and up to the short circuit ratings of the switchgear, irrespective of the distribution of the current between individual circuits. The protection shall have CT saturation detective function in order to avoid mal operation external fault.

**5.14.2 Binary Circuits**

**Binary inputs:** Combinations of NO and NC auxiliary contacts on each isolator or breaker shall be provided for opening and closing the bus bar replica of the protection in such a sequence that the auxiliary contactors operate before reaching the pre-arcing distance on closing the isolator, and after the pre-arcing distance has been exceeded on opening the isolator. This shall be demonstrated during commissioning at site.

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced. The binary input requirement will increase for gas insulated substations and they are separately listed below.

Index	Binary Inputs	Remarks
	Each Bay Unit	

1	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Q2 Closed (Double Bas bar system only)	Bus 2 isolator closed status directly from the isolator auxiliary contacts
4	Q2 Opened (Double Bas bar system only)	Bus 2 isolator opened status directly from the isolator auxiliary contacts
5	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
6	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
7	CBF initiated	CBF signal from other protection relays
8	CBF protection switched off	Selector switch
9	CBF protection switched on	Selector switch
10	Manual close initiated / AR close initiated	For end fault protection
	SF6 Lockout	Breaker failure protection
	<b>Central Unit</b>	
1	Block Zone 1	BB protection zone 1 Block signal
2	Block Zone 2	BB protection zone 2 Block signal

**Binary Outputs:**

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Signal	Remarks
	<b>Each Bay Unit</b>	
1	R phase Trip TC 1	R phase Trip* (*Where single-phase tripping is available)
2	Y Phase Trip TC 1	Y Phase Trip*
3	B Phase Trip TC 1	B Phase Trip*
4	R phase Trip TC 2	R phase Trip*
5	Y Phase Trip TC 2	Y Phase Trip*
6	B Phase Trip TC 2	B Phase Trip*
7	Lockout Trip 86BB (96)	General Trip
8	DTT via Multiplexer	
9	DTT to Main 1 FO	
10	DTT to Main 2 FO	
	<b>Central Unit</b>	
1	<b>BEN Fault Recorder</b> BB protection Zone 1 Trip	BB Zone 1 trip to trigger/record in the disturbance recorder
2	<b>BEN Fault Recorder</b> BB protection Zone 2 Trip	BB Zone 2 trip to trigger/record in the disturbance recorder

### 5.14.3 Other Protection Functions

#### 5.14.3.1 Stub (T Zone) Protection:

Stub protection function shall be provided for situations where 1 ½ breaker bus bar systems are implemented. All setting ranges and other requirements shall be as specified for BB protection.

#### 5.14.3.2 End Fault Protection:

In order to protect the dead zone between the circuit breaker and the associated current transformer, the bus bar protection should include an end fault protection. This shall be implemented in the bay units to cover each bay and the associated remote end.

#### 5.14.3.3 Circuit Breaker Failure:

A numerical type circuit breaker failure function (CBF) function shall be provided in the bay units of the BB protection system and shall monitor the feeders' phase currents by detectors in each phase. The current detector shall have a very fast reset time in order to achieve an overall reset function of the CBF system in less than 15 ms. They shall be sensitive to detect from 0.2 to 2.0 times the rated feeder current, adjustable in steps of less than or equal to 0.2 times this current and be capable of being operated continuously at 1.2 times the rated current.

The breaker failure function is to be provided for each individual circuit breaker. Further, it shall be initiated by all other protection device tripping commands to the circuit breaker and also by any remote tripping signal, which shall initiate tripping of that breaker. The information of the initiation shall be taken separately from the relays that operate the trip coil 1 and the trip coil 2 via potential free contacts. If the circuit breaker is designed for single phase trip and auto reclose then the breaker failure initiation scheme shall have a phase segregated design.

If a trip command fails to open the circuit breaker, after a period of delay (called T1 and shall be adjustable between 50 to 200 ms continuously or in steps smaller than 10 ms) the breaker failure relay shall give a "first step" tripping command to both trip coils of the respective circuit breaker.

If the operation of the "first step" of the CBF has no effect, the CBF-protection system shall give a different tripping command, after a second period of delay (called T2 and adjustable between 50 to 400 ms continuously or in steps smaller than 10 ms). This shall be done via the BB protection central unit to all circuit breakers around the one for which the trip has failed. i.e. a fully selective "second step" tripping command to the circuit breakers of the bus bar zone concerned, in order to interrupt the fault current. Facilities for initiation of a trip signal sent to the remote end breaker associated with the failed breaker's circuit shall be incorporated. This remote trip initiation shall reset when the fault is cleared.

For each CBF, facilities shall be provided to incorporate all the lock-out functions of the respective circuit breaker (e.g. under pressure relays of SF<sub>6</sub>-, N<sub>2</sub>- and oil-monitoring) to "set to zero" both time steps of the breaker failure relay. i.e. protection tripping of the concerned bus zone and trip-signal to the remote circuit breaker shall be without a time delay.

The bay-wise information received from the lockout functions shall be annunciated in the CBF and shall be kept permanent after occurrence of an actual trip signal. In this case, the signalisation to be reset manually.

A further function to be provided within the CBF protection to trip of the remote circuit breaker after the first time step if the tripping of bus bar protection failed.

The tripping of CBF shall be of the non-self-reset type until a reset initiation is activated locally. The tripping shall be three-phase and definite, i.e. blocking of the auto-reclosing shall be provided.

Indicators shall be provided to show clearly which circuit breaker caused tripping, at which time step and which of the other circuit breakers were tripped by the inter-tripping mode and to allow remote signalisation of essential functions. The respective external alarms shall be coordinated with the overall station alarm philosophy and potential free contacts shall be provided accordingly. Separate contacts to initiate the disturbance recorder shall also be provided.

The CBF function shall be furnished with test circuits to enable a check of all the logic circuits, start- and trip- functions. Measures shall be taken to prevent any false tripping during operation and tests, e.g. tripping only if a start input exists and testing only if the trip circuits are interrupted.

For each bay an on / off switch shall also be provided for the breaker failure protection. When the relay is blocked it shall be indicated locally as well as at station computer.

Extension of the CBF protection system shall easily be possible.

#### **5.14.3.4 Back up Over Current Protection by bay Units**

Over current protection is implemented in each bay of bus bar differential scheme. It shall function independently even if the central unit is out of service. Settings of over current function in Bay units installed in line bays shall be same as those of the backup over current function setting in the line protection implemented in the same bay. Settings of over current function in Bay units installed in Transformer bays shall be same as those of the backup over current function in the transformer protection implemented in the same bay.

#### **5.14.3.5 Backup Earth Fault Function by Bay units**

Earth fault protection is implemented in each bay of bus bar differential scheme. It shall function independently even if the central unit is out of service. Settings of Earth fault function in Bay units installed in line bays shall be same as those of the backup Earth fault function setting in the line protection implemented in the same bay.

**5.14.4 Trip Matrix:**

IED Type	ANSI No	Function	132kV/220kV CB						Communication			
			Local End TC1	Local End TC2	Remote End TC1	Remote End TC2	86BB(96)	Start CBF (50BF)	CH1	CH2		
BBP1 Central Unit	87B	Bus bar Protection							X(1)			
		Stub (T zone) protection for 1 1/2 breaker BB arrangement.							X(1)			
BBP1 Bay Unit	87B	Bus bar Protection (from central unit)	X(1)	X(1)			X(1)					
		Inverse Time Over current	X	X				X(1)				
		Inverse Time Earth Fault	X	X				X(1)				
50 BF	50 BF	Breaker Failure protection	X(2)	X(2)	X(3)	X(3)	X(2)		X(3) to remote end	X(3) to remote end		
		End Fault protection							X(1)	X(1)		
		Stub (T zone) protection for 1 and 1/2 breaker BB arrangement.	X(1)	X(1)			X(1)					
BBP2	87B	Bus bar Protection	X(1)	X(1)			X(1)	X(1)				
		50 BF	50 BF	Breaker Failure protection	X(2)	X(2)	X(3)	X(3)	X(2)		X(3) to remote end	X(3) to remote end
		50 EFP	50 EFP	End Fault protection						X(1)	X(1)	

\*X=IDMT trip time, X1=no delay; X2=100ms delay; X3=200ms delay; CH1=direct fiber; CH2=mux (fib or PLC)

**5.15 BUS COUPLER/SECTIONALISER OVER CURRENT FOR 220KV /132 KV**

Refer [Annexure 6](#) for Single Line Diagram and [Annexures 16 & 17](#) for panel arrangements. Two Protection/Control IEDs shall be housed in the same panel. In case of a meshed substation, implementation of busbar protection function is also required. In order to implement a de-centralised busbar protection element explained in chapter 5.14 two bus bar protection bay unit IEDs are required in the bus coupler bay. These two busbar bay units shall also be housed in the same panel.

To provide necessary protection functions the bus coupler bay shall contain two IEDs with 100% redundancy. Each IED shall contain following protection/control functions.

- Non – Directional Over Current function
- Non – Directional Earth Fault function
- BCU function
- Synchronism Check function

The control application shall be in accordance with the aspects discussed in detail in chapter 5.8.

**5.15.1 General Circuit Requirements:**

It was discussed in chapter 5.7.1 that hardware requirements of the IED shall change depending on it’s application. The hardware requirements for bus section/coupler bays at 132kV and above are discussed below.

**5.15.2 Analog Circuits:**

**Current Circuit:**

According to the current transformer availability requirement there will be two current transformers at either side of the bus section/coupler circuit breaker. Each current transformer will contain two cores. The core located at the bus side of the bus 1 side (with respect to the circuit breaker) current transformer shall be connected to the Main 1 IED and the core located at the bus side of the bus 2 side (with respect to the circuit breaker) current transformer shall be connected to the Main 2 IED. Disturbance recorder shall share the same core with the Main 2 IED and the circuit shall be arranged in a such a way that it first comes in to the Main 2 IED and terminated in the disturbance recorder panel. Current transformer circuit earthing in both cores shall be done at the relay panel. Current transformer secondaries shall be connected in “Holmgren” connection and connected to the first four analog inputs of each IED.

Analog Channel	Main 1 IED	Main 2 IED
Channel 1	Bus 1 Side R Phase Current	Bus 2 Side R Phase Current
Channel 2	Bus 1 Side Y Phase Current	Bus 2 Side Y Phase Current
Channel 3	Bus 1 Side B Phase Current	Bus 2 Side B Phase Current
Channel 4	Bus 1 Side Neutral Current	Bus 2 Side Neutral Current

**Voltage Circuit:**

Core 1 of bus 1 voltage transformers shall be connected in star configuration and connected to Main 1 relay and Core 1 of bus 2 voltage transformers shall be connected in star configuration and shared between Main 2 IED and the disturbance recorder. Voltage between R-Y phases of Core 2 at bus 2 voltage transformers shall be wired to Main 1 IED and voltage between R-Y phases of Core 2 at bus 1 voltage transformers shall be wired to Main 2 IED. Hence both Main 1 and Main 2 IEDs shall be equipped with four voltage channels.

Analog Channel	Main 1 IED	Main 2 IED
Channel 5	Bus 1 Side R Phase Voltage	Bus 2 Side R Phase Current
Channel 6	Bus 1 Side Y Phase Voltage	Bus 2 Side Y Phase Current
Channel 7	Bus 1 Side B Phase Voltage	Bus 2 Side B Phase Current
Channel 8	Bus 2 Side R-Y Voltage	Bus 1 Side R-Y Voltage

**5.15.3 Binary Circuits:**

**Binary Inputs:**

The binary inputs mentioned in the table below shall be wired to each Main 1 and Main 2 IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced. The binary input requirement will increase for gas insulated substations and they are separately listed below.

Index	Binary Inputs	Remarks
	Control and Interlocking	
1	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts
4	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts
5	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
6	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
7	Control in Mimic	Mimic status of the selector switch mounted on the relay panel
8	Control in Main 1	Main 1 status of the selector switch mounted on the relay panel. In the case of Main 2 IED Main 2 status of the selector switch shall be provided.
9	Lockout Relay 1 Operated	N/C contact from the lockout relay 1. In the case of Main 2 IED N/C contact from Lockout relay 2 shall be provided.
10	Busbar Lockout Relay Operated	N/C contact from the busbar lockout relay
11	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high. In the case of Main 2 IED trip circuit supervision relay 2 direct contact shall be provided.
<b>For GIS Applications</b>		
12	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
13	Bus 1 Earth Switch Opened	Bus 1 earth switch opened status directly from the earth switch.
14	Bus 1 Earth Switch Closed	Bus 1 earth switch closed status directly from the earth switch.
15	Bus 2 Earth Switch Opened	Bus 2 earth switch opened status directly from the earth switch.
16	Bus 2 Earth Switch Closed	Bus 2 earth switch closed status directly from the earth switch.
17	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Protection or Synch Check</b>		
18	Bus 1 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the marshalling kiosk and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
19	Bus 2 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the marshalling kiosk and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
<b>Alarming</b>		
20	Relay Panel DC or AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
21	Marshalling Kiosk DC/AC MCB Fail	A series connection of the auxiliary contacts in the DC and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.

22	Circuit Breaker Gas Pressure Low Alarm	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
23	Circuit Breaker Gas Pressure Lockout	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
24	Isolators are in Local Mode	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
25	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
26	CB in Local Mode	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.
27	Synchroscope Plugged In	This signal is taken through the synchrocheck console once it is plugged in.
28	Busbar Bay Unit 1 Healthy	This is taken through the watchdog contact of busbar bay unit 1. Signal shall be high when relay is health.
29	Busbar Bay Unit 2 Healthy	This is taken through the watchdog contact of busbar bay unit 2. Signal shall be high when relay is health.
30	Main 2 IED Healthy	This is taken through the watchdog contact of Main 2 IED. Signal shall be high when relay is health.

**Binary Outputs:**

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip
3	Lockout Trip 86/1	General Trip
4	Lockout Trip 86/2	General Trip
5	Start Breaker Failure 3 Phase to BU1	General Trip 3 Phase to initiate 3 phase breaker failure function
6	Start Breaker Failure 3 Phase to BU2	General Trip 3 Phase to initiate 3 phase breaker failure function
7	Q1 Isolator Close	Close Command to the bus 1 isolator
8	Q1 Isolator Open	Open Command to the bus 1 isolator
9	Q2 Isolator Close	Close Command to the bus 2 isolator
10	Q2 Isolator Open	Open Command to the bus 2 isolator
11	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
12	86/1 Reset	Contact to reset 86/1 through NCC/SAS
13	86/2 Reset	Contact to reset 86/2 through NCC/SAS
<b>Fault Recorder</b>		
14	Over Current and Earth Fault Trip	Over current or earth fault trip to trigger/record in the disturbance recorder



**5.15.4 Protection Functions Required in Bus Section/Coupler Applications**

There shall be directional and non-directional over current elements to detect faults in any of the three phases. The over current functions shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3. Standard Inverse Very Inverse Extremely Inverse Long time inverse Definite time

Additionally there shall be instantaneously operating elements as well. The overcurrent protection function shall be immune to current transformer saturation, capacitive voltage transformer transients and in rush currents caused by transformer energization and shall not respond to DC component.

There shall be at least four stages of inverse definite minimum time curve based elements. The function shall have a reset ratio of 95%. The user shall have the facility to configure following settings according to his requirement.

- Pickup value of the function
- The desired inverse definite minimum time curve
- Time multiplier setting of the IDMT curve
- Time delay if the selected curve is definite time

The over current IDMT elements shall have current ranges from 50% to 200%, adjustable in steps of 10%.

Each over current shall be supplemented with a definite time element having a range 5 to 30 times nominal current. The definite time setting shall be adjustable between zero and ten seconds in steps of 0.01 seconds.

Tripping shall occur from the instantaneous elements in less than 20 ms including main tripping contactor when three times the setting current is flowing.

An earth fault element shall have current ranges from 10% to 80%, adjustable in step of 10%. The time settings for both over current and earth fault IDMT elements shall be continuously variable from 0 to 1.0 or as an alternative, with steps of at least 0.05 from 0.05 to 1.0.

**5.15.5 Trip Matrix:**

	DC	TC1	TC2	Start CBF (50BF)	86-1	86-2
		all	all	all		
<b>Main 1</b>	1					
51		X	X	X	X	X
51N		X	X	X	X	X
86/1	1					
<b>Main 2</b>	2					
51		X	X	X	X	X
51N		X	X	X	X	X
86/2	2					
Bus bar Protection IED 1	3					
87BB Zone 1		X	X			
87BB Zone 2		X	X			
86BB	3	X	X			

**5.15.6 Interlocking**

Operation	Operating Location	Switchgear																		
		Q0	Q1	Q2	Q51*	Q52*	Bus 1 Isolators in all Other Bays	Bus 2 Isolators in all Other Bays	Live Bus Transfer	Bus 1 ES*	Bus 2 ES*	86/1	86/2	86BB	74/1	74/2	25	Bus 1 VT MCB Healthy	Bus 2 VT MCB Healthy	Hand Crank Not inserted
Q1 Close/Open	Any Location	Open	-	-	Open	Open	-	-	-	Open	-	-	-	-	-	-	-	-	-	Not Inserted
Q2 Close/Open	Any Location	Open	-	-	Open	Open	-	-	-	-	Open	-	-	-	-	-	-	-	-	Not Inserted
Q0 Close	CRP,SAS,NCC	-	I	I	-	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Not Operated	Not Operated	Permit to Close	Healthy	Healthy	Not Inserted
	Local Control Panel	-	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q0 Open	Any Location	-	I	I	-	-	-	-	Not Operated	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q51,Q52 Close/Open	Only from LCP	-	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Bus 1 ES Close/Open	Only from LCP	-	Open	-	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Bus 2 ES Close/Open	Only from LCP	-	-	Open	-	-	-	Open	-	-	-	-	-	-	-	-	-	-	-	Not Inserted

Shortened Term	Description
LCP	Local Control Panel; Refer Clause 5.8.2.1 and 5.8.2.2
CRP	Protection/Control Panel; Refer Clause 5.8.2.3
SAS	Substation Automation System; Refer Clause 5.8.2.4
NCC	National Control Centre; Refer Clause 5.8.2.5

\* - Only Available in GIS

I - Not Intermediate

Notes:

1. Bus 1/2 isolator in all other bays open signal shall be the series connection of N/C contacts in bus 1/2 isolators in all bays. Signal will be logically high when all the relevant bus isolators are in open condition.
2. Live bus transfer is operated if both bus isolators are in closed condition in any of the bays
3. Synchronism check shall be done according to "Synchronism Check" in chapter 5.9.6.2.
4. Bus 1 earth switch status and Bus 2 earth switch status shall be taken to individual bays through a bus wiring from the bus coupler bay. Signal shall be logically high when the earth switches are in open condition.
5. Bus VT MCB Healthy status will depend on the bus isolator closed at the moment of breaker closing. If Q1 is closed bus 1 VT MCB shall be checked and if Q2 is closed bus 2 VT MCB shall be checked. Bus VT MCB status shall be wired from the bus coupler panel as a bus wiring.

## 5.16 BUS COUPLER AND BUS SECTION PROTECTION FOR 33 KV / 11 KV SCHEMES

Please refer Single line diagram in [Annexure 7](#)

### 5.16.1 General Requirements

Bus section/coupler bays at 33kV and below voltage levels shall be equipped with one protection/control IEDs to provide backup protection function to the faults that can occur in other bays and 33kV busbar of the substation.

Available IED shall include the protection/control functions mentioned below and bay controlling function as it was discussed in chapter 5.8.2

- Directional / Non – Directional Over Current function
- Directional / Non – Directional Earth Fault function
- Synchronism Check function
- Breaker Failure Protection

The hardware requirements for 33kV protection applications in addition to those in chapter 5.7 are discussed within this chapter.

### 5.16.2 Analog Circuits

#### Current Circuits

The protection core of bus section/coupler current transformer secondaries shall be connected “Holmgren” connection and connected to the relay in the following manner.

Channel 1	R Phase Current
Channel 2	Y Phase Current
Channel 3	B Phase Current
Channel 4	Summation Current of the Three Phases

#### Voltage Circuits

Bus section/coupler 1 side voltage transformers shall be connected in star configuration and connected to the first three inputs of the relay. Busbar voltage between R and Y phases of bus section/coupler 2 side shall be connected to the fourth input. Voltage transformer secondary circuit shall be protected by a 3-pole MCB located in the protection/control panel and 2-pole MCB located in respective phase voltage transformer secondary terminal boxes.

Channel 5	Bus Section 1 R Phase Voltage
Channel 6	Bus Section 1 Y Phase Voltage
Channel 7	Bus Section 1 B Phase Voltage
Channel 8	Bus Section 2 R-Y Busbar Voltage

### 5.16.3 Binary Circuits

#### Binary Inputs

The binary inputs mentioned in the table below shall be wired to the IED. The requirements mentioned under the remarks column shall also be fulfilled. If additional inputs are required to fulfil the requirements mentioned within this specification, those may be introduced.

Index	Binary Inputs	Remarks
	Control and Interlocking	
1	Q1 Closed	Bus 1 isolator closed status directly from the isolator auxiliary contacts
2	Q1 Opened	Bus 1 isolator opened status directly from the isolator auxiliary contacts
3	Q2 Closed	Bus 2 isolator closed status directly from the isolator auxiliary contacts
4	Q2 Opened	Bus 2 isolator opened status directly from the isolator auxiliary contacts
5	Q0 3 Pole Opened	Series connection of individual phase circuit breaker opened status directly from the circuit breaker auxiliary contacts
6	Q0 3 Pole Closed	Series connection of individual phase circuit breaker closed status directly from the circuit breaker auxiliary contacts
7	Lockout Relay Operated	N/C contact from the lockout relay.
8	Trip Circuit 1 Healthy	A direct contact from the trip circuit 1 supervision relay. When the circuit is healthy signal shall be logically high.
9	Trip Circuit 2 Healthy	A direct contact from the trip circuit 2 supervision relay. When the circuit is healthy signal shall be logically high.
10	Breaker Failure Inter trip from Bus Section 1 Side	Breaker failure trip received from a bay connected to the same bus section 1.
11	Breaker Failure Inter trip from Bus Section 2 Side	Breaker failure trip received from a bay connected to the same bus section 2.
<b>For GIS Applications</b>		
12	Hand Crank Not Inserted	This input should be logically high when hand crank in any of the switchgear is not inserted.
13	Bus 1 Earth Switch Opened	Bus 1 earth switch opened status directly from the earth switch.
14	Bus 1 Earth Switch Closed	Bus 1 earth switch closed status directly from the earth switch.
15	Bus 2 Earth Switch Opened	Bus 2 earth switch opened status directly from the earth switch.
16	Bus 2 Earth Switch Closed	Bus 2 earth switch closed status directly from the earth switch.
17	Interlock Bypassed	Interlock bypassed state of the selector switch mounted on the local control cubicle
<b>Protection and Synchronism Check</b>		
18	Bus 1 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
19	Bus 2 VT MCB Healthy	A series connection of auxiliary contacts of the voltage transformer secondary circuit located in the protection/control panel and voltage transformer terminal box. This signal shall be logically high when the MCBs are in closed position.
20	Gas Pressure OK in CB Cubicle	Direct contact from the pressure gauge installed in the circuit breaker chamber. Signal shall be logically high when the gas pressure is healthy.
21	Gas Pressure OK in Busbar Cubicle	Direct contact from the pressure gauge installed in the circuit busbar chamber. Signal shall be logically high when the gas pressure is healthy.
<b>Alarming</b>		

22	Relay Panel DC or AC MCB Tripped	A series connection of the auxiliary contacts in the DC MCBs and AC MCBs installed in relay panel. Signal shall be logically high when all the MCBs are switched on.
23	Circuit Breaker Gas Pressure Low Alarm (Only for SF6 Breakers)	SF6 gas pressure low signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure low alarm is generated.
24	Circuit Breaker Gas Pressure Lockout (Only for SF6 Breakers)	SF6 gas pressure lockout signal from the circuit breaker. It is preferable to have this signal directly from the circuit breaker local cubicle. If not, this signal may be taken through a contact multiplication relay. Signal shall be logically low when gas pressure lockout alarm is generated.
25	Isolators are in Local Mode (Only for AIS)	This signal shall be logically high even when one of the isolators are in local position from the isolator local control cubicle. This shall be taken through a contact multiplication relay.
26	Circuit breaker Spring Charged	Spring charged signal from the circuit breaker. This shall be taken directly from the circuit breaker local control cubicle. This signal shall be logically high when the circuit breaker spring is in charged position.
27	CB in Local Mode (Only for AIS)	This signal shall be logically high when the circuit breaker is local position from the circuit breaker local control cubicle. This shall be taken through an auxiliary relay.

### Binary Outputs

The binary output circuits required for correct operation and application of the functions listed in this chapter are mentioned below. If additional outputs are required to fulfil the requirements mentioned within this specification, those may be introduced. In Gas Insulated Substations additional contacts may be required depending on manufacturers recommendations. And also, some outputs might not be required since in certain case Q1 and Q5 are operated using a single mechanism. Those may be introduced after the approval from the ENGINEER.

Index	Signal	Remarks
1	General CB Trip TC 1	General Trip
2	General CB Trip TC 2	General Trip
3	Lockout Trip 86	Tripping that initiates the lockout according to the trip matrix
4	Q1 Isolator Close	Close Command to the bus 1 isolator
5	Q1 Isolator Open	Open Command to the bus 1 isolator
6	Q2 Isolator Close	Close Command to the bus 2 isolator
7	Q2 Isolator Open	Open Command to the bus 2 isolator
8	Q0 Circuit Breaker Close	Close Command to the Circuit Breaker
9	86/1 Reset	Contact to reset 86/1 through NCC/SAS
10	Bus 1 Earth Switch Close	Close Command to Bus 1 Earth Switch
11	Bus 1 Earth Switch Open	Open Command to Bus 1 Earth Switch
12	Bus 2 Earth Switch Close	Close Command to Bus 2 Earth Switch
13	Bus 2 Earth Switch Open	Open Command to Bus 2 Earth Switch
14	Bus Section 1 Breaker Failure Timer 2 Trip	Trip command to other bays in Bus Section 1 when breaker failure timer 2 has operated.
15	Bus Section 2 Breaker Failure Timer 2 Trip	Trip command to other bays in Bus Section 2 when breaker failure timer 2 has operated.

#### **5.16.4 Protection/Control Functions Required in 11kV/33kV Bus Section/Coupler Protection**

##### **5.16.4.1 Directional / Non-Directional Over Current and Earth Fault Functions**

There shall be directional/non-directional over current elements to detect faults in any of the three phases. The over current functions shall support tripping based on the following inverse definite minimum time curves according to IEC 60255-3.

- Standard Inverse
- Very Inverse
- Extremely Inverse
- Long time inverse
- Definite time.

Refer chapter 5.9.4.5 for further information.

A directional/non-directional earth fault element to detect phase to ground faults and having the same curve specification like the over current elements shall be provided.

##### **5.16.4.2 Synchronism Check Function**

For manual closing of the circuit breaker a release signal from synchronism is required to ensure that the feeder is energised only if the two systems on either side the circuit breaker is in synchronism.

Refer chapter 5.9.5.2 for further information about the requirements of synchronism check function.

##### **5.16.4.3 Breaker Failure Function**

A circuit breaker failure shall be incorporated in protection/control IED in each bay which is initiated by each internal and external tripping commands and supervised by current detectors in each phase. Refer chapter 5.11.4.4 for further information regarding breaker failure function. Refer chapter 5.8.11 for further information regarding the breaker failure wiring/scheme.

**5.16.5 Trip Matrix**

	DC1	DC for Breaker Failure Scheme	TC1	TC2	Initiate 50BF	86	BFP Auxiliary Relay	Trip to Other Bays
<b>BCU</b>	X							
51			X	X	X	X		
50			X	X	X	X		
51N			X	X	X	X		
50N			X	X	X	X		
67			X	X	X	X		
67N			X	X	X	X		
50BF Re-trip			X	X		X		
50BF Timer 2 Trip								X
External BFP Trip Received from Other Bays							X	
86	X		X	X				
BFP Auxiliary Relay		X	X	X	X			

There shall be a hand resettable flag relay each energized when any of the following alarms are present.

- Circuit Breaker Spring Uncharged
- Circuit Breaker Gas Pressure Low (Not applicable for vacuum interrupters)
- Circuit Breaker Gas Pressure Lockout (Not applicable for vacuum interrupters)

5.16.6 Interlocking

Operation	Operating Location	Switchgear										86	74/1	74/2	25	Bus 1 VT MCB Healthy	Bus 2 VT MCB Healthy	Hand Crank Not inserted
		Q0	Q1	Q2	Bus 1 Isolators in all Other Bays	Bus 2 Isolators in all Other Bays	Live Bus Transfer	Bus 1 ES*	Bus 2 ES*									
Q1 Close/Open	Any Location	Open	-	-	-	-	-	Open	-	-	-	-	-	-	-	-	-	Not Inserted
Q2 Close/Open	Any Location	Open	-	-	-	-	-	-	Open	-	-	-	-	-	-	-	-	Not Inserted
Q0 Close	CRP,SAS, NCC	-	I	I	-	-	-	-	-	-	Not Operated	Not Operated	Not Operated	Permit to Close	Healthy	Healthy	-	Not Inserted
	LCP	-	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q0 Open	Any Location	-	I	I	-	-	Not Operated	-	-	-	-	-	-	-	-	-	-	Not Inserted
Q51,Q52 Close/Open	Only from LCP	-	Open	Open	-	-	-	-	-	-	-	-	-	-	-	-	-	Not Inserted
Bus 1 ES Close/Open	CRP, LCP	-	Open	-	Open	-	-	-	-	-	-	-	-	-	-	Healthy	-	Not Inserted
Bus 2 ES Close/Open	CRP, LCP	-	-	Open	-	Open	-	-	-	-	-	-	-	-	-	-	-	Not Inserted

\* - Only Available in GIS

I - Not Intermediate

Notes:

1. Bus 1/2 isolator in all other bays open signal shall be the series connection of N/C contacts in bus 1/2 isolators in all bays. Signal will be logically high when all the relevant bus isolators are in open condition.
2. Live bus transfer is operated if both bus isolators are in closed condition in any of the bays
3. Synchronism check shall be done according to "Synchronism Check" in chapter 5.9.6.2.
4. Bus 1 earth switch status and Bus 2 earth switch status shall be taken to individual bays through a bus wiring from the bus coupler bay. Signal shall be logically high when the earth switches are in open condition.

Shortened Term	Description
LCP	Local Control Panel; Refer Clause 5.8.2.1 and 5.8.2.2
CRP	Protection/Control Panel; Refer Clause 5.8.2.3
SAS	Substation Automation System; Refer Clause 5.8.2.4
NCC	National Control Centre; Refer Clause 5.8.2.5



## 5.17 BREAKER SWITCHED CAPACITOR BANK PROTECTION AND STATIC VAR COMPENSATOR (SVC) PROTECTION

### 5.17.1 Breaker Switched Capacitor Bank Protection

#### 5.17.1.1 General Requirements

Protection schemes of the Breaker Switched Capacitor bank shall comply with IEC 60871.

1. Protection shall be stable for external faults and switching transients
2. All the protection functions shall have at least two stages for alarm and trip
3. Protection and control functions shall be independent and shall be mounted on separate panels
4. Protection settings for capacitor bank shall be determined using recommendations of capacitor manufacturer

Protection scheme shall comply with IEC 60871-3. The protection relays shall be of numerical type with event and disturbance recording facilities.

Two separate protection relays are required to cover the protection scheme.

The protection scheme shall include but not limited to following functions.

Unbalance Protection

Over Current / Earth Fault Protection

Directional Over Current / Directional Earth Fault Protection

Over Load Protection

Over Voltage Protection

Under Voltage / Under Current Protection

The Capacitor Bank designer/manufacturer shall submit a detail designs, calculations and protection settings giving special attention to the technical aspects covered by IEC 60871. This shall be subjected to the approval of the Engineer.

#### 5.17.1.2 Internal Fuses for Capacitor Bank

Internal fuses shall be designed to isolate faulty capacitor elements, in order to allow operation of the remaining parts of that capacitor unit and the bank.

The technical requirement regarding performance testing and co-ordination of fuse protection shall be in accordance with IEC 60871-4.

The criteria to choose the appropriate fuses shall be:

- The smallest link which can carry the normal capacitor current including any harmonic current continuously without overheating or becoming degraded.
- The fuse link must be able to withstand transient current associated with the system and capacitor switching and with atmospheric over voltage.

#### 5.17.1.3 Protection Functions

##### 5.17.1.3.1 Unbalance Protection

The capacitors which are arranged in two parallel stars (ungrounded) shall be provided with current unbalance protection. A current transformer shall be connected between the neutrals and shall be rated for full system voltage.

The designer / contractor shall supply the voltage withstand curve Vs. time of the supplied capacitor unit so that this protection will be coordinated with the characteristics.

#### **5.17.1.3.2 Over Current / Earth Fault Protection**

This shall include three phase directional/non-directional over current and earth fault function and shall comply with section 5.11.4

Additionally, by considering all the current harmonics the relay shall have RMS over current protection function as well.

#### **5.17.1.3.3 Over Load Protection**

Definite time over current function shall be provided to detect current overloads.

#### **5.17.1.3.4 Over Voltage Protection**

Three phase over voltage protection function shall be arranged with following features Instantaneous and definite time.

Inverse voltage – time characteristics and this shall co-ordinate with capacitor voltage withstand curve.

#### **5.17.1.3.5 Under Voltage / Under Current Protection**

This function shall be used to detect incoming supply failure while the circuit breaker is still switched on.

Transformer 33kV over voltage protection :

Three phase over voltage function shall be provided as back up over voltage protection for the capacitor bank.

### **5.17.2 Static Var Compensator (SVC) Protection**

General – 145 kV S.V.C bank protection is covered under this section. Protection relays shall be mounted on separate panels and not on SVC control panels.

#### **5.17.2.1 Interconnection bay protection :**

The protection scheme shall comprise of over current and earth fault protection, restricted earth fault protection and overall differential protection scheme. The Over current and Earth fault protection shall comply with clause 5.11.4 while for Restricted Earth Fault Protection scheme and differential scheme shall comply with clause 5.12.5. The differential scheme shall include the main step down transformer and interconnecting cable / overhead line.

The main step down transformer shall have Buchholz protection and Oil and winding temperature protection and shall comply with clause 5.12.6.2 & 5.12.6.3

#### **5.17.2.2 S.V.C bank protection :**

This shall comprise Differential, Over current, Earth fault, Negative sequence and Over / Under voltage protection as a minimum. The protection scheme shall comply with relevant IEC standards.

#### **5.17.2.3 Reactors**

These shall be provided with Over Current, Differential and Thermal Over load protection.

#### **5.17.2.4 Capacitors**

These shall be provided with Over Current, Differential, Thermal Over load and Capacitor Unbalanced protection.

#### **5.17.2.5 Harmonic Filters**

These shall be provided with Over Current, Thermal Over load and Capacitor Unbalanced protection.

#### **5.17.2.6 Surge Arresters**

Surge Arresters shall be utilized to limit transient over voltages that could occur due to lightning and switching transients. Contractor shall study the expected over voltages and submit all the related calculations describing the selection of the surge arresters.

### **5.18 TELEPROTECTION SCHEMES**

It is required to provide (according to the requirement) direct and permissive-transfer-trip signalling channels to send and receive signals associated with over head lines, cable and breaker failure protection schemes. These permissive and direct channels shall have transmission times of less than 20 ms.

A segregated alarm for all the signals transmitted or received in a tele protection scheme will be included in each of the related protection board.

For digital differential protection, direct fibre optic and multiplexed communication links shall be provided.

All the interface wiring between the protection board and the respective communication equipment will be performed by the Contractor. Armoured fibre optic cables shall be used from protection panel to multiplexer panel and patch panel to avoid physical damages caused by rodents, insects etc. Inside the protection cubicles, protected fibre optic cables shall be used to give added protection to the communication link.

Facility shall be available to implement either permissive schemes or blocking schemes as explained in chapter 5.9.4.

In the case of the direct tripping equipment it shall be designed not to cause a trip out put under any of the following conditions.

- Removal of any printed circuit module in either transmitter or receiver of a link.
- Switching on / off of the power supply to the tele protection equipment.
- Switching on / off of the Fibre optic equipment at either end of the line.

Shorting the out put of the tele protection transmitter or shorting of the input to the tele protection receiver.

- Operation of the HV line isolators in switchyards.

Each distance and Directional Earth Fault protection shall have independent permissive/blocking channel for tele protection. A direct channel shall be provided for breaker failure/bus bar protection.

### **5.19 TRIP CIRCUIT SUPERVISION**

Trip circuit supervision relays shall be provided to monitor each trip circuit of 245 kV, 145 kV, 36 kV and 12 kV circuit-breakers and each relay shall have sufficient contacts for visual/audible alarm and indication purposes.

In 245 kV, 145 kV, 36 kV and 12 kV systems, both trip circuit 1 and trip circuit 2 shall be supervised by the two separate trip circuit supervision relays.

The trip circuit supervision scheme shall provide continuous supervision of the trip coils and trip circuits with the circuit breaker in either the open or closed position.

Relay elements shall be delayed on drop-off to prevent false alarms during faults on D.C. wiring on adjacent circuits, or due to operation of a trip relay contact.

Series resistance shall be provided in trip circuit supervision circuits to prevent maltripping a circuit-breaker if a relay element is short circuited.

The trip circuit supervision design shall be such that in the event of a fault in any one component it shall not be possible to inadvertently trip the circuit breaker. The continuous trip circuit supervision relays shall initiate a delayed alarm after several seconds. This alarm shall operate for loss of DC voltage and for any interruption in the trip circuit wiring.

Relay alarm elements should be equipped with well resetting flag indicators.

**5.20 STATION ALARMS**

As it was mentioned in chapter 5.8.9 there shall be two devices explained below which act as annunciation devices for the station common alarms.

**5.20.1 Input Module for Station Alarms**

In order to route the station common alarms to the substation automation system an input module is required. The specifications for the required hardware of the input module shall fulfil the requirements mentioned under chapter 5.7 (please note that the input module shall not have any analog channels).

The input module shall contain the minimum number of binary inputs mentioned under chapter 5.20.1.1 of suitable voltage rating according to the respective substation specification. The pickup and drop off thresholds shall be defined such that a positive or negative earth fault in an unearthed DC auxiliary power distribution shall not cause the binary inputs to get picked up erroneously. The inputs shall be debounced in order to avoid mal operations caused by bouncy contacts. Debouncing using software is also acceptable. The pickup and drop off thresholds shall depend on the DC auxiliary supply provided as mentioned below.

Nominal Voltage (V DC)	Pickup Threshold (V DC)	Drop Off Threshold (V DC)
110	88	66
220	176	132

The input module shall contain an IEC 61850 interface so that it can be directly connected to the substation automation system without any additional equipment in between.

The bidder shall submit IEC 61850 conformance certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850-10 for the specific device bidder is presenting.

**5.20.1.1 List of Station Alarms wired to Input Module**

Index	Binary Inputs	Remarks
	<b>Diesel Generator</b>	
1	DG Common Alarm	Any Common Alarm from the Diesel Generator
	<b>Inverter 1</b>	
2	Trip	Inverter Tripped signal
3	Load on Static Bypass	
4	Common Fault	Any Common Alarm from the Inverter 1
	<b>Inverter 2</b>	

5	Trip	Inverter Tripped signal
6	Load on Static Bypass	
7	Common Fault	Any Common Alarm from the Inverter 2
<b>110V Battery Charger 1</b>		
8	AC Main Fail	Shall be generated when the incoming AC input is not available.
9	Under Voltage	Rectifier output voltage is lower than the user set value
10	Over Voltage	Rectifier output voltage is higher than the user set value
11	Charger Fail	Shall be generated when the charger output has disappeared.
12	Battery Low	Shall be generated when the battery is discharging
13	Earth Fault Negative	Shall be generated in case a negative earth fault is detected
14	Earth Fault Positive	Shall be generated in case a positive earth fault is detected
<b>110V Battery Charger 2</b>		
15	AC Main Fail	Shall be generated when the incoming AC input is not available.
16	Under Voltage	Rectifier output voltage is lower than the user set value
17	Over Voltage	Rectifier output voltage is higher than the user set value
18	Charger Fail	Shall be generated when the charger output has disappeared.
19	Battery Low	Shall be generated when the battery is discharging
20	Earth Fault Negative	Shall be generated in case a negative earth fault is detected
21	Earth Fault Positive	Shall be generated in case a positive earth fault is detected
<b>48V Battery Charger 1</b>		
22	AC Main Fail	Shall be generated when the incoming AC input is not available.
23	Under Voltage	Rectifier output voltage is lower than the user set value
24	Over Voltage	Rectifier output voltage is higher than the user set value
25	Charger Fail	Shall be generated when the charger output has disappeared.
26	Battery Low	Shall be generated when the battery is discharging
<b>48V Battery Charger 2</b>		
27	AC Main Fail	Shall be generated when the incoming AC input is not available.
28	Under Voltage	Rectifier output voltage is lower than the user set value
29	Over Voltage	Rectifier output voltage is higher than the user set value
30	Charger Fail	Shall be generated when the charger output has disappeared.
31	Battery Low	Shall be generated when the battery is discharging
<b>LVAC Cubicle Incomer 1</b>		
32	Breaker Protection Trip	Incomer 1 protection trip
33	Control Voltage Healthy	DC MCB used for control voltage is tripped
34	Auto Changeover Failed	When the feedback that the relevant MCCB is not closed if the control close command is issued shall be taken
<b>LVAC Cubicle Incomer 2</b>		
35	Breaker Protection Trip	Incomer 2 protection trip
36	Control Voltage Healthy	DC MCB used for control voltage is tripped
<b>LVAC Cubicle DG Incomer</b>		
37	Breaker Protection Trip	DG protection trip
38	Control Voltage Healthy	DC MCB used for control voltage is tripped
<b>LVAC Cubicle Bus Section</b>		
39	Breaker Protection Trip	Bus Section Protection Trip
40	Control Voltage Healthy	DC MCB used for control voltage is tripped
<b>33kV Side</b>		

41	33kV BCU Healthy	A series connection of watch dog contacts in all BCUs at 33kV side. Signal shall be logically high when all BCUs are in healthy condition.
<b>Metering Panel 1</b>		
42	VT MCB Healthy	A series connection of auxiliary contacts in VT MCBs located in metering panel 1.
<b>Metering Panel 2</b>		
43	VT MCB Healthy	A series connection of auxiliary contacts in VT MCBs located in metering panel 2.
<b>GIS Gas Pressure Alarms</b>		
44	Busbar 1 Gas Pressure Low	Gas pressure low alarm directly from the pressure gauge available in the busbar chamber
45	Busbar 1 Gas Pressure Lockout	Gas pressure lockout alarm directly from the pressure gauge available in the busbar chamber
46	Busbar 2 Gas Pressure Low	Gas pressure low alarm directly from the pressure gauge available in the busbar chamber
47	Busbar 2 Gas Pressure Lockout	Gas pressure lockout alarm directly from the pressure gauge available in the busbar chamber
<b>DDR Panel</b>		
48	DDR Healthy	DDR Healthy alarm directly wired from the common healthy alarm contact of all DDRs
49	DDR GPS Clock Healthy	GPS clock healthy status directly from a contact in GPS clock inside the DDR panel
<b>SAS Panel</b>		
50	SAS Panel GPS Clock Healthy	GPS clock healthy status directly from a contact in GPS clock inside the SAS panel

### 5.20.2 Station Alarm Annunciator

In addition to the Input module installed, alarm annunciator which operates independently of the input module shall be installed for the station alarms in the busbar protection panel.

The number of annunciation windows shall suit the requirements discussed in chapter 5.20.2.1. Annunciator shall comprise of visual alarming capability using lamp indications and audible alarming capability using a “hooter”. Alarm units shall be arranged in a modular format such that failure of one module shall not disrupt the visual or audible alarming capability of other unaffected modules and any feature discussed within this chapter. The annunciation unit shall preferably be equipped with two independent power supply units. Failure of one shall be indicated and shall not derail the performance of the annunciation unit. Each power supply unit shall be capable of operating at 88VDC-264VDC voltage range without any hindrance and without involving any additional hardware.

Using an internally generated field voltage for the annunciation circuits is also acceptable.

Device shall consist of the following push buttons for convenient operation.

- Test – This push button is used to test the functions of the annunciator. When pressed all the lamps shall be illuminated and the audible alarm should be initiated. Using this the user can test the operation of lamps and the hooter conveniently.
- Silence – This push button is used to silence the audible alarm without acknowledging or resting the visual alarm.
- Acknowledge – This push button is used to acknowledge the visual alarm. Operation of acknowledge and reset push buttons will be described in the coming paragraphs.
- Reset - This push button is used to reset the visual alarm. Operation of acknowledge and reset push buttons will be described in the coming paragraphs.

When multiple alarms occur at once the first alarm to be initiated shall be indicated by the visual alarm. (By flashing when other alarms are solidly lit)

Following operating sequences shall be available in the visual alarming component and changing the operating shall be from the device itself.

- Status Only – There may be certain inputs which are considered to status of components needed to be monitored. When set in this mode, the change of status shall not initiate the audible alarm and will automatically get reset once the input disappears without operating personnel intervention.
- Flashing until Acknowledged – The visual alarm shall flash until the acknowledge button is pressed.
- Latched Until Reset – The visual alarm shall flash until the acknowledge button is pressed. And will not reset even if the input drops out until the reset button is pressed.
- Non-Latched/Reset when Acknowledged - The visual alarm shall flash until the acknowledge button is pressed. And will disappear if the input drops out without the need for pressing the reset button.

### 5.20.2.1 List of Alarms in Alarm Annunciator

Alarms mentioned in chapter 5.14.2.6.2 shall be taken a group alarms to the annunciation device.

Index	Alarm	Remarks
1	Diesel Generator Fail	Any common alarm in the diesel generator
2	Inverter 1 Fail	Any common alarm in inverter 1 panel
3	Inverter 2 Fail	Any common alarm in inverter 2 panel
4	220V DC Battery Charger 1 Fail	Any common alarm in 220V DC Battery Charger 1 panel
5	220V DC Battery Charger 2 Fail	Any common alarm in 220V DC Battery Charger 2 panel
6	48V DC Battery Charger 1 Fail	Any common alarm in 48V DC Battery Charger 1 panel
7	48V DC Battery Charger 2 Fail	Any common alarm in 48V DC Battery Charger 2 panel
8	33kV Side BCU Fail	Shall alarm when any of the 33kV BCU is failed
9	DDR Fail	Shall alarm when the DDR/GPS clock inside is not healthy
10	SAS GPS Clock Fail	Shall alarm when GPS clock inside the SAS panel is not healthy

## 5.21 DIGITAL DISTURBANCE RECORDER (DDR)

### 5.21.1 General Requirements

This specification establishes the technical requirements for designing, manufacturing, installation and testing of Digital Disturbance Recorder (DDR).

The DDR is expected to have a lifetime of at least twenty years. Design of this equipment shall emphasise system availability, reliability and facility for easy installation, maintenance and expansion. The PC based architecture/processing should not be used for DDR system operation, detecting or recording purpose.

The DDR system shall be a complete modular designed stand alone system to monitor analogue input channels and digital input channels as specified in 5.21.2. DDR system shall be capable of simultaneous monitoring for at least in 2 different sampling /scanning rates for required input channels.

The DDR shall be a complete automatic digital recording system capable of sensing, acquiring, storing and recording the data, printing and transmitting disturbance records to the analysis units (Local Station Computer & Remote Master Analysis Station). Disturbance

records shall be permanent and accurate and shall include information on the pre fault, fault and post fault of transient disturbances in the power system.

The failure and switching of DC power supply should not cause any false recording. All operating parameters and configuration data shall be stored in a non-volatile memory so that the system shall return to normal operation after a power up cycle.

The DDR shall have several programmable levels of password protection, in order to view data records, retrieve data records and to change parameters etc.

The DDR shall operate on either of two modes; the first mode requires DDR with a dial up modems to report a disturbance record immediately after recording the event to remote master analysis station and SMC. The second mode requires the DDR to hold its data transmission until pooled by Remote Master Analysis Station or SMC, either automatically or manually.

The Local Analysis Unit shall be a Microsoft Windows 10(or better) portable computer. Analysis unit shall not be permanently installed at the site.

Remote Master Analysis Station shall be a Microsoft Windows 10(or better) Computer, stationed at the Protection Branch.

The DDR shall register on each record, the sequential number of the fault, date, month, year, hour, minute, second, millisecond, substation name, feeder name and the parameter triggered.

DDR components mounted and wired in a standard 19 inch rack and enclosed in a cabinet..

### 5.21.2 Signal List for Digital Disturbance Recorder

DDR Signals for a typical 220kV Line Feeder			
A	Analog Channels	A1	Digital Channels
A2	1 Current Phase R	1	Circuit Breaker Trip - R
	2 Current Phase Y	2	Circuit Breaker Trip - Y
	3 Current Phase B	3	Circuit Breaker Trip - B
	4 Current Phase N	4	Main 1/Main 2 Fail
	5 Voltage Phase Rn	5	Main 1/Main 2 AR Close command
	6 Voltage Phase Yn	6	Pole Discordance
	7 Voltage Phase Bn	7	Lockout Relay Operated
		8	Main 1 Trip -R
		9	Main 1 Trip -Y
		10	Main 1 Trip -B
		11	Main 2 Trip -R
		12	Main 2 Trip -Y
		13	Main 2 Trip - B
		14	Main 1 Backup Protection Operated
		15	Main 1 Distance Protection Operated
		16	Main 1 Differential Protection Operated
		17	Main 1 Aided DEF Protection Operated
		18	Main 2 Back-up Protection Operated
		19	Main 2 Distance Protection Operated
		20	Main 2 Differential Protection Operated
		21	Main 2 Aided DEF Protection Operated
		22	Busbar /Breaker Failure Trip



<b>B DDR Signals for a Typical 220/132/33kV Transformer</b>			
<b>B2</b>	<b>Analog Channels</b>	<b>B1</b>	<b>Digital Channels</b>
1	220kV side Current Phase_R	1	Circuit Breaker Trip - 220kV
2	220kV side Current Phase_Y	2	Circuit Breaker Trip - 132kV
3	220kV side Current Phase_B	3	Circuit Breaker Trip - 33kV
4	220kV side Current Phase_N	4	Lockout Relay Operated
5	132kV side Current Phase_R	5	Differential Protection Operated
6	132kV side Current Phase_Y	6	220kV -Over Current /Earth Fault Operated
7	132kV side Current Phase_B	7	132kV-Over Current /Earth Fault Operated
8	132kV side Current Phase_N	8	33kV -Over Current /Earth Fault Operated
9	33kV side Current Phase_R	9	Stand by Earth Fault 132kV
10	33kV side Current Phase_Y	10	Stand by Earth Fault 33 kV
11	33kV side Current Phase_B	11	Restricted Earth Fault 132kV
12	33kV side Current Phase_N	12	Restricted Earth Fault 33 kV
13	220kV Voltage Phase_Rn	13	Directional Over current/Directional Earth Fault 33kV
14	220kV Voltage Phase_Yn	14	Over voltage Protection Operated
15	220kV Voltage Phase_Bn	15	Over fluxing protection operated
16	132kV Voltage Phase_Rn	16	Thermal Overload operated
17	132kV Voltage Phase_Yn	17	Transformer mechanical protection trip operated
18	132kV Voltage Phase_Bn	18	Transformer mechanical protection alarm operated
19	33kV Voltage Phase_Rn	19	Busbar /Breaker Failure TRIP
20	33kV Voltage Phase_Yn	20	Protection panel Relay 1/2/3/4/5 fail
21	33kV Voltage Phase_Bn	21	

<b>C DDR Signals for a typical 132kV Line Feeder</b>			
<b>C2</b>	<b>Analog Channels</b>	<b>C1</b>	<b>Digital Channels</b>
1	Current Phase_R	1	Circuit Breaker Trip
2	Current Phase_Y	2	Auto Reclose Close command
3	Current Phase_B	3	Lockout Relay Operated
4	Current Phase_N	4	Main 1 Backup Protection Operated
5	Voltage Phase_Rn	5	Main 1 Distance Protection Operated
6	Voltage Phase_Yn	6	Main 1 Differential Protection Operated
7	Voltage Phase_Bn	7	Main 1 Aided DEF Protection Operated
		8	Main 2 Back -up Protection Operated
		9	Main 2 Distance Protection Operated
		10	Main 2 Differential Protection Operated
		11	Main 2 Aided DEF Protection Operated
		12	21/67N/DTT Carrier Received
		13	21/67N/DTT Carrier Send
		14	Busbar / Breaker Failure Protection Operated
		15	Protection Relay Fail

<b>D DDR Signals for a typical Bus Coupler / Bus Section (220/132kV) and Bus Bar protection</b>			
<b>D2</b>	<b>Analog Channels</b>	<b>D1</b>	<b>Digital Channels</b>
1	BC / BS Current Phase_R		Circuit Breaker Trip
2	BC / BS Current Phase_Y		Over current /Earth fault Protection Operated
3	BC / BS Current Phase_B		Busbar / Breaker Failure Protection Operated
4	BC / BS Current Phase_N		Busbar Protection Zone 1 Trip
5	Bus 1 Voltage Phase_Rn		Busbar Protection Zone 2 Trip
6	Bus 1 Voltage Phase_Yn		Breaker Failure Protection Operated
7	Bus 1 Voltage Phase_Bn		
8	Bus 2 Voltage Phase_Rn		
9	Bus 2 Voltage Phase_Yn		
10	Bus 2 Voltage Phase_Bn		

E DDR Signals for a typical 132/33kV Transformer			
E2 Analog Channels		E1 Digital Channels	
1	132kV side Current Phase_R		Circuit Breaker Trip_132kV
2	132kV side Current Phase_Y		Circuit Breaker Trip_33kV
3	132kV side Current Phase_B		Differential Protection Operated
4	132kV side Current Phase_N		132kV Restricted Earth Fault Operated
5	33kV side Current Phase_R		33kV Restricted Earth Fault Operated
6	33kV side Current Phase_Y		132kV-Over Current /Earth Fault Operated
7	33kV side Current Phase_B		33kV -Over Current /Earth Fault Operated
8	33kV side Current Phase_N		Over Fluxing Operated
9	132kV side Voltage Phase_R		33 kV Stand by Earth Fault Operated
10	132kV side Voltage Phase_Y		Thermal Overload Protection Operated
11	132kV side Voltage Phase_B		Over Voltage Protection Operated
12	33kV Voltage Phase_Rn		33kV Directional Over current/Directional Earth Fault Operated
13	33kV Voltage Phase_Yn		Transformer mechanical protection Alarm operated
14	33kV Voltage Phase_Bn		Transformer mechanical protection Trip operated
			Busbar / Breaker Failure Protection Operated
			132kV or 33kV Relay failure

F DDR Signals for a typical Bus Coupler / Bus Section / Bus Bar (33kV)			
F2 Analog Channels		F1 Digital Channels	
1	BC / BS Current Phase_R		Circuit Breaker Trip
2	BC / BS Current Phase_Y		Overcurrent/Earthfault Protection Operated
3	BC / BS Current Phase_B		Breaker Failure Protection Operated
4	BC / BS Current Phase_N		
5	Bus 1 Voltage Phase_Rn		
6	Bus 1 Voltage Phase_Yn		
7	Bus 1 Voltage Phase_Bn		
8	Bus 2 Voltage Phase_Rn		
9	Bus 2 Voltage Phase_Yn		
10	Bus 2 Voltage Phase_Bn		

H DDR Common ALARMS			
H2 Analog Channels		H1 Digital Channels	
1	DC 1		DC Earth fault
2	DC 2		
3	Relay Room Temperature		

### 5.21.3 Input Channels

The input circuitry is to accurately reproduce all analogue signals with frequency components of less than one-third the variable sample rate.

The signals to the analogue inputs shall be connected from voltage and current transformers and station battery voltages. The signal conditioning equipment shall consist of the necessary current shunts, Voltage dividers or auxiliary current transformers, voltage transformers, isolators, and electronic devices to attenuate and condition the signal inputs.

Each input channel shall be supplied with a Surge Withstand Current (IEC 60255-5 standard), and automatically programmable low pass anti aliasing filters (digital channels require only fixed low-pass filters) before the A/D converter.

All analogue input signals shall be digitised with at least 16 bits of resolution for clear waveform reproduction.

Interactive software calibration adjustments of all channels shall be performed in the field. Test equipment shall have a better accuracy. Calibration shall be easily verified locally with the software. Calibration procedures shall provide real-time display of converted analogues. While the machine is recording no other functions of the machine shall be degraded in any way. Each input channel shall be isolated from all other inputs, station battery, and chassis as per IEC 60255-5. SURGE WITHSAND CURRENT shall be applied to analogue, digital, power supply inputs, and auxiliary inputs.

Preferably, all analogue input channels shall be easily converted between current input, voltage input, and DC voltage input.

Analogue channels, when used for the measurement of currents, shall have continuous current rating of 1 Ampere or 5 Amperes RMS appropriately. Input scaling shall be easily adjustable and the adjustments shall be easily accessed. If shunts or scaling resistors are used they must be easily and quickly changeable.

Analogue channels when used for measurement of Voltage shall have nominal rating of 110 V r.m.s, 50 Hz.

All the digital channels shall be capable of selectable triggering of the DDR on leading and/or trailing edges from either the normally open or normally closed state. The digital input shall be connected with 24 V – 250 V DC via potential contacts or dry contacts. The maximum event resolution time shall be 1 ms.

#### 5.21.4 Data Acquisition

##### Sampling

At least 2 (Two) different and simultaneously programmable sampling rates shall be available at any time to monitor the fast transient faults and Slow phenomena faults like, power swing, Frequency variation, Voltage drop and Higher Harmonics etc. Each sampling rate shall be independently programmable either locally or remotely.

**Fast sampling:** Fast sampling rate shall be programmable from 500 Hz to 10 kHz

Pre fault time shall be settable from 0.1 second to 2 seconds.

Post fault time shall be settable from 0.1 second to 20 seconds.

**Slow sampling:** Slow sampling rate shall be programmable from 10 Hz to 500 Hz.

Pre fault time shall be settable from 1 second to 300 Seconds.

Post fault time shall be settable from 1 second to 600 Seconds.

(Continuous change in sampling rate is preferred; in reasonable steps is also considered.)

The DDR system shall be capable of detecting and recording any type of incident without any alteration to the Dynamic fault /event length.

Fast transient and slow phenomena events should be able to identify, detect, record simultaneously and produce in two different graphical records. The DDR system shall be equipped to record and store such a data independently in the inbuilt storage unit for easy and fast diagnosis / analysis.

The DDR shall be capable of producing a record of the fault including the pre-fault information. The pre-fault memory shall be in operation at all times providing continuous system monitoring.

Upon occurrence of a trigger condition/s, the DDR shall automatically start to record data until the trigger condition/s disappears.

During the post-fault time if another trigger reoccurs, the recording time will be extended considering the fault time and post - fault time of the new trigger. Once the post fault time has been reached the DDR shall stop recording and wait for the next trigger condition. The DDR system should not alter the actual length of an event or it's characteristics in any manner in order to gain memory /Storage capacity.

##### Sensors:

The DDR shall be supplied with programmable and user selectable starting sensors from the following types; Over Voltage, Under Voltage, Over Current, Negative Sequence, Positive Sequence, Zero Sequence, Over Frequency, Under Frequency, Rate of Change of (Voltage,

Current, Power and Frequency), Power Swing etc. Trigger sensors shall be locally or remotely programmable and settable.

The Sensor's proprietary parameters shall be able to program individually for each sensor and should be able to record in a graphical form in addition to the connected physical input signals. [Such as Zero Sequence, Frequency etc..]

These Sensors shall be associated with the input signals used for recording purposes. Triggers on each channel can be armed or disarmed and the operator could change sensor levels while the DDR is operational. All sensors shall be automatically re-settable after a disturbance.

The recorder shall be capable of programming from the following user specified sensor library: for initiating (triggering) the recording of the system.

- External start (Manuel or remotely)
- Event channel level or edge sensor (for dry / wet contact)
- Level Sensor (Over / Under for Voltage, Current etc.)
- Negative sequence voltage / Current
- Zero sequence
- Rate of change, voltage, current, frequency, and power
- Over frequency or under frequency (Frequency deviation)

The trigger level and all other parameters (post-faults, maximum fault time etc.) shall be individually adjustable and all the triggers whether analogue or event shall be capable of being enabled or disabled locally or from the remote Master Analysis Station.

#### **5.21.5 Data Storage**

System shall provide a minimum memory (RAM) capacity of 512 MB with provision to up-grade its capacity. In addition to this memory (RAM) it should be equipped with an auto maintained integrated/in built hard disk/flash disk unit with a minimum capacity of 120 GB which shall be up-gradable, when required.

All operating parameters and configuration data shall be stored in a non-volatile memory so that the system shall return to normal operation after a power up cycle.

The operation of the DDR should not incur any loss of data.

#### **5.21.6 Communication**

One serial port shall be provided on the DDR for asynchronous communication of data between local and remote stations. Transmission shall be continuous asynchronous communications and not burst communications. A second serial port shall be provided for local direct communications. All or selected parts of a fault record should be transmitted. The operator shall interrupt transmission of a record at any time.

The DDR shall be capable of communicating with the Local Station Monitoring Computer (SMC) through a fibre optic media and Remote Master Analysis Station located at Protection Development office, Kent road, through Ethernet interface [LAN – at least 10Base –FL (TCP /IP)] which would be made available at the substation. The necessary hardware shall be supplied for this remote communication network and the network configuration shall be carried out by the bidder. The existing CEB fiber network from the relevant grid location to Kent Road premises is to be used as the communication media and the CEB can arrange site visit if necessary.

The bidder shall use the existing remote master analysis station at CEB Kent road adding the necessary hardware and software if it is compatible to the existing system. Otherwise a new Master station shall be provided to above location for the correct remote operations of proposed DDR

The Remote Master Analysis Station shall allow to retrieve data records from the installed DDR location manually, either all or a group of the available channels in the fault record

The proposed communication network layout drawing comprising the relevant local DDR and Master Stations at CEB Kent Road system shall be supplied with the offer.

### 5.21.7 Alarm Output Channels

Alarm outputs shall be capable of driving an annunciator system. The alarms shall be internally latched until the alarm condition returns to normal.

The alarm shall be programmable for the following functions.

The DDR shall be capable of self-checking (Watchdog) all circuitry including power supply circuitry and shall activate a hardware failure alarm when it fails the self-check function. The hardware failure alarm shall activate an NO and NC output contact as specified below.

Nominal Voltage (V DC)	Breaking Capacity with L/R=40ms (A)	Continuous current (A)	Make and Carry for 0.2s (A)
220	0.2 at 250 V DC	6	30

The DDR shall automatically alarm when Hard Disk is full. This shall be a selectable value above 50 % of hard disk used.

The DDR shall automatically alarm when the synchro clock signal is not present.

### 5.21.8 System Clock

The DDR shall be supplied with an accurate built-in calendar clock to provide Date, Month, Year, Hour, Minute, Second and millisecond. The System clock shall have a battery back up in case of power failure.

A GPS (Global Positioning System) clock shall be installed for the accurate time synchronising of the DDR internal clock. Failure of GPS clock shall be alarmed on the station alarm Annunciator and the SAS via the Input Module for station alarms.

### 5.21.9 Power Supply

The DDR system shall utilise a DC to DC converter type regulated power supply to provide transient surge isolation between the station battery and the DDR.

The power supply shall be self starting, operating over an input voltage range of 80% to 120% of rated voltage. The rated voltage at the station is 110 V DC or 220V DC.

The DDR system shall be equipped with an On- Off switch for power supply.

The power supply shall be immune for the damages occurring from accidental short circuiting of the input or out put DC supply.

The DDR system shall not produce any signal noise or impulse on the input DC supply.

## 5.21.10 Analysis Unit

### 5.21.10.1 Hardware Requirement:

The bidder shall use the existing remote master analysis station at CEB Kent road adding the necessary hardware and software if it is compatible to the existing system. Otherwise a new Master station shall be provided to above location for the correct remote operations of proposed DDR

The Remote Master Analysis Station computer shall be Intel® Core i5 Processors computer (or better) running under Windows 10 or later, desktop Minimum RAM memory shall be 2 GB.

The Remote Master Analysis Station should include a computer system with a DVD/CD read/write drive and one hard disk drive or equivalent storage with at least 1 TB of storage for execution of functions, and storage of information as assigned to the master unit. Interfaces from computer to hard disk shall be designed to industry standards.

The Remote Master Analysis Station computer should have one LAN (RJ45) port and four USB ports. The Remote Master Analysis Station should include one high resolution SVGA (1280 x 1024) non-interlacing colour LED monitor (17 inch or more), and the computer should include a compatible colour graphics display card with at least 3 GB of memory and interconnecting cables.

The transfer of data between the DDR and the Remote Master Analysis Station using Fibre optic based LAN/Ethernet network shall be possible.

The transmission of data between the Remote Master Analysis Station and the DDR shall include data integrity measures such as error checking and retransmit or error correction to ensure accurate data transfer.

The Remote Master Analysis Station and modems shall be powered from 230 VAC.

The local analysis shall be possible from a IBM compatible, Intel 6<sup>th</sup> Generation Core i7(or better) laptop computer running on windows 10 or later with at least 8 GB memory, 1 TB hard disk storage, DVD/CD read/write drive, 1 serial port, 1 USB port provided by CEB

### 5.21.10.2 Software Requirement:

The following features are the general software requirements of the Remote Master Station. Local analysis unit shall also have the same software.

The Remote Master Analysis Station display and analysis software shall have pull down menus and graphical symbols, and shall be easy to follow even for an inexperienced operator. This shall include graphics, and on-screen buttons or Menu driven windows commands.

The Remote Master Analysis Station shall be capable of loading a complete or partial fault record. Several screens of data shall be held in memory at the same time so that scrolling through screens will be very fast.

The operator shall have the capability of starting with any channel of a fault record and at any point on a waveform.

The operator shall also have the capability of displaying on a screen all channels or only operator selected channels, both analogue and digital channels with user selectable offsets, amplitude, and time scale shall be selectable by the operator. It should be possible to display at least 16 Analogue channels on the same page.

The software for the Remote Master Analysis Station shall be capable of displaying on a VGA / SVGA screen all analogue waveforms and digital signals.

Different user selectable colour waveforms shall be required.

User-selectable amplitude, time bases, and waveform placement shall be required. In addition, capability to place multiple waveforms on the same axis or inserting or deleting waveforms shall be required.

Software should be able to derive the system frequency (as a calculated channel or by any other method) from a current/voltage input. It shall be shown on screen as well as on hard copy.

Amplitude scaling of any analogue input trace up to full screen shall be required for ease in viewing. This function shall be available both on screen and on hardcopy.

The placement of the cursor shall automatically give values in either PEAK or RMS as selected by the operator. Multiple cursors shall be required to read the difference in time and the difference in amplitude of waveforms. Placement of a cursor on a waveform shall automatically read the value. Placement of 2 cursors shall read the time span of the two and the value of the selected cursor or the RMS value between the two cursors.

The operator shall be capable of selecting groups of waveforms for at least one cycle or more for a given time frame. The software shall then be able to perform RMS integration, harmonics analysis up to the 15<sup>th</sup>, and other manipulations on the selected waveform. This "time frame" can be scrolled over the entire waveform with the integration being recalculated as it moves.

The Remote Master Analysis Station shall identify each channel of a respective DDR. The Remote Master Analysis Station shall be capable of labelling each plotted output with the relevant information of the substation, feeder, date, time of trigger.

Analogue values should be labelled as r.m.s or peak values. Labels shall be specified in engineering units, which gives a facility to read primary or secondary side of the power system value.

The Remote Master Analysis Station shall be capable of producing calculated channels with the use of the recorded line currents and voltages. The Remote Master Analysis Station shall be able to store at least 10 predefined equations of a substation bus arrangement to calculate waveforms (e.g. Power, sequence, harmonics etc.). The Remote Master Analysis Station shall be able to automatically retrieve fault records from the DDR, calculate waveforms according to predefined equations, and print all calculated waveforms.

The Remote Master Analysis Station function shall allow the selection of a screen area for exporting to other software applications (e.g. Word processor, graphic program,)

The Remote Master Analysis Station shall offer the possibility to display the digital event information contained in a record as a time tagged listing of the signal transitions (sequence of Event Recorder type listing). This listing shall be available for display or printing (manually and automatically). Events shall be time tagged with a precision corresponding to the selected sampling rate.

All or selected parts of a fault record can be transmitted. The operator can interrupt transmission of a record at any time. An error in the communication shall not deter the transmission of a record in its entirety.

The Remote Master Analysis Station shall be able to receive a complete self-diagnostic report of the DDR. The Remote Master Analysis Station shall trigger and retrieve a record from a remote DDR, which shall enable the checking of the actual values and calibration. The Remote Master Analysis Station shall be capable of individually identifying all remote alarm conditions of the DDR.

The data format for DDR shall be convertible to Comtrade and to at least one other common "MATH" program file format.

If there is a different software for the configuration of the fault recorder equipment that shall be provided. The configuration software shall be capable of providing following facilities.

- Change communication parameters of the equipment
- Shall be capable of making the configuration online or offline through a template.
- Shall be capable of sending new configuration in to the DDR or retrieving the existing configuration.
- Shall be capable of creating users with different access levels.
- Shall be capable of adding new digital channels and configuring relevant signals associated with them.
- Shall be capable of adding new analog channels configuring relevant signals associated with them.
- Shall be capable of changing over current pickup thresholds in each analog channels.
- Shall be capable of calibrating the analog channels.
- Shall be capable of changing the pickup and drop off threshold values of binary input channels.

If the above-mentioned configurations can be done using the same software but from a different access level, user name and the password to access that level shall be provided.

#### **5.21.10.3 Analysis of Fault Data:**

Fault data analysis is the primary task of the Remote Master Analysis Station. The analogue and event data shall be displayed graphically both on the screen and on a printer with the operator having control over this display.

Once a fault record is stored within a PC the following display and analysis facilities should be achievable.

- Each analogue channel and each group of events shall be capable of being displayed individually or together with other selected channels.
- Each analogue channel shall be capable of being amplified individually or with other selected channels.
- The display's time base shall be capable of being expanded or contracted.
- The instantaneous primary values of current and voltage shall be capable of being displayed at a moveable cursor position.
- The instantaneous time with respect to a selectable cursor position shall be displayed.
- The identification of the station and circuit, the fault reference number, the trigger data, time and source, identification of individual analogue and event channels and amplitude scale shall all be capable of being displayed.
- Any display on the screen shall be capable of being printed out.
- The analysis package shall include mathematical analysis features such as calculation and display against time, harmonics, frequency, phase angles, real and reactive power X/R and time constant etc.



- It shall be possible to calculate manually the impedance between phases or phase to earth along the waveform.
- Calculation of the distance to the fault (Fault Location) and subsequent presentation of statistical data shall be possible. The algorithm of the fault locator shall be submitted for approval.
- Time measurement from any set cursor to trigger reference line.
- Multi-colour presentation.
- Vector presentation values and phase angle in graphical form.
- Harmonic analysis.
- ONLINE help text function etc.

The manufacturer shall supply necessary manuals and provide information with the system.

**5.21.11 Panel Installation and engineering works**

The DDR installation works shall be carried out by providing all necessary cables and other necessary accessories.

All control panel wiring, secondary control wiring in existing numerical relays/controllers shall be carried out in a neat and systematic manner with cable supported clear of the panels and other surfaces at all points to obtain free circulation of air.

In all cases, the sequence of the wiring terminals shall be such that the junction between multi-core and terminals is affected without crossover. Except where terminals are approved by CEB for use with bare conductors, claw washers or crimped connectors of approved type shall be used to terminate all small wiring. Insulating bushes shall be provided where necessary to prevent the chafing of wiring.

All panel wiring shall comply with the requirements of BS 6231, Type A or B, or the relevant IEC as appropriate. Conductors shall be of copper and have a minimum cross section as mentioned below. Generally, flexible conductors shall be used.

Single stranded conductors should only be employed for rigid connections which are not subject to movement or vibration during shipment, operating or maintenance. Flexible conductors equivalent to 1.5 mm<sup>2</sup> or smaller sizes generally shall only be employed with written approval.

The required list of analog channels and digital channels are shown in 5.21.2 and the minimum requirement will be to monitor all 220kV and 132kV bays in the grid.

**5.22 RELAYS (LOCKOUT RELAYS, FLAG RELAYS AND AUXILLIARY RELAYS)**

**5.22.1 General Requirements**

Offered relays shall conform with the following IEC standards.

Dielectric test	2kV, 50Hz, 1min. as per IEC 60255-5
Impulse voltage test	5kV, 1.2/50µs. 0.5J., as per IEC 60255-5

Insulation resistance	>100 M ohms at 500V DC. as per IEC 60255-5
Dry heat test	IEC 60068-2-2 +55°C and +70°C
Damp heat cyclic test	IEC 60068-2-30 12hrs+12hrs cycle at+55° C / +25° C with RH98% for 6days
Storage test	IEC 60068-2-8 +70° C for 72hrs and -25o C for 72 hrs
Vibration response	IEC 60255-21-1 Class-1 10-150Hz, 0.5g, 3 axis
Endurance test	IEC 60255-21-1 Class-1 10-150Hz, 1.0g, 3 axis

### 5.22.2 Lockout Relays

The relays that are used as “Lockout” relays shall be “Bistable” type relays. There shall be two relay coils known as “Set” and “Reset” coils. Once the “Set” coil is energised externally armature shall move towards one side and be locked permanently even if the “Set” coil is de-energised. It shall be unlocked and moved to the other side when the “Reset” coil is energised. Once the armature is moved towards one side due to energisation of either coil the supply to the respective coil shall be cut-off internally in order to avoid additional heating and power consumption. Both coils shall be protected by fly back diodes.

The relay coil circuits shall be insensitive to capacitive discharge current that can occur due DC circuit earth faults.

It shall be possible to reset the relay manually through a hand-operated mechanism. Additionally when the relay “Set” coil is operated and armature is moved a visual indication shall be available for the user in the relay itself.

Relay shall fulfil the following specifications.

Operating Voltage (U <sub>N</sub> ) in V	110V or 220V*	
Operation Range in % of UN	80-110	
Permitted Ambient Temperature in °C	0 to +55	
Current Carrying Capacity in A	200ms	90
	1s	50
	Continuous	10
Breaking Capacity (At L/R<40ms) in A	110V DC	3
	220V DC	1
Insulation Tests	Dielectric tests, 50 Hz, 1 min in kV	2.5
	Impulse voltage test, 1,2/50 μs, 0,5 J in kV	5

\* - This shall be selected according to the DC supply of the substation.

### 5.22.3 Flag Relays

Flag relays used in mechanical protection tripping and alarming in transformer bays shall contain at least four N/O outputs as explained in chapter 5.12.6.1. They shall contain clear flag indication to the user when the relay is operated. All the relays shall be of hand resettable type.

Relay shall fulfil the following specifications.

Operating Voltage (U <sub>N</sub> ) in V (DC)	110V or 220V*
Operation Range in % of UN	80-110

Permitted Ambient Temperature in °C		0 to +55
Current Carrying Capacity in A	200ms	90
	1s	50
	Continuous	10
Breaking Capacity (At L/R<40ms) in A	110V DC	3
	220V DC	1
Insulation Tests	Dielectric tests, 50 Hz, 1 min in kV	2.5
	Impulse voltage test, 1,2/50 μs, 0,5 J in kV	5

### 5.22.4 Auxiliary Relays

Auxiliary relays shall be used for contact multiplication purposes are discussed in this chapter. Those relays shall fulfil the following specifications.

Operating Voltage (U <sub>N</sub> ) in V		110V or 220V
Operation Range in % of U <sub>N</sub>		80-110
Permitted Ambient Temperature in °C		0 to +55
Continuous Current Carrying Capacity in A		5
Breaking Capacity (At L/R<40ms) in A	110V DC	3
	220V DC	1
Insulation Tests	Dielectric tests, 50 Hz, 1 min in kV	2.5
	Impulse voltage test, 1,2/50 μs, 0,5 J in kV	5

## 5.23 OTHER EQUIPMENT AND DOCUMENTATION

### 5.23.1 Selector Switches

Selector switches are used to switch between various states which are required to be operated independently. Locations where such switches are required was explained in previous chapters.

Selector switch shall contain an escutcheon plate which is used to emboss the wording that used to identify the various switching states of the switch by the user. Markings shall be clearly visible and indelible. All two position and three position switches shall be 60° type switches such that all the positions of the switch are separated by 60° angle between each other. Switch mounting method shall be inline with IP51 rating. Maximum wire gauge that can be used shall be at least 2.5mm<sup>2</sup>. There shall be proper insulation and separation between the terminals such that accidental external short circuiting is minimised.

Basically, there will be two types of selector switches.

- Lockable with a key switch

Selector switch can be moved only after it is unlocked by a key. It shall be possible to take the key out when the switch is at it's locked in position. Locking mechanism shall not derate the IP rating of IP51.

- Non-lockable

The selector switch shall be freely movable and not controlled by an external key.

### 5.23.2 Push Buttons

Each push button shall be of a modular design, which can be conveniently fixed and maintained by the user. Following modules shall be included such that installation and maintenance would be convenient.

- Front Element

Shall comprise of an ergonomic design and the front rings shall be of black colour. Elements shall be high resistance to external matter and shall have at least IP 66 class of protection. Push buttons with lamps shall be illuminated such that it is clearly in all external brightness levels.

- Legend Plate

Legend plate where the customized naming can be engraved.

- Fixation Ring

This is used to fix the front element to the panel.

- Coupling Plate

Coupling plate shall be used to mount the contacts blocks that contain N/C and N/O contacts.

- Contacts Blocks

Contacts blocks where the user can take N/O and N/C signals depending on his requirement.

### 5.23.3 Miniature Circuit Breakers and Auxiliary Contacts

Miniature circuit breakers shall comprise of a thermal element to protect against long duration overloads and magnetic element to protect against short circuits. A current limiting MCB is preferred which limits the energy dissipated by the fault until it's cleared by the MCB. Each MCB shall support mounting on a 35mm DIN rail. There shall be identical wire screw type connection at both load side and the source side. Switch on and off status shall be clearly visible to the user. Breaking capacity of all MCBs shall be 6kA according to IEC 60947-2. For all applications "C" characteristic according to IEC 60898 shall be used. Each MCB shall facilitate connecting at least two auxiliary contacts which operates based on the status of the MCB.

#### 5.23.3.1 Voltage Transformer Circuit MCBs

According to the content discussed in previous chapters there shall be a three pole MCB installed inside the marshalling kiosk/local control cubicle for each voltage transformer secondary circuit. Specification of the required MCB is as follows.

Type – 3 Pole

Operating Voltage – 110V AC

Current Rating – 2A (This may be increased in case it is difficult to coordinate with downstream MCBs if there are any or VT secondary burden is too small)

Current Breaking Capacity – 6kA

Auxiliary Contacts – At least two N/O (Closes when the MCB is "ON" state) contacts

#### 5.23.3.2 DC MCBs

According to the content discussed in previous chapters there shall be a two pole MCB installed inside the marshalling kiosk/local control cubicle for each DC circuit. Specification of the required MCB is as follows.

Type – 2 Pole

Operating Voltage – Operating voltage shall depend on the substation battery voltage (220V DC or 110V DC)

Current Rating – A proper MCB selection calculation and coordination study shall be performed.

Current Breaking Capacity – 6kA

Auxiliary Contacts – At least two N/O (Closes when the MCB is "ON" state) contacts.

#### 5.23.3.3 AC MCBs

According to the content discussed in previous chapters there shall be a two pole MCB installed inside the marshalling kiosk/local control cubicle for each DC circuit. Specification of the required MCB is as follows.

Type – 2 Pole

Operating Voltage – 240V AC

Current Rating – A proper MCB selection calculation and coordination study shall be performed.

Current Breaking Capacity – 6kA

Auxiliary Contacts – At least two N/O (Closes when the MCB is “ON” state) contacts.

#### 5.23.4 Discrepancy Switches

Discrepancy switches are used to control circuit breakers, disconnectors and earth switches (In GIS applications) and monitor and display the status of the relevant switchgear. There shall be an internal LED lamp which shall be illuminated when the actual switchgear is in a different position to the position indicated by the discrepancy switch.

Vertical position of the switch shall indicate closed status and the horizontal position shall indicate the opened status. If the switchgear close command has to be sent, the user has to rotate the switch 45° clockwise while pushing the it. If the switchgear open command has to be sent, the user has to rotate the switch 45° anticlockwise while pushing it inwards. When the switch is released it shall return to the previous state either at close or open position.

Specification required in the discrepancy switch is as follows.

Maximum Switching Voltage – 250V DC

Lamp Voltage – Lamp voltage shall depend on the substation battery voltage (220V DC or 110V DC)

#### 5.23.5 Semaphore Switches

In order to indicate the state of the earth switches in Air Insulated Substations which cannot be controlled from the mimic a semaphore indicator is used. It shall include a solenoid coil that moves the indicator to illustrate the status of the switchgear. When it is in closed status the indicator will be rotated and remained at vertical position and when the switchgear status is opened indicator shall be rotated and remained at horizontal position. The solenoid coil shall be appropriately rated for continuous load. Rotating indicator shall be in black colour in white background. It is preferred to have a device without external current limiting resistors.

#### 5.23.6 Under Voltage Relays

In 132kV and above line bays three single phase under voltage monitoring relays shall be used to provide “No voltage” release for the line earthing switch as explained in chapter 5.9. A convenient mechanism shall be available for the user to select the under voltage monitoring setting to provide “No Voltage” release signal. The setting range shall be from 2V AC to 20V AC. At least one output contact shall be available which shall be closed when the measured voltage is less than the set value. Output contact shall be rated for the substation battery voltage. There shall be a LED indicator for the user to identify whether the relay has operated or not.

#### 5.23.7 Heating Element and Temperature Controller

##### Heating Element

An anti-condensation heating element shall be installed for the following applications.

- Keeping the temperature inside the enclosure at stable value.
- Keeping the temperature inside the enclosure above the ambient temperature and dew point to avoid moisture condensation due to trapped moisture.

Operating voltage shall be 240V AC and use of external resistors shall be avoided. All the connectors shall be made of an inflammable material. The heating elements and it's housing shall not be corroded. Heating element shall be installed using screws at the bottom of the relevant panel.

##### Thermostat

In order to regulate the heating element there shall be a thermostat mounted inside the panel. It shall contain a thermostatic bimetal sensor which shall open the voltage free contact (NC contact) when the temperature increases above the user settable value. It shall be possible to mount it on a 35mm DIN rail. Contact operating voltage shall be 240V AC.

#### **5.23.8 Lamp Assembly and the Door Switch**

Lamp assembly shall be mounted on top of the inside of the panel such that it illuminates the inside of the panel for the user to observe the devices inside. Lamp shall be fluorescent lamp which operates with 240V AC supply, equipped with a door switch such that when the door is completely closed the lamp will be darkened. Door switch contact shall be rated based on the power rating of the lamp.

#### **5.23.9 CT/VT Sizing Calculation**

The CT/VT sizing calculation shall be carried out and based on calculated results the parameters of CTs and VTs should be submitted for approval. All system data required for calculation shall be obtained from the Engineer.

#### **5.23.10 Protection Settings**

Relay settings with calculations for all unit type protective schemes, overhead line and cable protection relays shall be submitted to the Engineer one month prior to commissioning of any plant / substation for approval. All system data required for calculating the settings shall be obtained from the Engineer.

The settings of 220 kV, 132 kV, 33 kV and 11 kV protection equipment shall be properly coordinated with the existing protection schemes.

The settings shall also be provided for breaker failure, auto-recloser and other equipment. (DFR, fault locator etc.)

The complete trip matrix shall be subjected to Engineer's approval prior to design.

#### **5.23.11 Documentation**

When the general arrangements and details of the Plant have been finalised and not later than the erection commences, the Contractor shall submit the following documents. (Soft copy only)

1. Type Test Certificate as per relevant International Standards carried out at a reputed independent test laboratory.
2. Functional Test Certificate as per relevant International Standards carried out at a reputed independent test laboratory.
3. Factory Acceptance Test Sheets
4. Approved Single Line Diagram, Panel layout Diagram, Schematic Drawings, Wiring Schedule, Cable Schedule.
5. Approved CT and VT sizing calculation
6. Approved relay setting calculation
7. Application Manual, Commissioning Manual, Product Guide, Technical Manual etc. of Protection and Control IEDs.
8. Calibration Certificates of Test Equipment
9. Format of Test Sheets of each type of Protection and Control IEDs, CTs.
10. CV of Commissioning Engineer
11. Relay management, communication and configuring software of relay/control IED of equipment manufacturer (with required licences) shall be supplied.

## 5.24 SUBSTATION AUTOMATION SYSTEM

### 5.24.1 General

The Substation Automation System (SAS) shall be installed to control and monitor the complete substation equipment from the local operator console and from remote control centres (NSCC & RDCC) as well.

The SAS shall contain the following main functional parts:

- Station Human Machine Interface (HMI)
- Managed switched Ethernet Local Area Network communication infrastructure with redundant communication paths at Bay level.
- Two Redundant HOT-HOT industrial grade gateways for remote supervisory control from NSCC & RDCC, the gateways should be able to communicate with NSCC & RDCC on IEC 60870-5-104 protocol, independently without relying on HMI workstations. (Please refer Chapter 6 for further information on Gateway)
- GPS Time Server
- Remote Web HMI
- Engineering Workstation with firewalled Ethernet interfaces, for protection relay parameterization, accessing disturbance records and performing SAS maintenance.
- Peripheral equipment like Computer monitors, keyboards, mouse etc.
- Adequate Cyber Security with Firewalls, remote access controlling and recording software and/or devices as per relevant.
- Periodic disk image backup software

It shall enable local station control means of PC based human machine interface (HMI) and control software package, which shall contain an extensive range of supervisory control and data acquisition (SCADA) functions tailored for the power transmission sector.

It shall include two redundant HOT-HOT communication gateways and inter IED communication infrastructure. An architecture drawing for SAS is enclosed in Annexure 7.

The communication gateway shall facilitate the information flow with remote control centres. The HMI and Gateways should be functionally independent from each other.

The bay level intelligent electronic devices (IED) for protection and control shall provide the direct connection to the switchgear to perform control, protection, and monitoring functions. (Please refer Chapter 5 for further information on bay level IEDs)

Remote setting parameterization and fault evaluation from the Engineering workstation, inter-bay-bus, Intelligent Electronic Devices (IED) for bay control and protection shall be possible via the Engineering Workstation.

#### 5.24.1.1 SAS Manufacture

The SAS manufacturer shall be the original equipment manufacturer of either Main 1 or Main 2 Control & Protection IEDs. SAS Manufacture shall provide the SAS panels as per the specifications. The SAS software shall be a product of the SAS Manufacture. Partners of the SAS manufacture are not allowed to offer, configure, supply, test, and commission the SAS. The SAS manufacturer shall demonstrate that the system proposed is designed, engineered, installed, configured, and tested in accordance with IEC 61850 edition 2. The SAS manufacturer shall be the system integrator who will configure, test and commission the SAS and shall be the one to provide the license for the SAS software. All Control & Protection IEDs,

AVR IEDs, IO Box, Ethernet switches and GPS Time server shall be fully integrated to the SAS at the manufacture place.

**5.24.1.2 SAS Manufacturer's Experience**

Only manufacturers with minimum 8 years of experience in developing and manufacturing of IEC 61850 compatible substation automation systems for Transmission Grid Substations will be accepted. This experience has to be substantiated by means of reference installations of SAS according to IEC 61850 being in service under similar environmental conditions for at least 6 years and 4 years of which shall be outside the country of manufacture. In order to assess the manufacturer's experience with similar projects, the manufacturer is required to submit the following with his bid:

1. Technical design specifications and description of SA system.
2. Catalogues and brochures of equipment and devices offered.
3. Reference list

**5.24.1.3 Compliance with standards and quality assurance**

For design and type testing of the control equipment, the following standards shall be applicable:

Standard	Description
IEC 60038	IEC Standard voltages
IEC 60068	Environmental testing
IEC 60068-2-3	Test Ca: Damp heat steady state
IEC 60068-2-30	Test Db and guidance; Damp heat, cyclic
IEC 60664	Insulation coordination for equipment within low-voltage systems
IEC 60870-3 class 2	Digital I/O, Analogue I/O dielectric tests
IEC 60870-3/class 2	Radio interference test
IEC 60870-5-101	For power system monitoring, control & associated communications for tele control, tele protection, and associated telecommunications for electric power systems
IEC 60870-5-104	IEC 60870-5-101 functions in TCP/IP method.
IEC 61000	Digital I/O Surge withstand test
IEC 61000	Transient fast burst test
IEC 61000	Static discharge
IEC 61000	Electromagnetic fields
IEC 61000	Transient fast burst test
IEC 61850-1 edition 2 2011	Introduction and overview
IEC 61850-2 edition 2 2011	Glossary
IEC 61850-3 edition 2 2011	General requirements
IEC 61850-4 edition 2 2011	System and project management
IEC 61850-5 edition 2 2011	Communication requirements for functions and device models



IEC 61850-6 edition 2 2011	Configuration description language for communication in electrical substations related to IEDs
IEC 61850-7-1 edition 2 2011	Basic communication structure for substations and feeder equipment – Principles and models
IEC 61850-7-2 edition 2 2011	Basic communication structure for substation and feeder equipment – Abstract communication service interface (ACSI)
IEC 61850-7-3 edition 2 2011	Basic communication structure for substation and feeder equipment – Common data classes
IEC 61850-7-4 edition 2 2011	Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes
IEC 61850-8-1 edition 2 2011	Specific Communication Service Mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3
IEC 61850-9-1 edition 2 2011	Specific communication service mapping (SCSM) – Sampled values over serial unidirectional multidrop point-to-point link
IEC 61850-9-2 edition 2 2011	Specific communication service mapping (SCSM) –Sampled values over ISO/IEC 8802-3
IEC 61850-10 edition 2 2011	Conformance testing
IEC 62439-1	Rapid Spanning Tree Protocol (RSTP)

The bidder shall submit IEC 61850-conformance certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850-10 for all the SAS equipment and software including IEDs.

Quality Assurance of design and development, production, installation and servicing of material and workmanship shall be governed by ISO 9001. Supporting documents to prove ISO 9001 third party approval shall be provided with the offer and shall be available during the FAT.

**5.24.1.4 Project Specifications**

Specific required functions and boundary conditions of the SAS are detailed elsewhere in this specification as follows:

- Overall single line diagram
- General system architecture
- Location of substation buildings
- Recommended panel layout arrangements
- Control and operation principles
- Protection arrangement and schemes

- Technical Specification of the Gateway

## 5.24.2 System Design

### 5.24.2.1 General system design requirements

The Substation Automation System (SAS) shall be suitable for operation and monitoring of the complete substation including future extensions. The systems shall be of the state-of-the-art suitable for operation under electrical environments present in Extra high voltage substations, follow the latest engineering practice, ensure long-term compatibility requirements and continuity of equipment supply and the safety of the operating staff.

The system shall be designed such that personnel without any background knowledge in Microprocessor-based technology are able to operate the system. The operator interface shall be intuitive such that operating personnel shall be able to operate the system easily after having received some basic training.

The offered SAS shall support remote control and monitoring from Remote Control centres via gateways. It shall be possible to monitor and control the station from NSCC should all the Station PCs fail.

The system shall incorporate the control, monitoring and protection functions specified, self-monitoring, measuring, alarm generation and event recording.

Maintenance, modification, or extension of components shall not require a shutdown of the whole station automation system.

Self-monitoring of single components, modules, software, and communication shall be incorporated to increase the availability of the equipment while minimizing maintenance time to repair. In an event of a failure, the redundant elements shall be automatically brought into operational use as necessary. No loss of functionality or performance shall occur under these circumstances. Replacement of faulty items of equipment and restoration to full system status shall not result in any loss of functionality or performance. The standby elements of the redundant subsystems shall be always monitored. The SAS design shall ensure that no conflict of action or inconsistency of the system data can occur, as a result of interactions and changeover between redundant subsystem elements.

The SAS manufacturer shall demonstrate that the SAS software supplied, comply with this technical specification during the design review stage.

### 5.24.2.2 System architecture

The SAS shall be based on a decentralized architecture and on a concept of bay-oriented, distributed intelligence. Functions shall be decentralized, object-oriented and located as close as possible to the process.

The main process information of the station shall be stored in distributed databases (i.e., in IED level). The typical SAS architecture shall be structured in two levels. i.e., in a station level and a bay level.

**Bay level**

At bay level, the IEDs shall provide all bay level functions regarding control, monitoring and protection, inputs for status indication and outputs for commands. The IEDs should be directly connected to the switchgear without any need for additional interposition or transducers.

Each control and protection IED shall be independent from each other and its functioning shall not be affected by any fault occurring in any of the other control and protection IEDs of the station.

The data exchange between the electronic devices on bay and station level shall take place via the communication infrastructure.

Data exchange is to be realized using IEC 61850 protocol edition 2.

**Signal List and naming of devices**

All the signals used in the SAS shall be according to the signal list given in Annexures 20 to 29. Signal List must be submitted for approval during the design stage. The naming of the signal list shall be as per the Annexures 20-21

All the IEDs available in the substation network should be uniquely designated with a technical reference key; thus, they can be identified in the IEC 61850 environment. Naming will be based on a hierarchy as shown below.

1	2	3	4	5	6	7	8	9	10	11
IEC 61850 Server Name			Voltage Level		Bay Index			IED/IO Module Name		

Altogether, the technical key will contain a maximum of 11 characters.

**IEC Server Name:**

This represents the server where each IED is connected in the substation. Typically, there is only one server, and it would be named as “AA1”. In case there are multiple servers, they could be designated as AA2, AA3 .....

**Voltage Level:**

Depending on the primary voltage level to which the device belongs to, two additional characters are introduced. Following letters will be used for each voltage level.

Voltage Level	Designation
220kV	D1
132kV	E1
33kV	H1
11kV	K1

**Bay Index:**

The next three letters in the naming convention represent the bay identification. There will be multiple bays under the same voltage level in a typical substation. During the design stage each bay will be given a unique index in an orderly manner. (Bay 1, Bay 2 ....) This index will

be used with a prefix Q to represent the bay. Busbar protection central unit and the station alarm IO box are in a separate panel in the substation; however, it will be represented by the same index as the bus coupler bay. In addition, AVR relays and the Transformer mechanical alarm IO box shall be represented by the respective transformer bay index even though there is a separate panel in the substation. Hence, two AVR relays and the Mechanical alarm IO boxes installed in the same panel will contain two different bay indexes.

Eg: Bay 1 – Q01, Bay 2 – Q02

**IED/IO Module Name:**

Final three/two letters are reserved for the representation of the IEDs available in the substation. Each IED shall be designated as follows. All control and protection IEDs will be designated with “FN” and main 1 would be designated as “FN1”. All control relays and IO modules, which do not contain any protection functions, will be named as “A” and will be indexed based on the number of such devices available in a single bay. Any IEDs that contain only protection functions (busbar protection IED) shall be designated as “FP”.

IED	Designation
Main 1	FN1
Main 2	FN2
IO Module	A1 or A2 (In a transformer bay IO module is considered as the second device behind AVR and in busbar protection bay it will be named as A1)
AVR	A1

In the annexures bay number is not considered in IED naming. Actual bay number with respect to the substation design shall be considered in bay numbering.

For single phase transformer units mechanical alarms shall be available for each phase. Bus bar protection over current signals are only required for transformer bays. Here it is assumed that there are only two transformer bays.

The corresponding datasets of the IEDs shall be as given in annexures 30 to 39. Further, following information shall be added to the signal list when it is required and must be submitted for approval.

Column Name	Description
NSCC Signal name	If the signal is connected to NSCC you will find the corresponding signal name, alarm group or command name.
NSCC Address	The Address which is used to connect The signal to The NSCC.
NSCC Logical name	Internal Reference/Name of the used process object for NSCC connection.
NSCC Index	Internal reference/Index of the used process object for NSCC connection.

## Station level

At station level, the entire station shall be controlled and supervised from the station HMI. It shall also be possible to control and monitor the bay from the bay level equipment at all times. Clear control priorities shall prevent operation of a single switch at the same time from more than one of the various control levels, i.e., NSCC or RDCC, station HMI, bay level or apparatus/MIMC level.

The priority shall always be on the lowest enabled control level. The station level contains the station-oriented functions, which cannot be realised at bay level, e.g., alarm list or event list related to the entire substation, gateway for the communication with remote control centres.

The GPS time synchronisation signal for the synchronization of the entire system shall be provided.

### 5.24.2.3 Bay level functional requirements

The IED shall support IEC 61850 edition 2 standard in terms of the following:

- Buffered Report Control Blocks (BRCB) – Status Information (Binary)
- Unbuffered Report Control Blocks (URCB) – Measurements, Counters Information (Analog)
- Customization of the reports and data sets
- Ability to freely rename data sets, and logical devices.
- Ability to add prefixes and suffixes to logical nodes.
- Use specific logical node name for commonly used information rather than generic data references (such as GGIO)
- Ability to change data sets and reporting configuration via Configuration Tool.
- Ability to download CID file directly into IED (send to the IED) via Configuration Tool
- Ability to download CID file directly into IED (send to the IED) via Ethernet using standard TCP/IP mechanism from remote such as from Engineering Workstation.
- Flexible configuration of data sets
- Ability to setting logical devices, logical nodes, and their contents.
- Ability for user to query IED directly and to verify which IEC 61850 configuration file (“cid” file) is active within the IED.
- Select before operate method shall be implemented for controlling.

The relevant IED configuration software to undertake above activities shall be available at engineering workstation with license from the IED manufacturer. Further, the software installation setup with additional license shall be handed over to CEB. The CID files (conforms to the as built) for all the IEDs shall be available at the engineering workstation.

#### **5.24.2.4 System level functional requirements**

##### **5.24.2.4.1 Status supervision**

The position of each switchgear, e.g., circuit breaker, isolator, earthing switch, transformer tap changer etc., shall be supervised continuously. Every detected change of position shall be immediately displayed in the single-line diagram on the station HMI screen, recorded in the event list. Alarms shall be initiated in the case of spontaneous position changes. The switchgear positions shall be indicated by two auxiliary switches, normally closed (NC) and normally open (NO), which shall give ambivalent signals. An alarm shall be initiated if these position indications are inconsistent or if the time required for operating mechanism to change position exceeds a predefined limit.

Following status of the network equipment shall be continuously monitored by the SAS and relevant updates in HMI screen shall be made. Associated events and alarms shall be raised.

- Ethernet Port status of Ethernet Switches
- Status indications of Ethernet Switches, Firewall
- Status indications of GPS Time Server
- Status indications of the Workstations and Gateway

The SAS shall also monitor the status of substation auxiliaries (LVAC, DC and Inverter). The status and control of auxiliaries shall be done through a separate one or more IED and all alarm and analogue values shall be monitored and recorded through this IED.

##### **5.24.2.4.2 Measurements**

The analogue values acquired/calculated in the bay control/protection unit shall be displayed locally on the station HMI. The analogue values shall be updated every 2 seconds. Threshold limit values shall be selectable for alarm indications. The operator shall be graphically alerted by blinking the measurements when the thresholds are exceeded

##### **5.24.2.4.3 Event and alarm handling**

Events and alarms are generated either by the switchgear, by the IEDs, or by the station level units. They shall be recorded in an event list in the station HMI. Alarms shall be recorded in a separate alarm list and appear on the screen. All, or a freely selectable group of events and alarms shall also be selected for display. The alarms and events shall be time-tagged with a time resolution of 1 ms. The time tagging shall be done at the lowest level where the event occurs, and the information shall be distributed with the time tagging.

Alarm hooter shall be activated with a new alarm and shall be deactivated upon pressing the silence command.

An OPC-DA server shall be configured with selectable alarm class and/or alarm group for remote monitoring of the SAS condition (e.g.: alarms & events relating to SAS station such as RAID, etc.,) to send to an NMS (Network Management System) via the engineering workstation.

#### 5.24.2.4.4 Control

The different electrical apparatuses within the station shall either be operated manually by the operator or automatically by programmed switching sequences. However, the operation shall be possible by only one operator at a time.

The operation shall depend on the conditions of other functions, such as interlocking, synchro check, etc. (as specified in the Chapter 5 of technical specification) and overriding of the interlocking function shall be disabled.

It shall be possible to control the station either from HMI or NSCC/RDCC. The control authority transfer shall be implemented by means of a soft switch in the HMI.

Following approach shall be followed when a command is issued using an HMI.

##### (a) Select-before-execute

For security reasons the command is always to be given in two stages: selection of the object and command for operation under all modes of operation except emergency operation. Final execution shall take place only when selection and command are actuated.

##### (b) Command supervision

Bay/station interlocking and blocking Software.

##### (c) Run Time Command cancellation

Command execution timer (configurable) must be available for each control level connection. If the control action is not completed within a specified time, the command should get cancelled.

Failure to operate a command shall be indicated to the user in the control box if the necessary control feedback is not received, further it should be clearly indicated in the Alarms list and the HMI SLD.

#### 5.24.2.4.5 Cyber Security

The Substation Automation Systems supplied should have cyber security embedded and should form an integral part of the system. This means that cyber security concerns should be addressed by the SAS manufacturer in every phase from design and development to maintenance of the products & systems.

The systems supplied should have undergone rigorous security testing procedures to warrant a high level of robustness against cyber security attacks.

##### Electronic perimeter protection and defence

The substation automation system perimeter shall be protected by Firewalls. Firewalls shall be placed on network boundaries (places where traffic enters/leaves the SAS network). Communication from outside to the SAS shall be via the firewall with the whitelisting.

## **System architecture precautions**

The substation automation system shall allow network segmentation or creation of several zones in order to minimize any adverse impact in case one zone is compromised.

## **Product & System hardening**

All components of the system shall harden according to well-known tools and best-practice guides. For example, unused services and unused ports shall be closed. The products shall be tested using state-of-the-art commercial and open-source security robustness testing tools. Furthermore, the latest security patches and service packs shall be installed upon hand over of the system. Unnecessary user accounts, default users, programs, network protocols and services shall be removed.

## **Logging and alarming of security events**

Security event logging Products in a substation automation environment shall have the possibility to log all security-relevant user activity such as user log-in, log-out, change of parameters or configurations, and updates to software or firmware. For each event, date and time, user, event ID, outcome and source of event shall be logged. Access to the audit trail shall only be available for authorized users only.

Security Event Collection Security Event shall be collected using standard IEC61850 mechanism or similar de facto standard such as Syslog. It should be possible to analyse the security events in a central place and a report shall be generated.

## **Authentication and authorization (User Account Management)**

The system shall allow user authentication and authorization on an individual user level. User authentication shall be required, and authorization shall be enforced for all interactive access to the products. User accounts shall be managed freely, allowing creating, editing, and deleting user accounts, and defining usernames and passwords according to the policies.

## **Malware Protection**

Anti-virus or other malicious software prevention tools (such as Application Whitelisting) shall detect, prevent, deter, and mitigate the introduction, exposure, and propagation of malware.

## **Patch Management Process**

A Patch Management process shall be in place which verifies the compatibility between SCADA application and security patches released for 3rd party software.

### **5.24.2.5 Station HMI**

#### **General**

The operator station HMI shall be a redundant workstation with hot standby and shall provide basic functions for supervision and control of the substation. The operator shall give commands to the switchgear on the screen via mouse clicks. The HMI shall give the operator access to alarms, events, measurement reports and trends displayed on the screen.

An acoustic alarm shall indicate abnormalities, and all unacknowledged alarms shall be accessible from any screen selected by the operator.



**(a) Substation HMI Operation:**

On the HMI the object has to be selected first. In case of a blocking or interlocking condition is not met, the selection shall not be possible, and an appropriate event shall occur. If a selection is valid the position indication will show the possible direction, and the appropriate control execution button shall be pressed in order to close or open the corresponding object. Control operation from other places (e.g., REMOTE) shall not be possible in this operating mode (as the device is selected for operation).

**(b) Presentation and dialogues**

The following standard pictures shall be available from the HMI:

- Overall Single line diagram
- Single-line diagram showing the switchgear status and measured values voltage Level wise (220 kV / 132 kV / 33 kV/11 kV)
- Individual Bay views
- Control dialogues with interlocking or blocking information details. This control dialogue shall tell the operator whether the device operation is permitted or blocked.
- Real-time interlock schemes
- Measurement dialogues
- Alarm list, station / bay-oriented
- Event list, station / bay-oriented
- User Login information
- Blocking list
- SAS Overview (Equipment and Communication Network status)
- Auxiliary system diagram with LVAC, DC and Inverter Controlling and Alarms
- Trends and Archives
- Auto and Manual Trip counters and Circuit breaker operation counters for each circuit breaker
- Tap Changer view
- Manual Synchronizing view bay wise (Graphical illustration of voltmeters to compare Line Voltage with Bus Voltage, frequency meters to compare frequencies of Line Voltage with Bus Voltage and synchroscope with rotating hand to monitor phase angle differences between Line Voltage and Bus Voltage. The rpm of the rotating hand shall be proportional to frequency difference of Line Voltage and Bus Voltage. Separate circuit breaker switch on facility apart from normal switching dialog box, shall be implemented to switch on circuit breaker of high voltage line automatically when synchronizing criteria is fulfilled as per the synchro check function of IED. Synchro check override switch on facility shall be implemented only for high level users such as Engineer)
- Under frequency Load shedding (Facility to controlling of under frequency load shedding of 33 & 11 kV Feeders On / OFF and monitoring activated load shedding stages of all of 33 & 11 kV Feeders)
- Time synchronizing status of IEDs with time drift

- Auto-Reclosing (Facility to controlling of auto reclosing of 220, 132, 33 & 11 kV bays On / OFF)
- Graphical Interlock condition monitor picture (for all equipment of whole substations in bay wise and all the available interlock conditional shall be illustrated with hardware interlock)

### **(c) HMI design principles**

Consistent design principles shall be adopted with the HMI concerning labels, colours, dialogues, and fonts. Non-valid selections shall be dimmed out. The object status shall be indicated using different status colours for:

- Selected object under command
- Selected on the screen
- Not updated, obsolete values, not in use or not sampled
- Simulated /Substituted
- Alarm or faulty state
- Warning or blocked
- Update blocked or manually updated
- Control blocked
- Normal state

### **(d) Process status displays and command procedures**

The process status of the substation in terms of actual values of currents, voltages, frequency, active and reactive powers as well as the positions of circuit breakers, isolators and transformer tap-changers shall be displayed in the station single-line diagram.

In order to ensure a high degree of security against undesired operation, a "select-before-execute" command procedure shall be provided. After the "selection" of a switch, the operator shall be able to recognize the selected device on the screen, and all other switchgear shall be blocked. As communication between control centre and device to be controlled is established, the operator shall be prompted to confirm the control action and only then final execute command shall be accepted. After the "execution" of the command the operated switching symbol shall flash until the switch has reached its new position.

The operator shall be in a position to execute a command only, if the switch is not blocked and if no interlocking condition is going to be violated. The interlocking statements shall be checked by the interlocking scheme implemented at bay and station level.

Following shall be evaluated on enabling the control soft keys (for switches), and proper notification shall be given otherwise.

- control authority of the station (NSCC/RDCC/Local/off)
- control authority of the IED

- basic interlocks
- basic synchro check (if relevant)
- control block modes / simulation states
- tap position already reached its end / Master Follower Parallel Single operation modes
- capacitor bank control mode (auto/manual)
- user authority (guest/operator/engineer/administrator)

The override function shall be disabled at all times, which is used to by-pass the interlocking function in cases of maintenance or emergency situations.

After command execution the operator shall receive a confirmation that the new switching position has been reached or an indication that the switching procedure was unsuccessful with the indication of the reason for non-functioning.

#### **(e) System supervision & display**

The SAS system shall be comprehensively self-monitored such that faults are immediately indicated to the operator, possibly before they develop into serious situations. Such faults are recorded as a faulty status in a system supervision display. This display shall cover the status of the entire substation including all switchgear, IEDs, communication infrastructure and remote communication links at the station level, etc.

The display shall mainly include:

- Status of the station SA system master station including peripherals. i.e., whether online, stand by, in service, faulty etc.
- Status of the Workstations, Gateways, Engineering Workstation, GPS Time Server, Ethernet Switches and Alarm Device.
- Status of the communication links to the National System Control Centre.
- Status of the protection and control IED's.
- Status of the LVAC, DC and inverter power supply system.
- Transformer AVR Control
- LVAC and DC Alarm
- Status of the communication buses and links.
- Status of the time synchronization for IEDs and PCs.
- Alarms and events generated internally to the SAS and peripherals concerning status changes in any of the above shall appear in the alarm and event lists

**(f) Alarm list**

Faults and errors occurring in the substation shall be listed in the alarm list. It shall contain unacknowledged alarms and persisting faults. The date and time of occurrence shall be indicated (with 1 ms resolution or better, stamped at the IED level). The alarm list shall consist of a summary display of the present alarm situation. Each alarm shall be reported on one line that contains:

- The date and time of the alarm
- The name of the alarming object
- A descriptive text
- The acknowledgement state (acknowledged/unacknowledged)
- The plant voltage level
- Device which alarm was generated

Selection of alarm list shall result in the latest page being displayed, preferably with new alarms added to the top of the list. An alarm list on display shall automatically be updated with new alarms as they occur.

Whenever an alarm condition occurs, the alarm condition must be shown on the alarm list and must be displayed in a different font colour (preferably in Red). After acknowledgement of the alarm, it should appear with another colour (preferably in Blue). The alarms that physically clear before the acknowledgement should appear with another colour (preferably in Black)

There shall be two separate sections in the alarm window for persisting and fleeting alarms. The state of the alarms shall be shown in the alarm list (Unacknowledged and persistent, Unacknowledged and cleared, Acknowledged and persistent).

- Persisting – physically exists and Unacknowledged (Red), physically exists and acknowledged (Blue)
- Fleeting - physically clear before the acknowledgement (Black)

The alarm should disappear from the alarms list only if the alarm condition has physically cleared and the operator acknowledged the alarm.

It shall be possible to block an alarm signal directly from the right context menu (obtained with a right clicking on a signal) of the alarm list, depending on the user authority level. In addition, it shall be possible to navigate to the relevant bay view from the same right click context menu. Facility shall be available to insert a note to an alarm from the same right click context menu.

Please refer to the signal list for a detailed list of signals, expected values and representation format.

Filters for selection of a certain type or group of alarms shall be available as for alarms. A sorting and merging facility shall be available to produce a reduced list, i.e., for substation alarms, SAS alarms and individual IED alarms.

Filtered alarms list shall have the facility to be exported in CSV, Excel, PDF, etc., formats.

### (g) Event list

The event list shall contain events that are important for the control and monitoring of the substation. The event and associated date-time (with 1 ms resolution or better) of its occurrence has to be displayed for each event and that shall be stamped at the IED level. The operator shall be able to call up the chronological event list on the monitor at any time for the whole substation or sections of it. The events shall be registered in a chronological event list in which the type of event and its time of occurrence are specified. Incorrected time stamps (IED which fail to synchronize time with Time server) shall be represented in a separate column for each event.

It shall be possible to store all events in the computer for at least for five years.

The chronological event list shall contain:

- Position changes of circuit breakers, isolators, and earthing devices
- State change of binary signals of bay control and protection IED's, such as but not limited to:
  - Bay Authority change – Remote/BCU/Mimic/Disable
  - Change of tap position
  - Mechanical protection signal
  - etc.,
- Indication of protective relay operations – Trip/Pickup/Load Shedding State etc.,
- Manufacturer recommended indications and Fault signals for HV switchgears and other auxiliary systems.
- Indication when analogue measured values exceed upper and lower limits. Suitable provision shall be made in the system to define two levels of alarm on either side of the value, or which shall be user defined for each measurand.
- Loss of communication, changes in the communication network such as ethernet port status
- Alarms with acknowledgement and alarm persistence status together with the timestamp. During changing in the acknowledgement and persistence state different separate events shall be generated with timestamps.
- Login events (success/failure/logout), all the user administration events.
- Control commands issued from Station HMI with following parameters:
  - Operator ID
  - Control command type – Select/Execute/Cancel/Timeout/Feedback
- Control Authority change - NSCC/RDCC/SAS/Disable
- System generated messages, e.g., control action tracking messages, fault messages.

- SAS related – Redundancy changes, Low Disk space, RAID status, temperature alarms, SAS application status (Hot/Warm/Standby/Cold/Inactive), SAS Workstation (Online/Offline), Client connected (application instance started)
- Modifications to data points of the process database such as:
  - Scan ON/OFF
  - Substitution of values
  - Blocking conditions - update/control/alarm/event
- Introduction of warning signs or notes together with Operator ID
- Filters for selection of a certain type or group of events shall be available. The applied filter should be clearly visible at all times. The filters shall be designed to enable viewing of events grouped per:
  - Date and time
  - Bay
  - Device
  - Function e.g., trips, protection, operations etc.,
  - Alarm class
  - Value  
(ON/OFF/Normal/Cleared/Trip/Raised/Lowered/Operated/Selected/Canceled/Logi  
n etc.,)

Please refer to the signal list for a detailed list of signals, expected values and representation format.

Selection of the event list shall result in displaying the latest page, preferably with new events added to the top of the list. An event list display shall be automatically updated with new events as they occur. A sorting and merging facility shall be available to produce a reduced list, i.e., for substation events, SAS events and individual IED events.

It shall be possible to block an event directly from the right context menu (obtained with a right clicking on a signal) of the event list, depending on the user authority level. In addition, it shall be possible to navigate to the relevant bay view from the same right click context menu. Facility shall be available to insert a note to an event from the same right click context menu.

Filtered event list shall have the facility to be exported in CSV, Excel, PDF, etc., formats.

#### **(h) Alarm Hooter**

Alarm hooter shall be available for signals categorized and appearing in the alarms list. The system shall have both hardware based and PC based alarm generation capability. There shall also be visual indication by means of an icon (Red colour) in all the HMI windows to indicate the audio alarm is activated/sounding.

The audio hooter shall be silenced by pressing a button in the HMI. Any user who has logged in to the HMI shall have the ability to silence the running audio hooter and it should not acknowledge any alarms.

The alarm shall be activated via the station alarm & annunciation I/O box (refer Annex 7) and shall be hard wired to an audio hooter (loud enough for it to be heard in the control building). Further, the facility shall be available to send the audio alarm as a binary output to a remote station. This shall be achieved by hard wiring the alarm binary output contacts to communication multiplexer digital input contacts for activating audio hooter in a remote station as illustrated in the Annexure 7. Similarly, the alarms generated by the SAS watchdog system shall activate the audio alarm and shall be transmitted to the remote station.

#### **(i) Object picture – Context based Property Window**

When selecting an object such as a circuit breaker or isolator in the overview single-line diagram, the associated bay picture (bay view) shall be selected first. In the selected object picture, all attributes like,

- Type of blocking
- Authority
- Local / remote control
- RSCC / SAS control
- Errors
- Warning signs and Notes
- etc.,

shall be displayed.

#### **(j) Control dialogues**

Dedicated control dialogues for controlling at least the following devices shall be available:

- Breaker, disconnector/isolator and earth switch
- Transformer tap-changer
- Capacitor bank controller (if relevant)
- Reset of Protection Functions/IEDs

The control dialog shall appear when a switching device is clicked with a pointing device. The operator shall give commands to the system by means of buttons on the selected control dialog. It shall also be possible to use the keyboard for buttons activation.

The method of man-machine dialogue shall be a multi-stage procedure with software and hardware verification at each stage to ensure security control. The control authority of the IED shall be evaluated on enabling the control buttons. The system shall permit the operator to execute a command only if the selected object is not blocked and if no interlocking condition is going to be violated. The interlocking conditions shall be checked by the interlocking

scheme which is implemented on the bay level. The operator should be able to see if there is any interlock or warning note relevant to the operation, in the commanding dialog box, prior to the operation.

The control method and security precautions incorporated in the design shall include, but not limited to the following minimum requirements:

- Operator cursor/mouse selection of the plant device, which results in change of colour or flashing of the device symbol.
- Operator selection of control operation.
- System displays a control window, which includes a full description of the plant selected. Simultaneously IEC61850 select command shall be issued the relevant device.
- Confirmation / selection of open/close or other appropriate controls for the plant selected.
- Operator execution of the control by the operator, from the control window.

The control operation shall be capable of being cancelled at any stage before the execute command is given. Control mode shall time out after a predetermined time if an operator fails to respond at a given stage.

Both the control and execution and the associated change of state shall raise an event. Failure of the plant to change state in accordance with the control execution, within a predetermined time, shall raise an alarm.

### (k) Property Windows

When selecting an object belongs to following categories relevant status and control actions shall be available:

- HMI Computer - SAS Application status (Hot/Standby/Warm/Cold/Inactive/Offline), Network interface status (Connected/Disconnected, IP address, Next hop device ID with port number), Hard Disk status (RAID Mirroring Fail/S. M. A. R. T), System Temperature, Control button to Force switch the application to Hot, Connection status (Connected/Failed)
- Gateway – IEC 60870-5-101/104 Link status, Gateway status (Hot/Standby/Offline), Network interface status (Connected/Disconnected, IP address, Next hop device ID with port number), Hard Disk status (RAID Mirroring Fail/S. M. A. R. T ), System Temperature, Connection status (Connected/Failed)
- IED – Network interface status (Connected/Disconnected, IP address, Next hop device ID with port number), Connection status (Connected/Failed)



- Ethernet Switch - Network interface status (Connected/Disconnected, IP address, Next hop device ID for each port), Connection status (Connected/Failed)
- Printer and other devices – Paper out, Network interface status (Connected/Disconnected, IP address, Next hop device ID with port number), Connection status (Connected/Failed)

### (l) User-authority levels

It shall be possible to restrict activation of the process pictures of each object (bays, apparatus...) within a certain user authorisation group. Each user shall then be given access rights to each group of objects, e.g.:

- Display only
- Normal operation (e.g., open/close of switchgear)
- Restricted operation (e.g., by-passed interlocking)
- System administrator

For maintenance and engineering purposes of the station HMI, the following authorisation levels shall be available:

- No engineering allowed
- Engineering/configuration allowed
- Entire system management allowed

The access rights shall be defined by passwords assigned during the log-in procedure. Only the system administrator shall be able to add/remove users and change access rights.

### (m) Reports

The reports shall provide time-related follow-ups of measured and calculated values for one or more any measurement values. There should be a facility to select the required measurements. The data displayed shall comprise:

- Day (at 15 minutes interval direct value)
- Month (daily maximum value)
- Year (monthly maximum value)

Scrolling between e.g., days shall be possible. Uncertain values shall be indicated in a different colour (Preferably Purple). It shall be possible to select the time period for which the specific data are kept in the memory. The report shall have the facility to be generated as tabular form and curve format as required.

Maximum, Min, Average, Sum values shall be displayed clearly for each selected measurement.

Following reports shall be available for viewing and exporting on demand:

- i. Provision shall be made for logging information about breaker status like number of operations with date and time indications along with the current value it interrupts (in both conditions i.e., manual opening and fault tripping)
- ii. Daily bay wise tripping report for all bays along with tripping types. (e.g., OC, EF)
- iii. Daily Equipment operation details
- iv. Daily Tap Positions, fans operations and temperature variations of power transformers.
- v. Monthly circuit breaker wise Manually and Auto Tripping Report

It shall be possible to export all reports in MS Excel and PDF formats.

#### **(n) Trend display**

It shall be possible to illustrate all types of process data as trends - input and output data, binary and analogue data. The trends shall be displayed in graphical form as column or curve diagrams with a maximum of 10 trends per screen. Adjustable time span and scaling ranges must be provided. The minimum time resolution for trend display shall be 2 seconds or less.

It shall be possible to change the type of value logging (direct, mean, sum, or difference) on-line in the window. It shall also be possible to change the update intervals on-line in the picture as well as the selection of threshold values for alarming purposes.

It shall be possible to export all trends in MS Excel and PDF formats.

#### **(o) Safety Tagging**

Operators shall be provided with facilities to affix safety-tagging symbols on the single line diagram (a safety tag applied shall be automatically displayed on the overall display and the individual bay display).

Following safety tagging shall be implemented:

- Permit to work
- Sanction for test
- Limitation of access
- Danger
- Do not operate

Certain of the tags affixed to a plant item shall prevent SAS controls being issued to that plant. It shall be possible to insert a warning note as a description to a safety tag with the timestamp, Operator ID and other details of the tags affixed. Events shall be generated in the event list regarding insertion of safety tags with timestamp and user ID. Removal of safety tag shall delete the relevant warning note and an event shall be generated.

Generated safety tags shall be applied immediately in all the operator workstations and remote operator stations (including Web HMIs) seamlessly.

**(p) Warning Notes**

It shall be possible to insert a warning note to a switch gear with the timestamp and Operator ID. All the warning notes relevant to a bay shall be displayed in the particular bay view with timestamp, Operator ID and the Note text together with relating parent item (Alarm, Event, Safety tag or Switch gear). It shall be possible to delete warning notes.

Event shall be generated in the event list regarding insertion or deletion of warning notes with timestamp and user ID.

**(q) Manual Updating/Simulation of Station Information**

The operator shall be able to remove from scan any measurement, status, or alarm. The system shall maintain a list of items thus removed from the scan. Where the item is shown on the lists and/or single line diagrams, the removal from scan shall be indicated. (e.g., use of colour or annotation symbol).

Facilities shall also be provided to inhibit controls on plant items (password operation). The system shall maintain a list of plant on which controls are inhibited. Inhibited plant controls shall be indicated on single line diagram displays.

The higher-level operator shall be able to enter manual value for any measurement, status or alarm. Where the item is shown on list and/or single diagrams, the manual value shall be indicated with different colour. However, the Topological Colouring scheme should use this simulated status for maintain the topological colouring in the single line diagrams.

In the event of a “Chatter contact” occurring, this shall not inhibit controls to any plant item being completed. The operator shall be able to manually remove the status /alarm from scan of the “chatter contact”.

Events shall be generated in the event list regarding manual updating/simulation of a switch gear with timestamp and user ID.

**(r) Topological Colouring and Power flow indications**

The SAS shall have the facility to change the colours indicated in the bus bars depending on the energisation and earthing condition automatically. Further, the Power flow direction shall be indicated with an arrow symbol for every feeder, depending on the power flow direction.

The SAS manufacturer shall utilize the licensed Topological Colouring scheme for archiving this functionality.

**(s) Remote Web HMI**

The facility shall be available to monitor and control the SAS from an external PC via a Web Browser, similar to use in the station HMI. The SAS manufacturer shall engineer all the necessary features with the relevant license for at least 50 Clients.

This shall provide user-friendly web-based graphical user interface.

- to deliver secure, accurate & timely SAS information to multiple users
- to incorporate interactive web-based applications to the user interface
- to allow remote access from multiple users with different authorization level

The audio alarm facility shall be available via the PC speakers. A separator Operator ID shall be created for this facility. The remote operator workstation shall load this Web HMI without any user intervention in both its monitors.

**(t) Blocking List**

All the blocking enabled in the station shall be displayed with the following details.

- Bay
- Device
- Description
- Timestamp
- Operator ID
- Types of applied blockings (Update, Control, Alarm, Event, etc.,)

It shall be possible to unblock any blockings applied selecting any blocked signal in this list.

**(u) User log activity list**

All the user activities as given below shall be displayed.

- User Login/ Logout
- User Creation/Deletion/Modification

Following details shall be displayed for above user activities.

- Operator ID
- Authority Level
- Timestamp
- Logging application (Local/Remote Web HMI)
- Logging source IP
- Logging /Logout cause (automatic/manual/timeout)

**(x) Automatic disturbance file transfer**

All recorded data from the IEDs with integrated disturbance recorder as well as dedicated disturbance recording systems shall be automatically uploaded (event triggered or once per day) to the engineering workstation. Relevant software with license to analyse the disturbance records shall be provided.

**(y) IED parameter setting**

It shall be possible to access all protection and control IEDs for reading the parameters (settings) from the engineering workstation. Relevant software with license shall be provided.

**(z) Automatic sequences**

Sequence control is an automatic function, which reduces the interaction between the operator and the system. A single control shall for example start a sequence to connect a circuit to one of the busbars.

Typical sequences are,

- Connect a circuit to a particular bus bar
- Disconnect a circuit, including earthing (if applicable)
- Connect transformer, including earthing (if applicable)
- Transfer of bus bar

The available automatic sequences in the system should be listed and described, (e.g. sequences related to the bus transfer). It must be possible to initiate pre-defined automatic sequences by the operator and also define new automatic sequences.

### **5.24.3 System hardware:**

#### **5.24.3.1 Redundant Station HMI, Remote HMI and Engineering Workstation**

The contractor shall provide redundant station HMI in hot standby mode. The servers/workstation PCs used in these workstations shall be of industrial grade, dual monitor, dual network port redundancy, rack mountable, powered with redundant DC power supplies. It shall be capable of performing all functions for the entire substation including future requirements as indicated in the SLD. It shall use industrial grade components. Processor and RAM shall be selected in such a manner that during normal operation not more than 30% capacity of processing and memory are used.

#### **Data Storage**

Hard disks of the computers shall be Solid State Drive (SSD) type with RAID1 Redundancy.

The disk drive shall have error detection and reporting facilities such as S.M.A.R.T. and should have a system to report RAID status and physical drive status via SNMP. Any state change related to Hard disks shall raise an alarm in the SAS Alarm log.

The capacity of the hard disk shall be 1 TB or greater and shall be sufficient for storing alarms and events, measurement archives and trend data for at least 5 years.

#### **Power Supply**

Both operator workstations, remote HMI and engineering workstation shall be DC powered with redundant power supplies.

#### **Keyboard & Mouse**

All the computer keyboards shall be full sized QWERTY USB wired keyboards (with numeric pad) and shall be slip resistant.

All mice shall be optical USB wired interface and they shall not require any batteries for their operation.

Connection via armoured USB extension is required and connection via KVM extension switches is not acceptable.

#### **Computer speaker**

Branded computer speaker systems should be provided to each workstation, which directly connects to the workstation on board audio device.

#### **Graphic Interface**

HDMI or Display port shall be available with Dual monitor capability.

### **Network Interface**

Dual port network redundancy (Interface Teaming), connecting to two different network switches.

### **Self-Monitoring**

Each workstation computer shall have a self-monitoring facility that monitors the following as a minimum:

- Computer memory
- Power supplies
- Hard Disk Low disk space warnings, S.M.A.R.T. status, RAID status
- Temperature
- Fan failure
- Timely completion of all programs

An alarm shall be generated when a fault is detected. Warning messages shall be raised for both critical and non-critical faults. In the event of a critical fault occurring, an orderly shutdown of the computer shall occur as follows.

Where applicable (SAS Main Computer), the redundant computer shall automatically assume online duties. These events shall be available as means of SNMP or OPC-DA, to be transmitted to a remote NMS via the Engineering Workstation. In the event of both SA system Station computers failing, a hardware stall audio alarm shall be raised.

#### **5.24.3.2 HOT-HOT Gateways**

Please refer the SCADA communication section for this section

#### **5.24.3.3 Computer Monitors**

The display units shall have high resolution and reflection protected picture screen. High stability of the picture geometry shall be ensured. The screen shall be at least 27" diagonally in size and capable of colour graphic displays. The display shall accommodate resolution of 2560 × 1440 pixels. For each workstation, there should be two numbers of these monitors.

Monitors provided for text and diagrams shall have flicker free, professional grade legible displays that can be observed for long periods without operator fatigue. The monitor shall be designed for continuous operation (24 / 7). Approved means shall be provided to minimize glare and reflections visible to the operator.

The following features shall apply to monitors:

- HDMI or DisplayPort video interface, connected with HDMI or DisplayPort fibre extensions.
- wide angle (16:9) to be minimum of 27 inches measured diagonally, and in landscape orientation.
- resolution of the display shall be at least 2560 × 1440 pixels.
- adjustment of the screen height, tilt angle shall be incorporated.
- power supply to monitor shall be DC or AC obtained from an inverter.

#### 5.24.3.4 Ethernet network topology

The Ethernet network shall comply with IEC 62439-1 Rapid Spanning Tree Protocol (RSTP), to provide high availability in the automation network. The ethernet network shall be 100 Mbps or higher.

Bidders shall submit necessary compliance certificates for RSTP from independent authority/certifying agencies like KEEMA, UCA, etc.

The maximum number of switches for a RSTP ring shall be in accordance with the IEC 62439-1 and number of rings shall be increased accordingly.

#### 5.24.3.5 Ethernet Communication media:

The bidder shall provide the Ethernet communication media as follows.

- Between ethernet switches for the RSTP ring – Armoured Fibre
- Between ethernet switch to IED – Protected Fibre
- Between ethernet switch to PC, GPS, Firewall, and other devices – Protected Copper
- Between ethernet switch/ Firewall/Gateway to Multiplexer – Armoured Copper
- Armoured ethernet media shall be used between panels and protected ethernet media shall be used inside the panel.
- Tested factory fitted communication mediums shall be used. Termination at site is not accepted.

Additional two sets of fibre optic cables shall be available as spares between the station level SAS cubical and every Bay level cubical segment (One bay ring) for utilizing in an event of fibre failure.

#### 5.24.3.6 Ethernet switches

Industrial grade, Layer 2 Manageable Ethernet switches that fulfil the hardened requirements concerning temperature and EMC suitable to be installed in substations shall be provided. The switches shall support Rapid Spanning Tree Protocol (RSTP) and should not be a proprietary protocol. Switches shall be supplied such that there is no interruption or reconfiguration of the Ethernet ring if one or several bay devices are taken out of service. To increase the reliability, the Ethernet Switches shall have redundant DC power supplies (110 V or 220V DC) and shall be powered from two different sets of station battery banks.

The number of bays per set of switches shall be guided by attached scheme drawing at the end. Each switch shall have at least two fibre spare ports, one copper RJ45 spare port and one spare port for connecting station bus (fibre). All the un-utilized ethernet ports shall be kept disabled, as a measure to increase Cybersecurity.

The system supervision facility of the SAS shall monitor the status of the ethernet interfaces via the ethernet switch's SNMP or IEC61850. Further, the hardware health contact shall be hard wired to the station alarm and annunciation I/O box failure alarms.

It is necessary to provide IEEE 1588 PTP time synchronisation facility to connected devices. Therefore, ethernet switches shall support IEEE 1588 PTP.

The software related to configuration and managing these ethernet switches shall be provided and installed in the engineering workstation. The CID files relating to switches (if relevant only) shall also be provided to CEB.

#### **5.24.3.7 GPS Time Server**

An intrinsically accurate master clock equipped with a radio-receiving terminal capable of receiving a time signal from the Global Positioning Satellite system shall be provided. The master clock shall be automatically corrected by the received time signals. All the Station computers, IEDs and other devices shall be time synchronized for 1 ms accuracy with the GPS satellite clock receiver.

GPS Time Server shall support following service allowing synchronization of both network devices such as PTP slaves and NTP clients, giving priority to PTP.

- IEEE 1588 PTP time server including IEC 61850-9-3
- NTP Server (NTP & SNTP v2, v3, v4)

The GPS Time Server shall

- have a stability of  $\pm 0.01$  seconds per day.
- be equipped with an internal battery backup supply to provide a running reserve of 24 hours.
- have a local calendar/time display with facilities to manually set date and time.
- have outputs for directly driving slave calendar and time displays by means of standard interfaces. The LED display clock which is synchronized with GPS master clock time via station Ethernet bus.
- incorporate alarms for fault conditions, which shall be displayed locally on the unit, Alarm annunciator and SAS via the IO Box for station alarms.

The GPS receiver antenna shall be mounted on a high-unobstructed elevation adjacent to the master clock location. GPS Time Server shall be connected to two different Ethernet Switches of Station Level Network through redundant Ethernet links. The power supply the GPS time server shall be two redundant DC power supplies.

Large time display which is synchronized with Time Server shall be installed to display the GPS time in the control room.

#### **5.24.3.8 Firewall**

Reputed ethernet firewalls shall be provided to guard against external threats to the substation ethernet network and its components at the security perimeter of the SAS. Firewalls shall be designed to work as Next Generation Firewall or Next Generation Threat Prevention, which can be Logging via Syslog. Logs shall be stored in a Firewall device, and able to be exported to a Log Collector or an external equipment. In addition, the Firewall shall be able to detect and control at least, but not limited to, the following ICS/SCADA Protocols:

- IEC 61850
- IEC 60870-5-104
- RDP
- SNMP
- FTP



- OPC
- SMB
- etc.,

All firewalls will be configured with the white-list-principle according to the latest Cybersecurity guidelines. All dropped packets shall be logged. It shall have the possibility to raise an alarm in the SAS via IEC61850 or SNMP protocols.

#### **5.24.4 Software structure**

The software package shall be structured according to the SAS architecture and strictly divided in various levels. Necessary firewalls shall be provided at suitable points in software to protect the system. An extension of the station shall be possible with lowest possible efforts. Maintenance, modification or an extension of components of any feeder may not force a shut-down of the parts of the system which are not affected by the system adaptation.

##### **5.24.4.1 Station & Bay level software**

Human-machine interface (HMI) The base HMI software package for the operator station shall include the main SAS functions and it shall be independent of project specific hardware version and operating system. It shall further include tools for picture editing, engineering, and system configuration. The system shall be easy to use, to maintain, and to adapt according to specific user requirements. Systems shall contain a library with standard functions and applications.

The SAS HMI application shall have the facility to operate as a Terminal Server Application. The manufacturer shall provide necessary license for two operator workstations and two remote workstations.

The software shall run in client server architecture and all the clients shall login to the Hot computer to access its server program. These clients shall be configured to connect as terminal server client sessions. The status whether Hot or Standby of workstations shall be indicated in the SAS overview display. Facility to change the Hot Workstation, shall be available by means of a button click for users with administrative authority in the SAS overview display. In an event of change in the Hot standby state all the clients including Remote clients and Remote Web HMIs shall automatically connect to the Hot Workstation. All the alarms, events, HMI pictures, measurements & trend data shall be synchronized between the Hot Standby Server programs seamlessly.

The SAS software shall be configured to execute as a Windows Service. The windows service shall start automatically without need for a user to log in and without any user intervention.

Online software updates for SAS and Gateway shall be provided free of charge for 10 years. A corporate account shall be provided to download software updates and patches as well as to report errors and issues.

#### **Operating System**

Latest Microsoft Windows Server operating system shall be used for the operator station and terminal server license shall be available for the two HMI workstations with additional two sessions.

### **SAS Software & License**

HMI license with following features and protocols:

- Topological colouring (Bus Bar Colouring)
- 50% additional data points
- IEC61850 client
- OPC DA server and client
- SNMP protocol
- Terminal Server HMI application for 4 workstations
- ODBC Server
- Web HMI application
- HMI Engineering – SAS configuration license for 10,000 or greater data points

### **Backup and Disaster recovery software**

Backup and Restore copies of the most important files shall be stored, to be always prepared for the worst. Regular backups shall be stored to another drive, or to a network attached storage (NAS).

### **Network Monitoring System**

The contractor shall provide a network management system software for following management functions:

- Fault Management
- Performance Monitoring

This system shall be used for monitoring of communication devices and other IEDs in the system. This NMS can be loaded in engineering workstation and shall be easy to use, user friendly and menu based. The NMS shall monitor all the devices in the SAS and report if there is any fault in the monitored devices. The NMS shall;

- maintain performance, resource usage, and error statistics for all managed links and devices and present this information via displays, periodic reports and on demand reports.
- maintain a graphical display of SAS connectivity and device status.
- issue alarms when error conditions occurs.
- provide facility to add and delete addresses and links.

### **Other Software**

- Microsoft Office Professional version with license
- Antivirus software with license for at least 05 years

#### **5.24.4.2 Extendibility in future**

Offered substation automation system shall be suitable for extension in future for additional bays. During such requirements, all the drawings and configurations, alarm/event list etc. displayed shall be designed in such a manner that its extension shall be easily performed by CEB.

During such an event, normal operation of the existing substation shall be unaffected, and the system shall not require a shutdown.

The contractor shall provide all the necessary software tools along with protected files and source codes to perform addition of bays in future and complete integration with SAS by CEB. These software tools shall be able to modify HMI pictures & data points, integrate/configure IED, add additional analogue variables, alarm list, event list, modify interlocking logics etc., for additional bays/equipment which shall be added in future.

Further, the software configuration tools used by the SAS manufacture during the integration of the SAS shall be provided with the necessary license. The latest project file shall be handed over to CEB to carry out future modification works. The provided project file shall be able to be used in the provided software configuration tool seamlessly without needing to do any manual conversions or modifications.

#### **5.24.5 Tests**

The substation automation system offered by the bidder shall be subjected to following tests to establish compliance with IEC 61850 for EHV substation equipment installed in sheltered area in the outdoor switchyard and specified ambient conditions:

SAS related test, type test, routine test, Factory Acceptance Test (FAT), and Site Acceptance Test (SAT) shall be conformed with IEC 61850-4, and IEC 61850-10.

##### **5.24.5.1 Factory Acceptance Tests**

The SAS manufacturer shall submit a test specification for factory acceptance test (FAT) and commissioning tests of the station automation system for approval. For the individual bay level IEDs, applicable type test certificates shall be submitted.

The manufacturing and configuration phase of the SAS shall be concluded by the factory acceptance test (FAT). The purpose is to ensure that the SAS manufacturer has interpreted the specified requirements correctly and that the FAT includes checking to the degree required by CEB. The general philosophy shall be to deliver a system to site only after it has been thoroughly tested and its specified performance has been verified, as far as site conditions can be simulated in a test lab. During FAT, the entire Substation Automation System including complete control and protection system to be supplied under present scope shall be tested for complete functionality and configuration in the original manufacturing factory itself. The extensive testing shall be carried out during FAT. The purpose of Factory Acceptance Testing is to ensure trouble free installation at site. No major configuration setting of the system is envisaged at site.

HMI Picture of Process Displays shall be submitted for approval, advance to the FAT.

During the FAT, a hardware integration test shall be performed on the specified system. The operation of each item shall be verified as an integral part of the system. Applicable hardware diagnostics shall be used to verify that each hardware component is completely operational

and assembled into a configuration capable of supporting software integration and factory testing of the system.

The equipment expansion capability shall also be verified during the FAT. The vendor specifically demonstrates how to add a device in future in SAS during FAT. The device shall be from a different manufacturer than the SAS manufacturer.

If the complete system consists of parts from various suppliers or some parts are already installed on site, the FAT shall be limited to sub-system tests. In such a case, the complete system test shall be performed on site together with the site acceptance test(SAT).

During the FAT, SAS tests shall verify the stability of the hardware and the software. During the tests all functions shall run concurrently, and all equipment shall operate a continuous 24-Hour period. The integrated system test shall ensure the SAS is free of improper interactions between software and hardware while the system is operating as a whole.

#### **5.24.5.2 Site Acceptance Test & Commissioning**

The site acceptance tests (SAT) shall completely verify all the features of SAS hardware and software. The SAS manufacturer shall submit the detailed SAT procedure and SAT procedure shall be read in conjunction with the specification.

During the commissioning work, site modification in SAS and Gateway and testing shall only be carried out by qualified employees of SAS manufacturer with more than 5 years of experience with the SAS software. Curriculum Vitae of SAS Commissioning Engineers shall be produced for approval prior to the commissioning of the SAS with references.

During the SAT, a full SAS systems check shall be performed before the commissioning starts. During signal testing, end to end testing has to be performed, and simulation of signals is not allowed. SAS commissioning shall not be combined with another commissioning or testing such as SCADA to NSCC, Protection & Control, or operation.

If a new SAS is supplied or existing SAS is modified by the SAS manufacturer, at the completion of total commissioning after all modification works, License for additional 50% of data points shall be available for both SAS and Gateway. All SAS and Gateway engineering, configuring, and testing software shall be handed over to CEB with full licenses. The SAS manufacturer shall demonstrate that the SAS software (Runtime and Configuration) contains full facilities for CEB to undertake necessary modification in future and the availability of additional 50 % data points.

All the latest version of relevant “cid” and “scd” files for the substation shall be handed over to CEB.

Followings shall be accomplished during commissioning when the SAS integration work is carried out by CEB:

- Control & Protection IEDs which will be supplied shall be compatible with IEC 61850 protocol. The bidder shall submit IEC 61850 conformance certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850 for the Control & Protection IEDs.

- New control & protection IEDs shall be connected to the communication network using protected multimode fibre optic cables. IEC 61850 SAS communication network shall be extended supplying the required number of Ethernet Switches which support existing RSTP redundant protocol. The new Ethernet switches which will be supplied shall be compatible with SNMP V1, V2, V3 or IEC 61850. Configuration software and relevant files of Ethernet Switches shall be delivered to CEB.
- Contractor shall provide high quality ICD and CID files of new control & protection IED along with the relevant IED software with license to CEB in advance to commissioning work.
- After the integration work, the integrated signals shall be tested up to SAS from the field by the certified employer of control protection supplier during SAS commissioning work.

#### 5.24.6 Documentation

All the necessary documents listed in the bidding document along with following documents shall be provided by the SAS manufacturer with the endorsement of the bidder during the bidding stage.

- System Architecture Drawing
- Warranty certificates for SAS equipment
- IEC 61850 conformance and interoperability certificate issued by an independent laboratory empowered by UCA International Users Group tested according to the IEC 61850, for all the SAS software, Gateway software and Control & Protection IEDs
- Esurance shall be submitted by the SAS manufacturer, all design, engineering, manufacturing, configuration, integration, and testing shall be carried out by qualified employees of SAS manufacturer at their original manufacture place.
- Hardware Specification
- Functional Design Document including typical HMI Pictures of SAS overview, alarm & event list, etc.,
- Guaranteed technical parameters
- Test Specification for Factory Acceptance Test (FAT)
- Product Manuals
- Software and License details

The following documents shall be submitted to CEB in soft format only before the commissioning of the substation by the SAS manufacture:

- a) As built System Architecture Drawing
- b) Clear procedure describing how to add an IED/bay/diagram in future covering all major supplier.
- c) The following documentation to be provided. All CAD drawings to be provided in “dxf” format.
  - List of Drawings
  - Substation automation system architecture
  - Block Diagram

- I/O Signal lists
- Schematic diagrams
- List of Apparatus
- List of Labels
- List of License
- Logic Diagram (hardware & software)
- Factory Acceptance Test (FAT) certificate
- Product Manuals
- Assembly Drawing
- Operator's Manual
- Complete documentation of implemented protocols between various elements
- Listing of software and loadable in CD/DVD ROM

#### **5.24.7 Warranty**

Substation Automation System and its parts including software should cover warranty period of five (05) years starting from commercial operation of the SAS. Warranty should be issued by the SAS manufacturer only. Warranty issued by parties other than the SAS manufacturer is not acceptable. The warranty should cover one to one replacement of faulty equipment such as workstation PCs, Gateways, Ethernet Switches, GPS Time Server, and all other SAS equipment. The warranty should address the method of bug fixing of SAS software too. There should be a 24-hour Online Support Service of the SAS manufacturer to report SAS related issues by email.

The manufacturer shall assure for long-term maintenance and availability of spares. Moreover, a guarantee certificate shall be submitted with the offer for the availability of spares of the SAS equipment and software support/update for not less than 10 years from the date of commissioning.

#### **5.25 TRANSFORMER AUTOMATIC VOLTAGE REGULATION**

##### **a) General Requirements for Voltage Regulation**

On-load tap-change control shall be performed with devices automatically controlling the voltage(s) at the transformer(s) secondary side(s) to pre-determined value(s).

In the case of a voltage drop or rise in the network, voltage regulation devices connected to measure voltage and current at the MV-level shall control automatically the on-load tap-changer as provided at the HV-level, or as otherwise specified.

The Specifications for transformers refer to requirements to the on-load tap-changer equipment and the supervision and monitoring facilities to be provided and installed at the transformer and its control cubicles/marshalling boxes. This chapter shall define the required functions of the voltage regulation, supervisory and auxiliary functions and the control of parallel operation of transformers.

Micro-processor based voltage regulator device(s) shall be provided, which perform the automatic control of the motor driven on-load tap-changer(s) of each transformer. The voltage regulation system shall be mounted into transformer control cubicle(s) to be located at the substation control room or as otherwise specified in these Specifications.

The continuous self supervision of both hardware and software shall be incorporated.

All voltage regulation instruments to be provided shall be made by first class reputable manufacturer with well-proven supply records. The submission of reference lists and the readiness to prove the supplied quantities must be confirmed by the Bidder. The Bidder shall be responsible for the design interface and the supply of well coordinated equipment of the voltage regulator system to suit the requirements of the on-load tap-changer and the substation control and interlocking system.

The equipment shall be fully tropicalized to ensure long life and stability at the climate and surrounding conditions.

All devices for voltage regulation shall have flush mounting cases and/or are built into standard 19" racks into panels. The wiring must be complete in every respect from the regulating devices to suitable terminal blocks in the cubicles or panels for external connections.

Equipment and devices shall provide automatic, electronic and/or thermal cut-out protection to avoid jeopardizing of the equipment in case of any defect.

The voltage circuits shall be operated from the voltage transformers as specified under Scope of Work/ Scope of Supply. If not otherwise specified, the star/star voltage transformer secondary side provides 110 V between phases and  $110/\sqrt{3}$  V between phase and neutral. The voltage measuring system shall be designed to cover both.

Current measuring circuits shall be supplied from the current transformer cores for metering purposes as specified, Scope of Work/Scope of Supply. If not otherwise specified, the secondary rated current shall be 1 A.

Make before break contacts are required wherever current transformer circuits are provided on removable modules. Terminal blocks shall allow the shortening of the current transformer circuits by links of an approved design. Shortening facilities shall be supplied for each of the voltage regulation system's current transformer circuit at each terminal block provided.

The thermal rating of the voltage regulation system instruments shall allow, at Site conditions, a 20% continuous overloading referred to nominal rating of the current- and voltage-transformer circuit.

Screening of cables used for current and voltage transformer circuits shall not be required from the regulation devices. In general, the internal voltage regulation measuring circuits shall be galvanically separated against the external current and voltage transformer circuits.

All interface wiring from the station control system and the transformer motor drive and etc. shall be via suitable terminal blocks with disconnection facilities of individual functions and signals.

Interface relays providing potential free contacts of sufficient rating for the RAISE/LOWER commands, signalling out-of-range voltage(s) and current(s) and automatic/manual operation are required in minimum.

The control shall follow the step-by-step principle, i.e. a single control pulse shall operate the tap changer from one service position to the next. A RAISE or LOWER control signal shall be generated by the voltage regulator and issued to the motor drive whenever the measured voltage deviates from pre-set conditions.

Both the sensitivity limits and time of response must be adjustable to avoid a multiple of tap-changer operations in the case of short-time voltage fluctuations. Voltage sensitivity must be adjustable in very small steps.

The front panel(s) of the voltage regulating devices shall contain all necessary information of the operational data on a display and a series of push buttons or a keyboard shall allow the setting and the data information reading.

The voltage regulator system shall be prepared with facilities and be extendible by interface equipment for control of parallel operation of transformers for future extensions.

The manufacturer shall supply the necessary manuals and provide information to the Contractor to enable the engineers be trained at site for setting, operating and maintaining the voltage regulator system.

b) Methods of Parallel Operation of Transformers with On-Load Tap-Changers

Special consideration shall be given to the parallel operation of transformers. For operating transformers in parallel, If the transformers are identical (i.e. same voltage ratios on each tap position, same vector group, same percentage impedance at each corresponding tap position and same phase sequence) master and follower method shall be utilize. However provisions shall be available for paralleled by a control mode regulating according to the minimum circulating current.

b1) Control by Minimising Circulating Current (PARALLEL CONTROL UNIT)

The control of parallel operation of transformers by means of voltage regulators and parallel control units according to the circulating current method shall monitor the circulating reactive current.

Each of the transformers to be operated in parallel shall be equipped with its voltage regulator as specified below and for up to six transformers one parallel control unit shall be provided.

Interlocking with transformer/bus bar circuit breakers to verify the actual number of parallel operating units shall be accomplished by means of auxiliary contacts from the circuit breakers and the bus bar isolators, wired to the parallel control unit. The parallel control unit shall automatically adapt the actual configuration of busbars and transformers relative to the bus coupler circuit breaker position ON or OFF.

The parallel control unit shall include the following:

- Terminals for connection of the input current from the voltage regulator, the contacts for feeder circuit breaker and isolator position, complete with suitable termination of cable shielding (if required)
- Terminals for remote signalization of alarms, such as general alarms of circulating current and function of the paralleling unit, as well as single alarms for failure of individual channels
- Adjustment facility of SENSITIVITY in 0.5 to 20% of the rated current
- Adjustment facility of the unit STABILITY in 0 to 100% of the set voltage level
- Adjustment facility of TIME DELAY in 20 to 200sec in order to delay the alarming of the parallel control unit for indication of circulating currents prior to completion of the tap-change operation
- Local indicators of the transformer/bus bar circuit breaker positions and indications of exceeding the permissible circulating current as well as indication of failure of channel between voltage regulator and parallel control unit.
- Communication between parallel operating unit and voltage regulators shall be performed through a serial interface (RS 485 standard) on serial bus lines.



c) Requirements for the Interface of the Voltage Regulator Devices

If specified in Scope of Work/Scope of Supply, that the voltage regulation system as described under clause 5.21.1.1 shall be supplied with interface facilities for microprocessor controlled SA system, the devices shall be provided with the following facilities:

- Serial interface shall provide for transmitting data to a National Control Centre (NCC) according to IEC 60870-5-101 and for other serial bus protocols (SCADA).

### 5.25.1 Voltage Regulator

Additional to the general requirements, the basic voltage regulator system units shall provide the following functions:

- Both options of line drop compensation and load dependent regulation shall be selectable at the regulator.
- The voltage level setting in the range of 85 to 140 V in steps of 0.5 V shall be performed locally and the related bandwidth shall be adjustable at least within the range of  $\pm 0.5\%$  to  $\pm 9.0\%$  in steps of 0.1 %
- The regulator shall be prepared to accept additional facilities (installation shall be possible at Site) for future extension of voltage level setting from a remote source, e.g. from National Control Centre. The input shall accept proportional constant current signals of 4 mA to 20 mA
- The time response for operating the on-load tap-changer shall be selectable to be a linear function of the voltage difference or to be an inverse function. The delay time shall be adjustable between 0.00 to 180 sec for linear function and in the inverse function shall be inversely proportional to the ratio of deviation voltage to the band-width down to a delay of 1.0sec.
- A second adjustable time step from 0.00 to 10sec shall be available for overriding the delay time as above, if more than one tap-change operation is necessary to bring back the deviation within bandwidth limits.
- The tap changer operation shall be blocked by adjustable settings of:
  - Under voltage below 95% down to 70%
  - Over current above 100 % up to 210%
  - For each of these functions related signalling contacts for remote indication and alarming shall be provided
  - For adjustable setting of 105 to 130% of the actual set voltage, an over voltage detection with tap changer high speed return to actual set voltage shall be incorporated.
- Remotely selectable voltage level shifting (load shedding) shall be possible by 3 external contacts to be closed to reduce the actual set voltage by 0 to 9%.
- The voltage regulator shall be proposed by the contractor is subjected to the approval of the engineer.

### 5.25.1.1 Voltage Regulator (Programmable Unit)

This type of voltage regulator system shall be built also into 19" rack(s) and shall consist of a programmable solid state unit. The voltage regulator shall be housed in cubicle(s).

The general requirements as specified in the Clause as above, remain applicable, however, the programmable voltage regulator system shall provide the following features:

- It shall be programmable to suit the parallel operation of transformers CONTROL BY MINIMIZING OF CIRCULATING CURRENT, as described in clause 5.24.b1) without the need of additional further equipment. Both methods shall require one unit per transformer.
- Communication between parallel operating units shall be performed through a serial interface (RS 485 standard) on serial bus lines to which any number of units can be connected.
- All essential settings and functions of the voltage regulator shall be permanently monitored by self-checking facilities provided by the microprocessor.
- The unit shall include the switches for selection AUTO-MANUAL and for RAISE-LOWER of tap position, both for LOCAL or REMOTE operation, controlled by a key-operated switch and LED indication of the switch position.
- A multiple screen display shall be included, to reflect the following:
  - basic operating data, such as:
    - set voltage
    - actual voltage
    - actual current
    - power factor
    - tap position
  - settings, such as
    - band-width
    - delay times
    - limit over voltage,
    - limit under voltage
    - limit over current and etc.
  - status of self monitoring system
  - configuration of control for parallel operation of transformers.
- The voltage regulation system shall be monitored and controlled from the Substation Automation System(SAS) with IEC61850 protocol. Please refer chapter 5.23.9.5 for details.

The regulation module shall be equipped with the following features:

implemented hardware for the protocol as specified, i.e. wired to a socket at the rear of the module,

at least 8 digital spare inputs,12 digital spare outputs for transmission of further digital signals

provisions for the maximum available numbers of analogue and/or digital inputs/outputs to meet future requirements, such as e.g. processing of transformer circuit breaker signals and signals from motor drive supervisory and parallel control unit.

The unit shall suit the custom made software, special requirements on the field of voltage regulation, control of parallel operation of transformers and the supervisory thereof, as specified.

The independent supervisory of the total voltage regulation system shall be provided in a separate 19"-rack together with the regulation unit if so specified in Scope of Work/Scope of Supply. The details of the supervisory module shall be as follows:

- monitoring of the transformer voltage regarding over- and under-voltages,

- monitoring of the voltage regulation by tap changer operation resulting from "high speed action" control, i.e. the "O.L.T.C.- FAILURE"-check,

- monitoring of the voltage regulator output signals RAISE and LOWER, i.e. "VOLTAGE REGULATION RELAY FAILURE"-check,

- monitoring and stopping of the motor drive to prevent out of limits-travel, e.g. due to sticking motor contacts

The supervisory and regulation module shall be equipped with the implemented hardware for the protocol as specified, i.e. wired to a socket at the rear of the module and the related software protocol as specified.

The voltage regulation system and the supervisory equipment shall have incorporated the required elements for power supply and power conversion to adapt the system to the available auxiliary supply. The power converter/supply module shall be adaptable to voltages of 110 and 220 V DC and shall provide 110/220 V AC power of adequate rating.

## 5.26 FACTORY/SITE TESTS AND STANDARDS

The Contractor shall submit the applicable type test certificates in accordance with latest IEC standard for all relays before they are approved.

A reference list to show when and where these relays have been used before shall be submitted with the Bidding Documents. This list should also state the year of commissioning.

Separate schedules for protection equipment factory- and site-tests shall be submitted for approval at least one month before the start of tests.

The Engineer/Employer inspection of control and protection panels shall be arranged at least two weeks prior to packing for shipment when the contractor is ready for panel inspection. Customer's inspector shall have the authority to reject any items which are found defective or not in conformity with the requirements of the specification. If the inspector rejects any item, the contractor either replaces or makes alterations necessary to meet specification requirements free of charge.

Protection schemes mounted in cubicles shall be completely wired, tested and inspected at the manufacturer's factory. The only work to be performed at site shall be the connection to the external devices and the commissioning tests.

FAT for SA system shall be based on "System" testing and not on the testing of individual items of the SA system. It shall comprise, A test of all the SA system functions, Selective data base testing, Performance testing (based on simulation of ultimate system size), Reliability test. Simulation of the load dispatch centre system equipment and selective data testing to/from the SA system, together with verification of communications capabilities shall also be included. A detailed description on the SAS testing is given under 5.23.13 and Annexure 9

The Contractor shall provide sufficient number of experienced test personnel during inspection tests and at Site (preferably Senior Engineers), and shall be present through responsible personnel, when any item of protection equipment is switched on for the first time.

The commissioning engineer of the Protection Systems shall be from the manufacturer and he shall have sufficient experience of the supplied protection systems. The C.V. of the commissioning engineer should be submitted for approval before starting of the commissioning work.

The Contractor shall indicate that the equipment has been manufactured, erected and commissioned correctly by carrying out approved factory and site tests. The types of test equipment used shall also be subject to approval. Test equipment shall have valid calibration certificates.

All types of test equipment and tools required by the Contractor for tests at Site and commissioning tests shall be provided and included in the quoted Scope of Work / Scope of Supply, whether specifically mentioned or not. Where work permits are required, the Contractor shall give sufficient notice to the Engineer to allow the necessary outage to be arranged.

Overall tests involving more than one Contractor's equipment shall be coordinated by the protection relay supplier. The test and commissioning program shall be subject to approval by the Engineer at site.

The results of all tests shall be submitted, in handwritten form immediately following completion of the tests, and within ten days typewritten copies shall be supplied according to the requirements of these Bidding Documents.

The Contractor shall submit the results (as requested) of any test he may carry out on his own, following manufacture, installation or Site testing, as well as those required herewith.

The equipment shall meet the requirement of IEC 60255-11 and their performance shall not be affected under the following conditions:

Interruption to the DC auxiliary supply of a duration up to 10 ms

AC component (ripple) in the DC auxiliary supply up to 5% of rated value.

#### Dielectric

The equipment shall meet the requirement of the dielectric tests in IEC 60255-5. The equipment shall have a rated insulation voltage of not less than 250 V.

#### Impulse Voltage

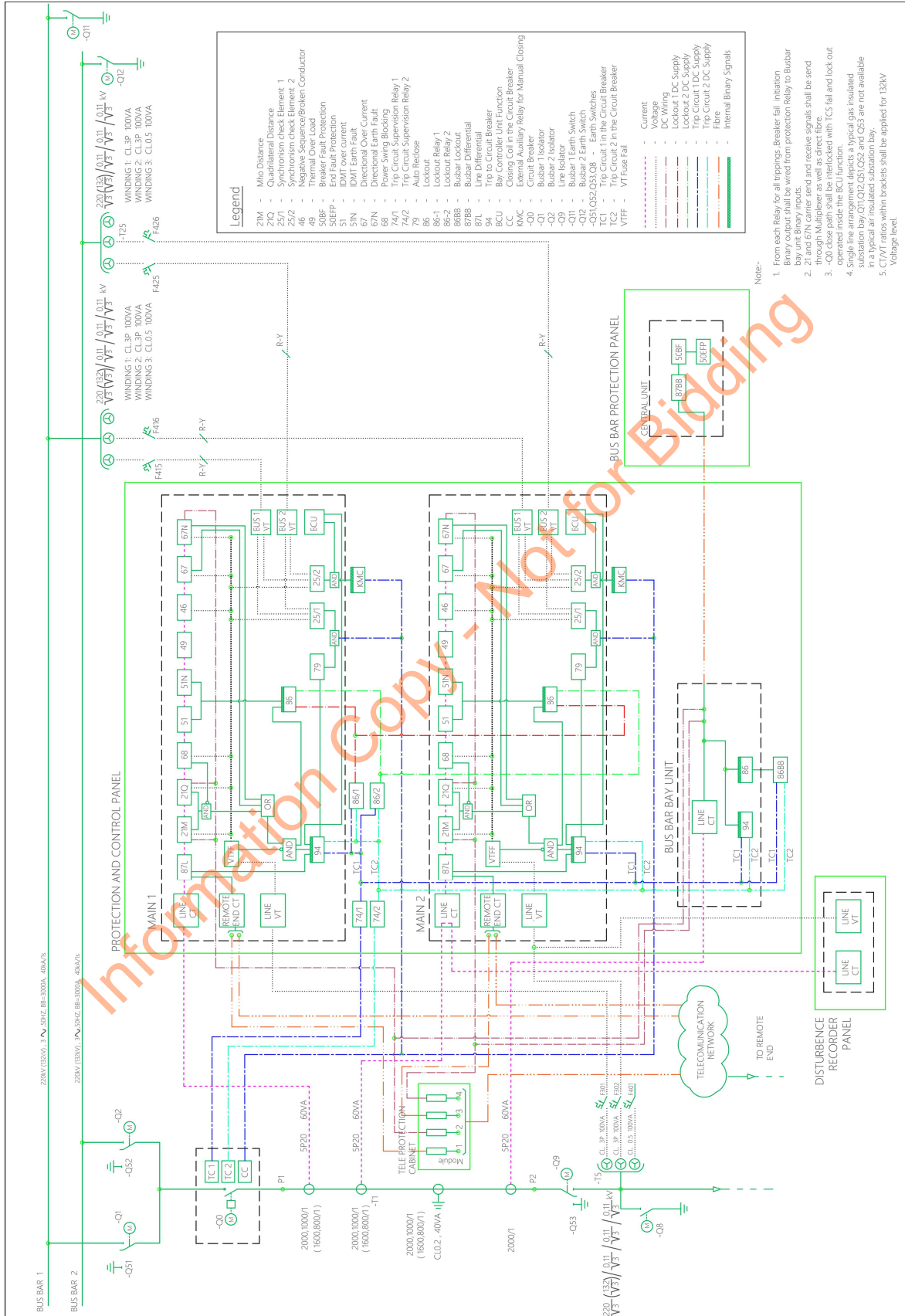
The equipment shall meet the requirement of the impulse voltage tests in IEC 60255-5 with a test voltage of 5kV.

### **5.27 HANDING OVER OF OPERATING AND MAINTENANCE INSTRUCTIONS AND AS BUILT DOCUMENTS**

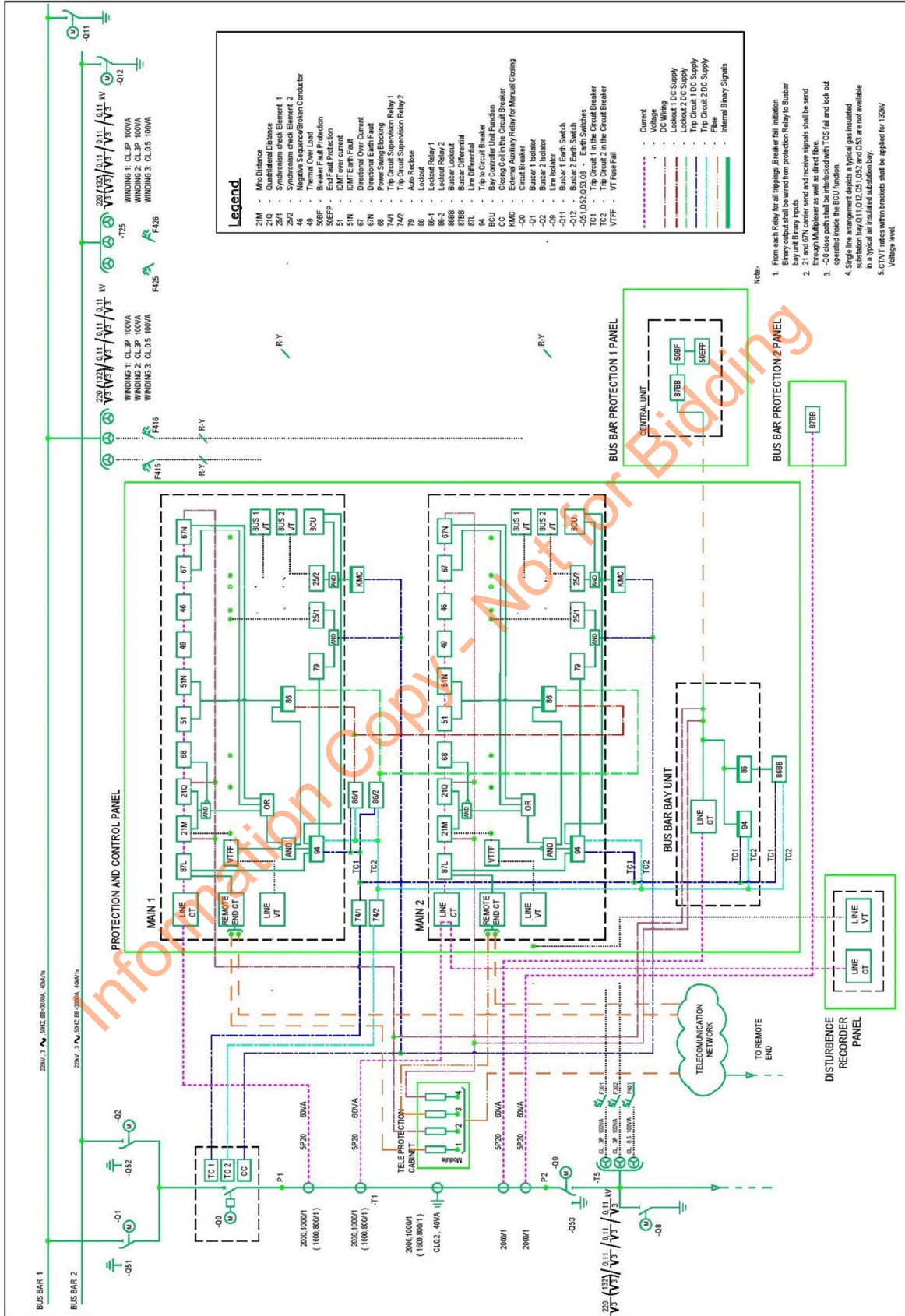
Before Taking Over Certificate is issued the contractor shall submit Operating and Maintenance Instructions and As-Built Documents in accordance with Chapter 12.1.9 and following Control and Protection related documents shall be included.

1. Documents listed under 5.23.11
2. As Built Drawings
3. Site Acceptance Test Sheets of CTs, Protection and Control IEDs, DDR etc.

Annexure 1 A 132kV Line Bay Single Line Diagram

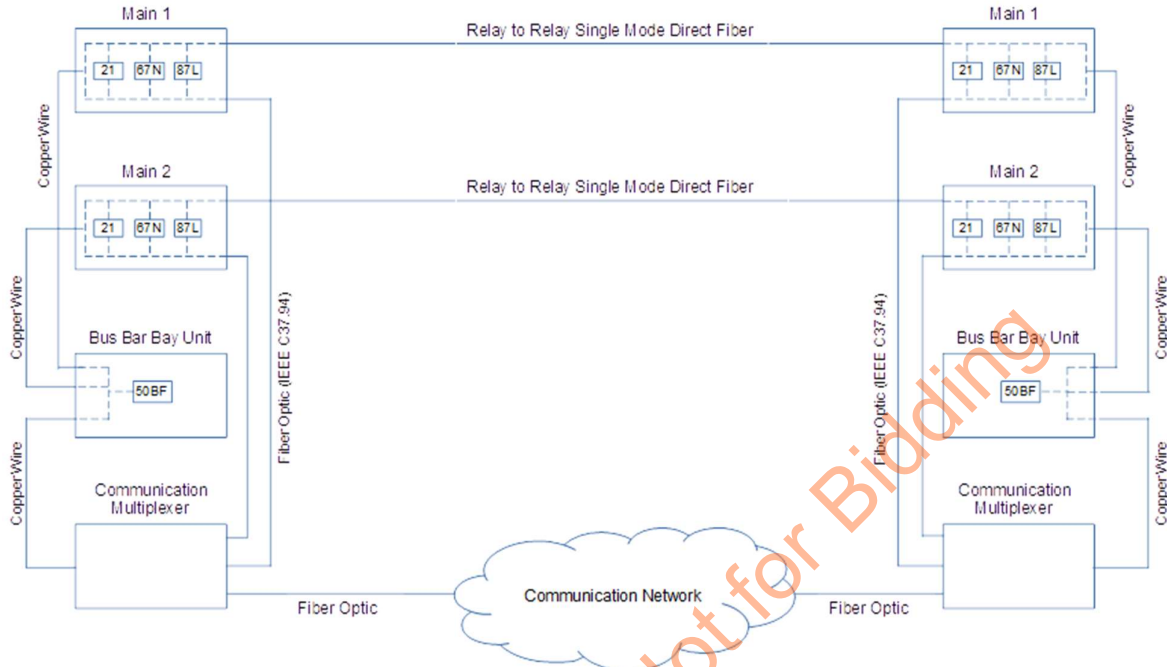


Annexure 1 B 220kV Line Bay Single Line Diagram

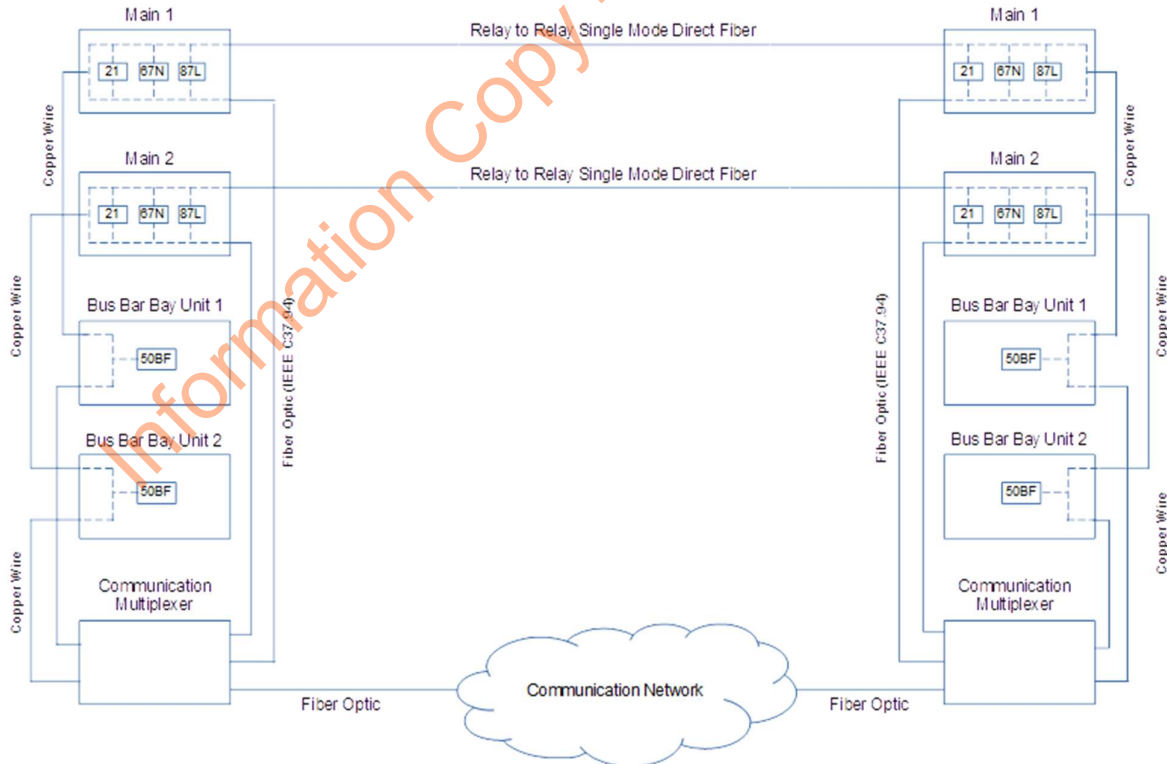


**Annexure 1 C Communication Overview for Line Protection Schemes**

(a) Communication Overview - Protection Scheme of 132 kV Line

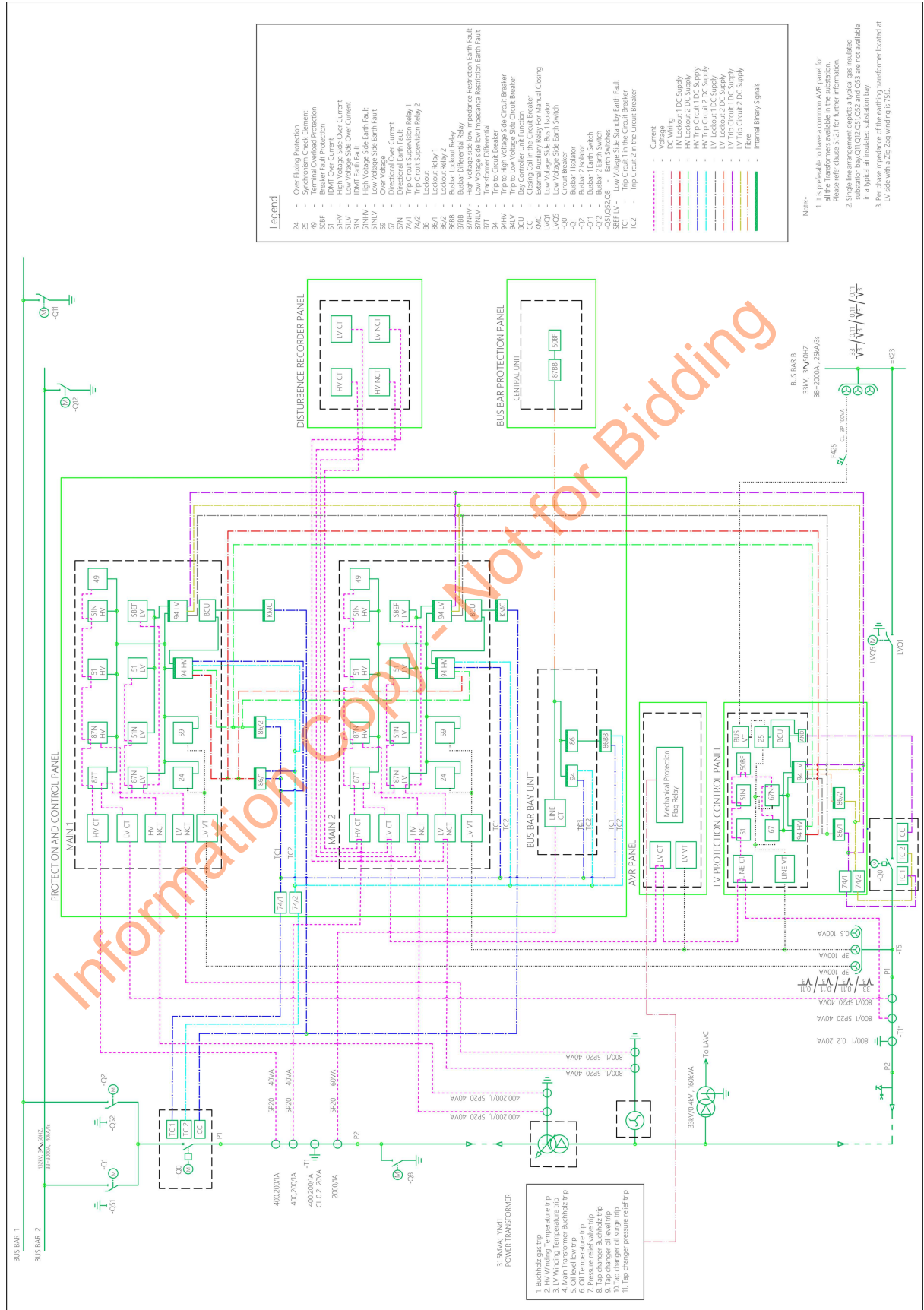


(b) Communication Overview - Protection Scheme of 220 kV Line

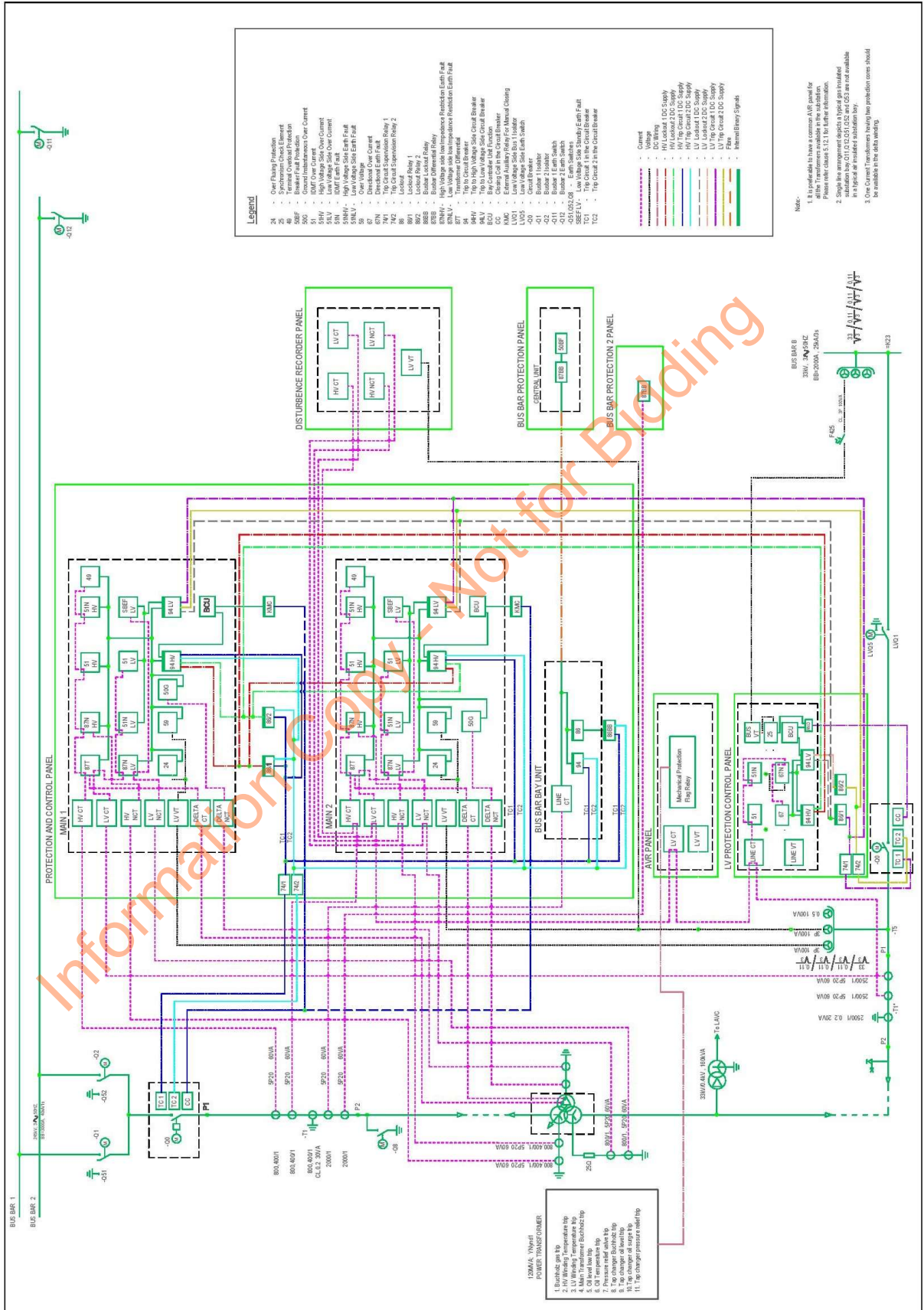




**Annexure 2 132kV/33kV Transformer Protection Single Line Diagram**

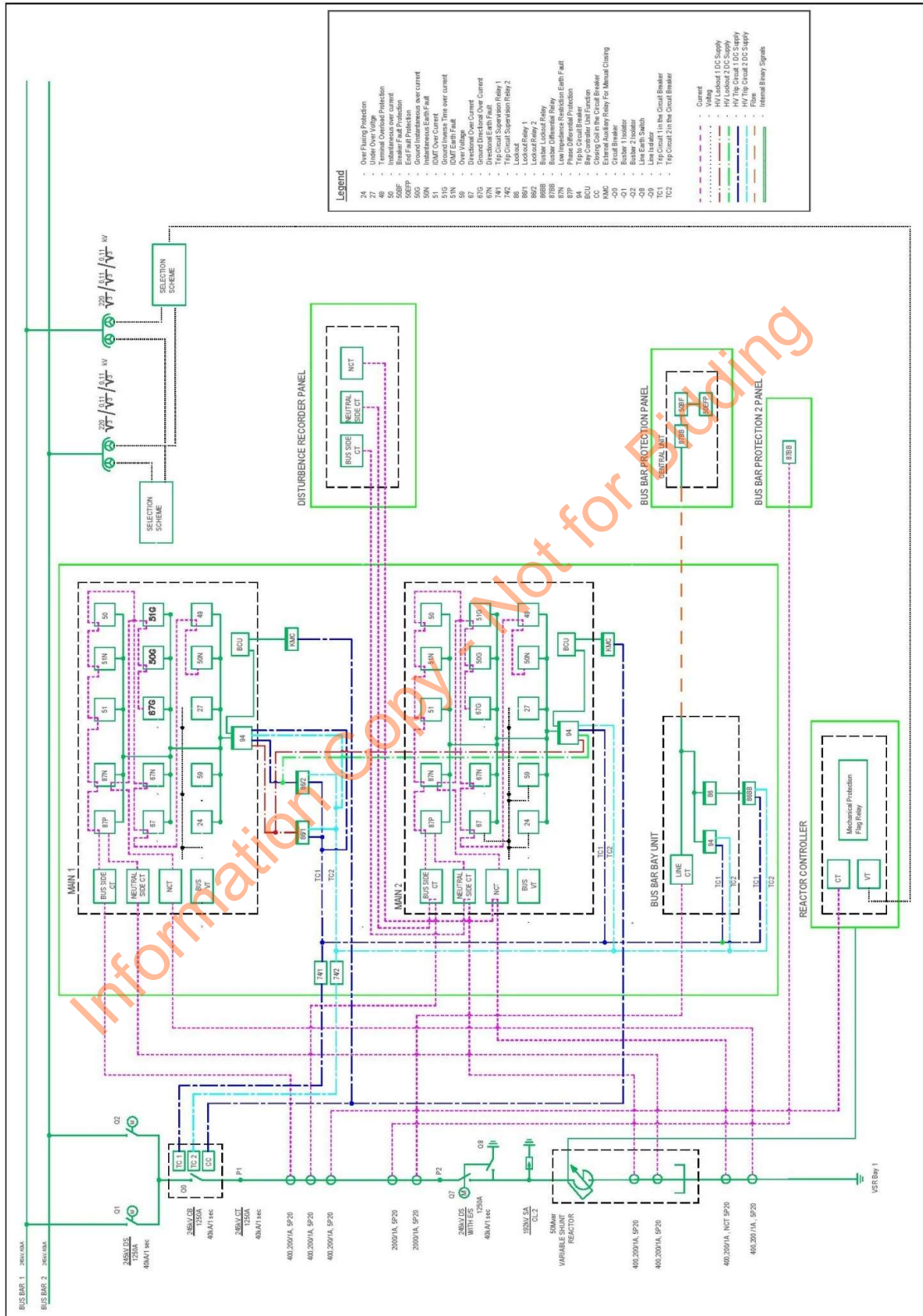


Annexure 3 220kV/33kV Transformer Protection Single Line Diagram

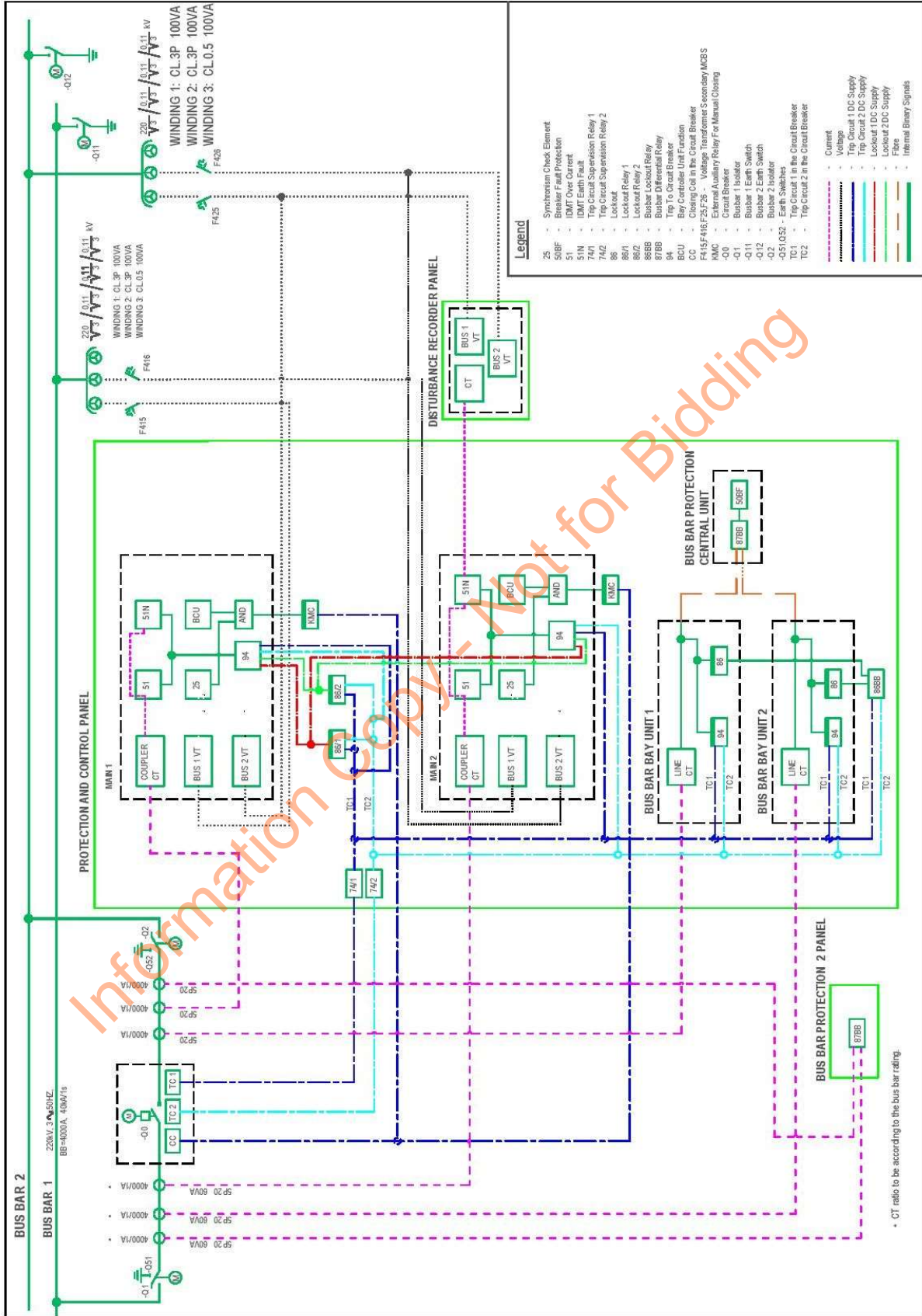




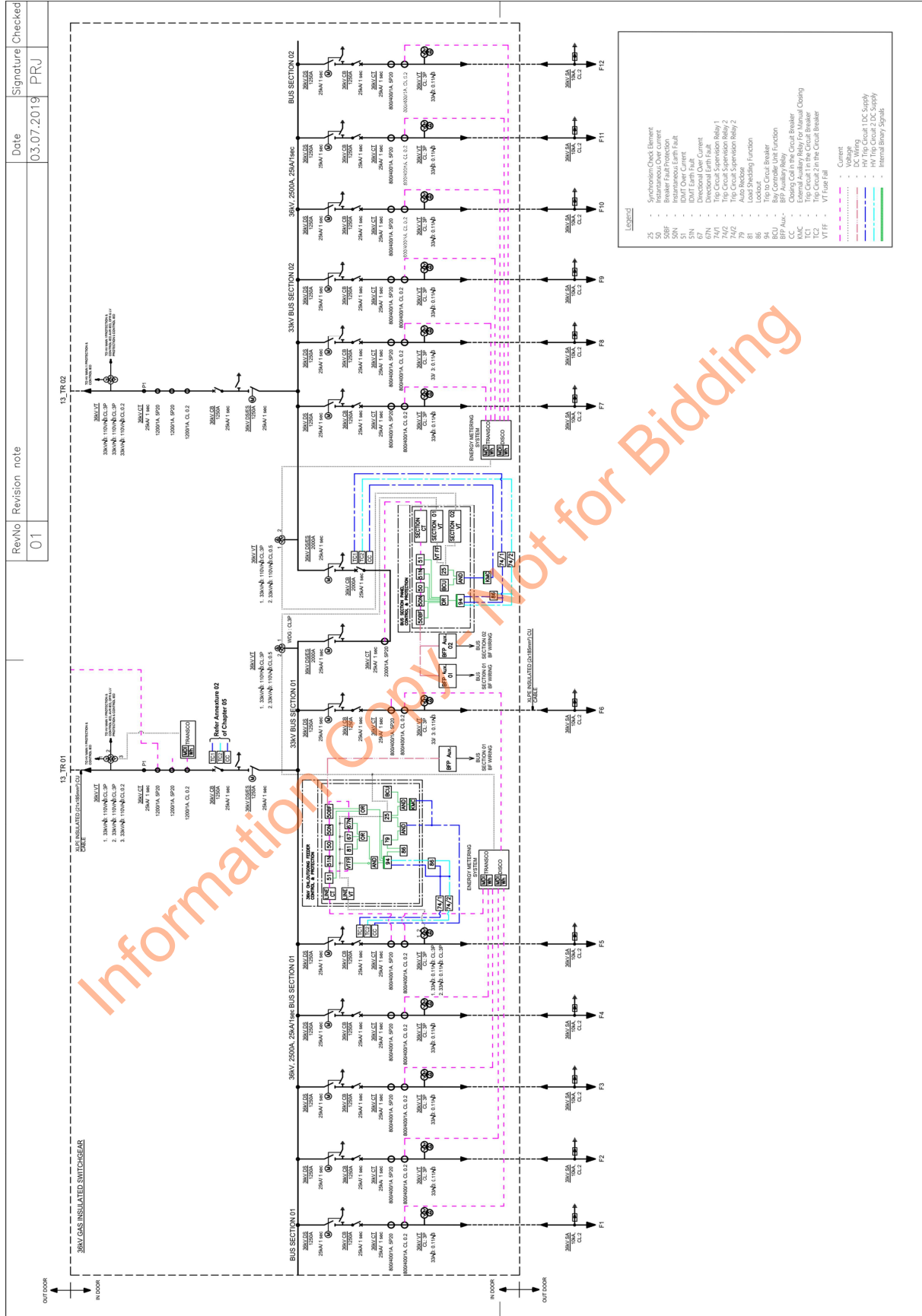
Annexure 5 220kV Shunt Reactor Protection Single Line Diagram



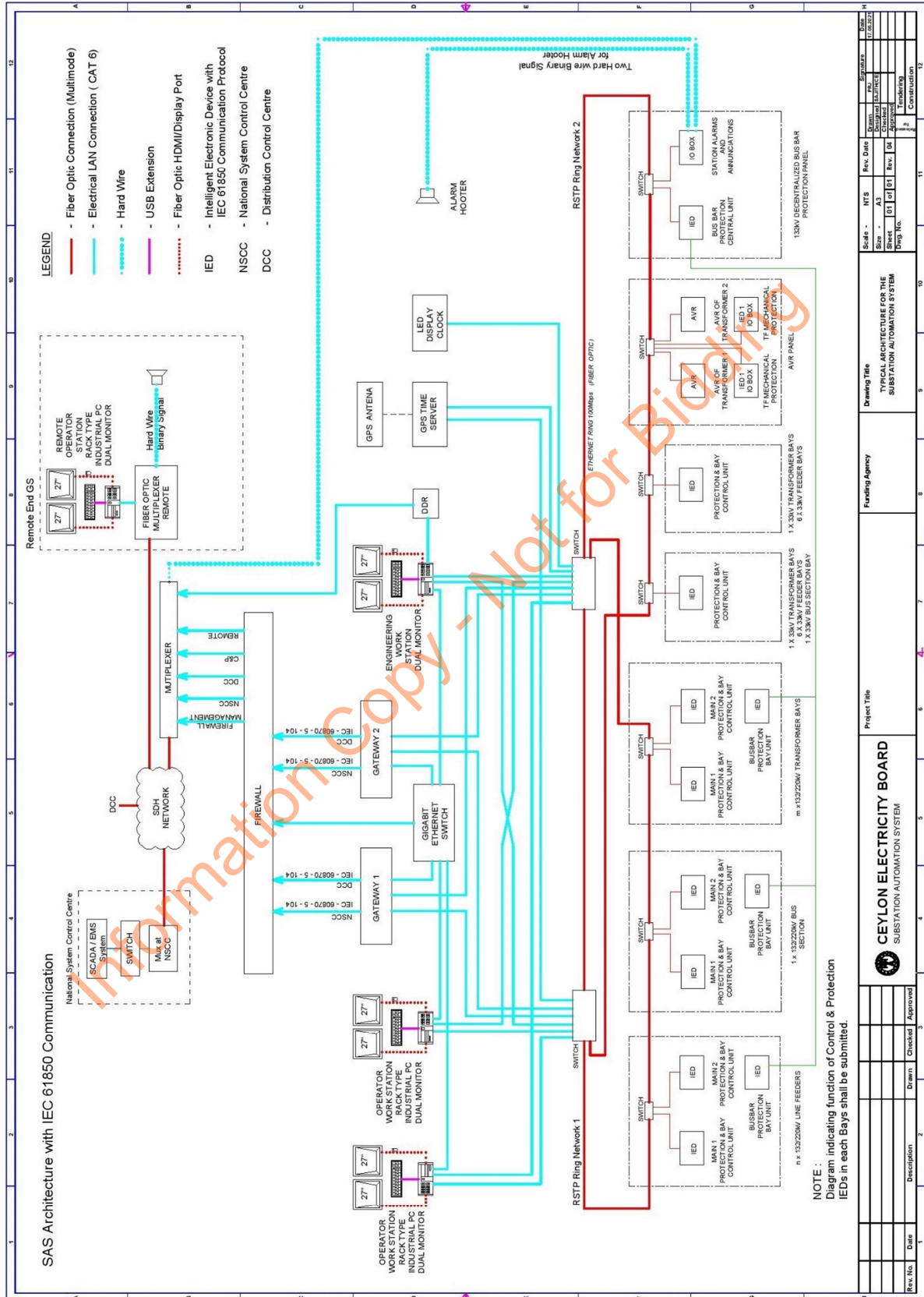
**Annexure 6 Bus Coupler Protection Single Line Diagram**



Annexure 7 33kV GIS Grid Substation Protection Single Line Diagram



### Annexure 8 SAS Architecture



Rev. No.	Date	Description	Drawn	Checked	Approved

Scale	NTS	Rev. Date	Rev. No.	Rev. Description	Rev. By	Rev. Date
A3	01	01	01			
01	01	01	01			
01	01	01	01			
01	01	01	01			
01	01	01	01			
01	01	01	01			

Sheet	of	Total	Drawn	Checked	Approved
01	of	01			
01	of	01			
01	of	01			
01	of	01			
01	of	01			
01	of	01			

Project Title	Funding Agency	Drawing Title
CEYLON ELECTRICITY BOARD SUBSTATION AUTOMATION SYSTEM		TYPICAL ARCHITECTURE FOR THE SUBSTATION AUTOMATION SYSTEM

**Annexure 9 Panel Arrangement 132kV Line Protection-Air Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
	Bus 2 Core 2 VT MCB Healthy	KVT2BB2		
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				
Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
Main 2, Lockout 2 Supply	F111			



Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
Backup Control Supply	F131		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Line Isolator	DSQ9		
<b>Semaphore Switches</b>			
Earth Switch	SQ8	Front Panel	Refer Chapter 5.23.5
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
Lockout Reset	PBLR		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2/Mimic	SSCTRL		
AR Main 1/ Main 2/ OFF	SSAR		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
AC Supply Socket	XPS	Inside the Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8

	Door Switch	SD	Inside Top of the Panel	
<b>Metering Equipment</b>				
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>				
	Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
	Current Transformer Core 2	XCT2		
	Current Transformer Core 3	XCT3		
	Current Transformer Core 4	XCT4		
	Voltage Transformer Core 1	XVT1		
	Voltage Transformer Core 2	XVT2		
	Voltage Transformer Core 3	XVT3		
	Bus Voltage Transformer Circuit	XVTBB		
	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	DC F112	XDC112		
	DC F121	XDC121		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Isolator	XQ9		
	Earth Switch	XQ8		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Marshalling Kiosk	XMK		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101		Refer Chapter 5.23.3

Circuit Breaker Trip Circuit 2	F111	Inside the Panel (DIN Rail)	
Isolator Control Supply	F121		
Circuit Breaker Motor Supply	F131		
Bus 1 Isolator Motor Supply	F132		
Bus 1 Isolator Motor Supply	F133		
Line Isolator Motor Supply	F134		
Line Earth Motor Supply	F135		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
MCB for VT Core 3	F403		
<b>Under Voltage Relays</b>			
Under Voltage Relay for R Phase	KUVR	Inside the Panel (DIN Rail)	Refer Chapter 5.23.6
Under Voltage Relay for Y Phase	KUVY		
Under Voltage Relay for B Phase	KUVB		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		

Voltage Transformer Core 2	XVT2
Voltage Transformer Core 3	XVT3
AC Distribution	XAC
DC Distribution	XDC
DC 101	XDC101
DC 111	XDC102
DC 121	XDC111
DC 131	XDC112
DC 132	XDC121
DC 133	XDC133
DC 134	XDC134
DC 135	XDC135
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Line Isolator	XQ9
Earth Switch	XQ8
Protection/Control Panel	XRP

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**Annexure 10 Panel Arrangement 132kV Line Protection-Gas Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
<b>Protection/ Control Panel</b>	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Earth Switch Closed	KB1ES		
	Bus 2 Earth Switch Closed	KB2ES		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
Bus 1 Core 2 VT MCB Healthy	KVT2BB1			
Bus 2 Core 2 VT MCB Healthy	KVT2BB2			
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				

Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Main 2, Lockout 2 Supply	F111		
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
AR Main 1/ Main 2/ OFF	SSAR		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		

	Voltage Transformer Core 2	XVT2		
	Voltage Transformer Core 3	XVT3		
	Bus Voltage Transformer Circuit	XVTBB		
	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	DC F112	XDC112		
	DC F121	XDC121		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Isolator	XQ9		
	Earth Switch	XQ8		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Local Control Cubicle	XLCC		
<b>Local Control Cubicle</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 1 Isolator Motor Supply	F133		
	Line Isolator Motor Supply	F134		
Line Earth Motor Supply	F135			

Backup Control Supply	F141		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
MCB for VT Core 3	F403		
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Under Voltage Relays</b>			
Under Voltage Relay for R Phase	KUVR	Inside the Panel (DIN Rail)	Refer Chapter 5.23.6
Under Voltage Relay for Y Phase	KUVY		
Under Voltage Relay for B Phase	KUVB		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Selector Switches</b>			
Control Local/Remote	SSLCTRL	Front Panel	Refer Chapter 5.23.1
Interlock Bypassed/Not Bypassed	SSIB	Front Panel	Refer Chapter 5.23.1
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4



Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Line Isolator	DSQ9		
Earth Switch (Q51)	DSQ51		
Earth Switch (Q52)	DSQ52		
Earth Switch (Q53)	DSQ53		
Line Earth Switch (Q8)	DSQ8		
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1		
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102	Inside the Panel (DIN Rail)	Refer Chapter 5.3
DC 121	XDC111		
DC 131	XDC112		
DC 132	XDC121		
DC 133	XDC133		
DC 134	XDC134		
DC 135	XDC135		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Line Isolator	XQ9		
Earth Switch	XQ8		

Earth Switch (Q51)	XQ51	
Earth Switch (Q52)	XQ52	
Earth Switch (Q53)	XQ53	
Protection/Control Panel	XRP	

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**Annexure 11 Panel Arrangement 220kV Line Protection-Air Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
	Bus 2 Core 2 VT MCB Healthy	KVT2BB2		
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				
Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
Main 2, Lockout 2 Supply	F111			

Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
Backup Control Supply	F131		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Line Isolator	DSQ9		
<b>Semaphore Switches</b>			
Earth Switch	SQ8	Front Panel	Refer Chapter 5.23.5
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
Lockout Reset	PBLR		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2/Mimic	SSCTRL		
AR Main 1/ Main 2	SSAR		
AR OFF/1PH/3PH/1Ph or 3PH	SSARF		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
AC Supply Socket	XPS	Inside the Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			

Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
Bus Voltage Transformer Circuit	XVTBB		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
DC F121	XDC121		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Line Isolator	XQ9		
Earth Switch	XQ8		
Analogs from Bus Coupler Group 1	XIPA1		
Analogs from Bus Coupler Group 2	XIPA2		
Digitals from Bus Coupler Group 1	XIPD1		
Digitals from Bus Coupler Group 2	XIPD2		
DFR Panel	XDFR		
Marshalling Kiosk	XMK		
<b>DC MCBs</b>			

<b>Marshalling Kiosk</b>	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
	Circuit Breaker Trip Circuit 2	F111			
	Isolator Control Supply	F121			
	Circuit Breaker Motor Supply	F131			
	Bus 1 Isolator Motor Supply	F132			
	Bus 1 Isolator Motor Supply	F133			
	Line Isolator Motor Supply	F134			
	Line Earth Motor Supply	F135			
	<b>AC MCBs</b>				
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
	<b>VT MCBs</b>				
	MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
	MCB for VT Core 2	F402			
	MCB for VT Core 3	F403			
	<b>Under Voltage Relays</b>				
	Under Voltage Relay for R Phase	KUVR	Inside the Panel (DIN Rail)	Refer Chapter 5.23.6	
	Under Voltage Relay for Y Phase	KUVY			
	Under Voltage Relay for B Phase	KUVB			
	<b>Heater</b>				
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7	
	Temperature Controller	SH	Inside the Panel (DIN Rail)		
	<b>Lamp Assembly</b>				
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8	
	Door Switch	SD	Inside Top of the Panel		
	<b>Terminal Blocks</b>				
	Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3	
	Current Transformer Core 2	XCT2			
	Current Transformer Core 3	XCT3			
Current Transformer Core 4	XCT4				

Voltage Transformer Core 1	XVT1
Voltage Transformer Core 2	XVT2
Voltage Transformer Core 3	XVT3
AC Distribution	XAC
DC Distribution	XDC
DC 101	XDC101
DC 111	XDC102
DC 121	XDC111
DC 131	XDC112
DC 132	XDC121
DC 133	XDC133
DC 134	XDC134
DC 135	XDC135
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Line Isolator	XQ9
Earth Switch	XQ8
Protection/Control Panel	XRP

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**Annexure 12 Panel Arrangement 220kV Line Protection-Gas Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Earth Switch Closed	KB1ES		
	Bus 2 Earth Switch Closed	KB2ES		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
Bus 1 Core 2 VT MCB Healthy	KVT2BB1			
Bus 2 Core 2 VT MCB Healthy	KVT2BB2			
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				



Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Main 2, Lockout 2 Supply	F111		
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
AR Main 1/ Main 2	SSAR		
AR OFF/1PH/3PH/1Ph or 3PH	SSARF		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
AC Supply Socket	XPS	Inside the Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		

	Voltage Transformer Core 1	XVT1		
	Voltage Transformer Core 2	XVT2		
	Voltage Transformer Core 3	XVT3		
	Bus Voltage Transformer Circuit	XVTBB		
	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	DC F112	XDC112		
	DC F121	XDC121		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Isolator	XQ9		
	Earth Switch	XQ8		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Local Control Cubicle	XLCC		
<b>Local Control Cubicle</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 1 Isolator Motor Supply	F133		
	Line Isolator Motor Supply	F134		
	Line Earth Motor Supply	F135		
	Backup Control Supply	F141		

<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
MCB for VT Core 3	F403		
<b>Under Voltage Relays</b>			
Under Voltage Relay for R Phase	KUVR	Inside the Panel (DIN Rail)	Refer Chapter 5.23.6
Under Voltage Relay for Y Phase	KUVY		
Under Voltage Relay for B Phase	KUVB		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Selector Switches</b>			
Control Local/Remote	SSLCTRL	Front Panel	Refer Chapter 5.23.1
Interlock Bypassed/Not Bypassed	SSIB	Front Panel	Refer Chapter 5.23.1
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	Refer Chapter
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		

Line Isolator	DSQ9		
Earth Switch (Q51)	DSQ51		
Earth Switch (Q52)	DSQ52		
Earth Switch (Q53)	DSQ53		
Line Earth Switch (Q8)	DSQ8		
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102		
DC 121	XDC111		
DC 131	XDC112		
DC 132	XDC121		
DC 133	XDC133		
DC 134	XDC134		
DC 135	XDC135		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Line Isolator	XQ9		
Earth Switch	XQ8		
Protection/Control Panel	XRP		

**Annexure 13 Panel Arrangement 132kV side of 132kV/33kV Transformer Air insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Circuit Breaker in Local	KCBL		
	Isolators in Local	KIL		
	<b>DC MCBs</b>			
	Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Main 2, Lockout 2 Supply	F111			
Main 1 BI Supply	F102			
Main 2 BI Supply	F112			

Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
Backup Control Supply	F131		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0		
Bus 1 Isolator	DSQ1	Front Panel	Refer Chapter 5.23.4
Bus 2 Isolator	DSQ2		
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
Lockout Reset	PBLR		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2/Mimic	SSCTRL		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		

	Voltage Transformer Circuit	XVT1		
	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	DC F112	XDC112		
	DC F121	XDC121		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Low Voltage Panel	XLV		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Marshalling Kiosk	XMK		
	Transformer Local Control Panel	XTLCC		
	AVR Panel	XAVR		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>Heater</b>			

	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
	Door Switch	SD	Inside Top of the Panel	
	<b>Terminal Blocks</b>			
	Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
	Current Transformer Core 2	XCT2		
	Current Transformer Core 3	XCT3		
	Current Transformer Core 4	XCT4		
	AC Distribution	XAC		
	DC Distribution	XDC		
	DC 101	XDC101		
	DC 111	XDC102		
	DC 121	XDC111		
	DC 131	XDC112		
	DC 132	XDC121		
	DC 133	XDC133		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Protection/Control Panel	XRP		
	AVR Panel	XAVR		
<b>AVR Panel</b>	<b>AVR Relays</b>			
	AVR Relay for Transformer 1	AVRTF1	Front Panel	Refer Chapter 5.25.1
	AVR Relay for Transformer 2	AVRTF2		
	<b>Input Output Module</b>	IO	Front Panel	Refer Chapter 5.12.6.4
	<b>Mechanical Protection Flag Relays</b>			
	Main Transformer Buchholz Trip (Transformer 1/2)	KTMB (1/2)	Front Panel	Refer Chapter 5.22.3
HV Winding Temperature Trip (Transformer 1/2)	KTMHWT (1/2)			



LV Winding Temperature Trip (Transformer 1/2)	KTMLWT (1/2)		
Oil Temperature Trip (Transformer 1/2)	KTMOT (1/2)		
Buchholz Gas Trip (Transformer 1/2)	KTMBG (1/2)		
Tap Changer Oil Level Trip (Transformer 1/2)	KTTCOL (1/2)		
Tap Changer Oil Pressure Surge Trip (Transformer 1/2)	KTTCCPS (1/2)		
Tap Changer Buchholz Trip (Transformer 1/2)	KTTCCB (1/2)		
Main Transformer PRV Trip (Transformer 1/2)	KTMPR (1/2)		
Main Transformer Oil Level Minimum Trip (Transformer 1/2)	KTMOL (1/2)		
Tap Changer PRV Trip (Transformer 1/2)	KTTCCPR (1/2)		
Main Transformer Buchholz Alarm (Transformer 1/2)	KAMB (1/2)		
HV Winding Temperature Alarm (Transformer 1/2)	KAMHWT (1/2)		
LV Winding Temperature Alarm (Transformer 1/2)	KAMLWT (1/2)		
Oil Temperature Alarm (Transformer 1/2)	KAMOT (1/2)		
Tap Changer Oil Level Alarm (Transformer 1/2)	KATCOL (1/2)		
Main Transformer Oil Level Minimum Alarm (Transformer 1/2)	KAMOL (1/2)		
Tap Changer Buchholz Alarm (Transformer 1/2)	KATCB (1/2)		
<b>Auxiliary Relays</b>			
Transformer 1 Mechanical Protection Operated	KTF1MT	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
Transformer 2 Mechanical Protection Operated	KTF2MT		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	

<b>DC MCBs</b>			
Transformer 1 AVR Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Transformer 2 AVR Supply; (Only for Three phase transformer banks where a single panel can be used to accommodate two AVR relays)	F111		
Transformer 1 Mechanical Protection Supply	F102		
Transformer 2 Mechanical Protection Supply; (Only for Three phase transformer banks where a single panel can be used to accommodate two AVR relays)	F112		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Terminal Blocks</b>			
AC Distribution	XAC	Inside the Panel (DIN Rail)	Refer Chapter 5.3
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
Low Voltage Panel	XLV		
HV Side Protection/Control Panel	XRP		
DFR Panel	XDFR		
Transformer Local Control Panel	XTLCC		

**Annexure 14 Panel Arrangement 132kV side of 132kV/33kV Transformer Gas insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Circuit Breaker in Local	KCBL		
	Isolators in Local	KIL		
	<b>DC MCBs</b>			
	Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Main 2, Lockout 2 Supply	F111			
Main 1 BI Supply	F102			
Main 2 BI Supply	F112			
Busbar Bay Unit Supply	F121			

Busbar Bay Unit BI Supply	F122		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Circuit	XVT1		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		

	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Earth	XQ8		
	Line Isolator	XQ9		
	Low Voltage Panel	XLV		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Marshalling Kiosk	XMK		
	Transformer Local Control Panel	XTLCC		
	AVR Panel	XAVR		
<b>Local Control Cubicle</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		
	Line Earth Motor Supply	F134		
	Backup Control Supply	F141		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)		

<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Line Isolator	DSQ9		
Earth Switch (Q51)	DSQ51		
Earth Switch (Q52)	DSQ52		
Earth Switch (Q53)	DSQ53		
Line Earth Switch (Q8)	DSQ8		
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			
Control Local/Remote	SSLCTRL	Front Panel	Refer Chapter 5.23.1
Interlock Bypassed/Not Bypassed	SSIB	Front Panel	Refer Chapter 5.23.1
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102		
DC 121	XDC111		
DC 131	XDC112		

	DC 132	XDC121		
	DC 133	XDC133		
	DC 134	XDC134		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Earth	XQ8		
	Protection/Control Panel	XRP		
	AVR Panel	XAVR		
<b>AVR Panel</b>	<b>AVR Relays</b>			
	AVR Relay for Transformer 1	AVRTF1		
	AVR Relay for Transformer 2	AVRTF2	Front Panel	Refer Chapter
	<b>Input Output Module</b>	IO	Front Panel	Refer Chapter 5.12.6.4
	<b>Mechanical Protection Flag Relays</b>			
	Main Transformer Buchholz Trip (Transformer 1/2)	KTMB (1/2)	Front Panel	Refer Chapter 5.22.3
	HV Winding Temperature Trip (Transformer 1/2)	KTMHWT (1/2)		
	LV Winding Temperature Trip (Transformer 1/2)	KTMLWT (1/2)		
	Oil Temperature Trip (Transformer 1/2)	KTMOT (1/2)		
	Buchholz Gas Trip (Transformer 1/2)	KTMBG (1/2)		
	Tap Changer Oil Level Trip (Transformer 1/2)	KTTCOL (1/2)		
	Tap Changer Oil Pressure Surge Trip (Transformer 1/2)	KTTCP (1/2)		
	Tap Changer Buchholz Trip (Transformer 1/2)	KTTCB (1/2)		
	Main Transformer PRV Trip (Transformer 1/2)	KTMPR (1/2)		
	Main Transformer Oil Level Minimum Trip (Transformer 1/2)	KTMOL (1/2)		
Tap Changer PRV Trip (Transformer 1/2)	KTTCP (1/2)			
Main Transformer Buchholz Alarm (Transformer 1/2)	KAMB (1/2)			
HV Winding Temperature Alarm (Transformer 1/2)	KAMHWT (1/2)			

LV Winding Temperature Alarm (Transformer 1/2)	KAMLWT (1/2)		
Oil Temperature Alarm (Transformer 1/2)	KAMOT (1/2)		
Tap Changer Oil Level Alarm (Transformer 1/2)	KATCOL (1/2)		
Main Transformer Oil Level Minimum Alarm (Transformer 1/2)	KAMOL (1/2)		
Tap Changer Buchholz Alarm (Transformer 1/2)	KATCB (1/2)		
Cooling Fan Motor MCB Trip (Transformer 1/2)	KAFMT (1/2)		
Cooling Fan Motor Thermal Overload (Transformer 1/2)	KAFOT (1/2)		
Cooling Fan Switched On (Transformer 1/2)	KAFON (1/2)		
Cooling Fan Switched Off (Transformer 1/2)	KAFOFF (1/2)		
OLTC Motor MCB Trip (Transformer 1/2)	KATCMT (1/2)		
Tap Change Incomplete (Transformer 1/2)	KATCI (1/2)		
OLTC in Local (Transformer 1/2)	KATCL (1/2)		
OLTC Motor Thermal Overload (Transformer 1/2)	KATCOT (1/2)		
Earthing Transformer Buchholz Trip (Transformer 1/2)	KTEB (1/2)		
Earthing Transformer PRV Trip (Transformer 1/2)	KTEPR (1/2)		
<b>Auxiliary Relays</b>			
Transformer 1 Meachanical Protection Operated	KTF1MT	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
Transformer 2 Meachanical Protection Operated	KTF2MT		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>DC MCBs</b>			
Transformer 1 AVR Supply	F101		Refer Chapter 5.23.3



Transformer 2 AVR Supply; (Only for Three phase transformer banks where a single panel can be used to accommodate two AVR relays)	F111	Inside the Panel (DIN Rail)	
Transformer 1 Meachanical Protection Supply	F102		
Transformer 2 Meachanical Protection Supply; (Only for Three phase transformer banks where a single panel can be used to accommodate two AVR relays)	F112		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Terminal Blocks</b>			
AC Distribution	XAC	Inside the Panel (DIN Rail)	Refer Chapter 5.3
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
Low Voltage Panel	XLV		
HV Side Protection/Control Panel	XRP		
DFR Panel	XDFR		
Marshalling Kiosk	XMK		
Transformer Local Control Panel	XTLCC		

**Annexure 15 Panel Arrangement 220kV side of 220kV/132kV/33kV Transformer Air insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
Bus 2 Core 1 VT MCB Healthy	KVT1BB2			
Bus 1 Core 2 VT MCB Healthy	KVT2BB1			
Bus 2 Core 2 VT MCB Healthy	KVT2BB2			
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				
Main 1, Lockout 1 Supply, BB Lockout	F101		Refer Chapter 5.23.3	

Main 2, Lockout 2 Supply	F111	Inside the Panel (DIN Rail)	
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
Backup Control Supply	F131		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
Lamp Test for the Mimic	PBM		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2/Mimic	SSCTRL		
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
AC Supply Socket	XPS	Inside the Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8

Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
DC F121	XDC121		
DC F122	XDC122		
DC F131	XDC131		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Low Voltage Panel	XLV		
Medium Voltage Panel	XMV		
Analogs from Bus Coupler Group 1	XIPA1		
Analogs from Bus Coupler Group 2	XIPA2		
Digitals from Bus Coupler Group 1	XIPD1		
Digitals from Bus Coupler Group 2	XIPD2		
DFR Panel	XDFR		
Marshalling Kiosk	XMK		
Transformer Local Control Panel	XTLCC		

	AVR Panel	XAVR		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>VT MCBs</b>			
	MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	MCB for VT Core 2	F402		
	MCB for VT Core 3	F403		
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
	Door Switch	SD	Inside Top of the Panel	
	<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3	
Current Transformer Core 2	XCT2			
Current Transformer Core 3	XCT3			
Current Transformer Core 4	XCT4			
Voltage Transformer Core 1	XVT1			
Voltage Transformer Core 2	XVT2			
Voltage Transformer Core 3	XVT3			

	AC Distribution	XAC		
	DC Distribution	XDC		
	DC 101	XDC101		
	DC 111	XDC111		
	DC 121	XDC121		
	DC 131	XDC131		
	DC 132	XDC132		
	DC 133	XDC133		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Protection/Control Panel	XRP		
	AVR Panel	XAVR		
<b>AVR Panel</b>	<b>AVR Relays</b>			
	AVR Relay for 132kV Side	AVRMV		
	AVR Relay for 33kV Side	AVRLV	Front Panel	Refer Chapter 5.25.1
	<b>Input Output Module</b>	IO	Front Panel	Refer Chapter 5.12.6.4
	<b>Mechanical Protection Flag Relays</b>			
	Main Transformer Buchholz Trip	KTMB	Front Panel	Refer Chapter 5.22.3 If the transformer consists of three single phase banks there shall be relays on per phase basis. Then R phase relays' drawing reference shall contain a "R" at the end.
	HV Winding Temperature Trip	KTMHWT		
	LV Winding Temperature Trip	KTMLWT		
	Oil Temperature Trip	KTMOT		
	Buchholz Gas Trip	KTMBG		
	Tap Changer Oil Level Trip	KTTCOL		
	Tap Changer Oil Pressure Surge Trip	KTTCP		
	Tap Changer Buchholz Trip	KTTCB		
	Main Transformer PRV Trip	KTMPR		
Main Transformer Oil Level Minimum Trip	KTMOL			
Tap Changer PRV Trip	KTTCP			
Main Transformer Buchholz Alarm	KAMB			

HV Winding Temperature Alarm	KAMHWT		
LV Winding Temperature Alarm	KAMLWT		
Oil Temperature Alarm	KAMOT		
Tap Changer Oil Level Alarm	KATCOL		
Main Transformer Oil Level Minimum Alarm	KAMOL		
Tap Changer Buchholz Alarm	KATCB		
Cooling Fan Motor MCB Trip	KAFMT		
Cooling Fan Motor Thermal Overload	KAFOT		
Cooling Fan Switched On	KAFON		
Cooling Fan Switched Off	KAFOFF		
OLTC Motor MCB Trip	KATCMT		
Tap Change Incomplete	KATCI		
OLTC in Local	KATCL		
OLTC Motor Thermal Overload	KATCOT		
Earthing Transformer Buchholz Trip	KTEB		
Earthing Transformer PRV Trip	KTEPR		
<b>Auxiliary Relays</b>			
Transformer Mechanical Protection Operated	KTFMT	Inside the Panel (DIN Rail)	Refer Chapter 5.20.4. In the case of a transformer which consists of three single phase transformer banks there shall be three auxiliary relays on per phase basis.
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8

Door Switch	SD	Inside Top of the Panel	
<b>DC MCBs</b>			
Transformer MV AVR Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Transformer LV AVR Supply	F111		
Transformer Mechanical Protection Supply	F102		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Terminal Blocks</b>			
AC Distribution	XAC	Inside the Panel (DIN Rail)	Refer Chapter 5.3. If the transformer consists of three single phase banks there shall be terminal bars for each phase of the transformer local control cubicles.
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
Low Voltage Panel	XLV		
HV Side Protection/Control Panel	XRP		
DFR Panel	XDFR		
Local Control Cubicle	XLCC		
Medium Voltage Panel	XMV		
Low Voltage Panel	XLV		
Transformer Local Control Panel	XTLCC		



**Annexure 16 Panel Arrangement 220kV side of 220kV/132kV/33kV Transformer Gas insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
<b>Protection/ Control Panel</b>	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
	Bus 2 Core 2 VT MCB Healthy	KVT2BB2		
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				
Main 1, Lockout 1 Supply, BB Lockout	F101		Refer Chapter 5.23.3	

Main 2, Lockout 2 Supply	F111	Inside the Panel (DIN Rail)	
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR		Refer Chapter 5.23.2
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		

	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	DC F112	XDC112		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Earth	XQ8		
	Line Isolator	XQ9		
	Low Voltage Panel	XLV		
	Medium Voltage Panel	XMV		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Local Control Cubicle	XLCC		
	Transformer Local Control Panel	XTLCC		
	AVR Panel	XAVR		
<b>Local Control Cubicle</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		
	Line Earth Motor Supply	F134		
Backup Control Supply	F141			

<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
MCB for VT Core 3	F403		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Line Isolator	DSQ9		
Earth Switch (Q51)	DSQ51		
Earth Switch (Q52)	DSQ52		
Earth Switch (Q53)	DSQ53		
Line Earth Switch (Q8)	DSQ8		
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			
Control Local/Remote	SSLCTRL	Front Panel	Refer Chapter 5.23.1
Interlock Bypassed/Not Bypassed	SSIB	Front Panel	Refer Chapter 5.23.1

<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102		
DC 121	XDC111		
DC 131	XDC112		
DC 132	XDC121		
DC 133	XDC133		
DC 134	XDC134		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Line Earth	XQ8		
Protection/Control Panel	XRP		
AVR Panel	XAVR		
<b>AVR Panel</b>	<b>AVR Relays</b>		
	AVR Relay for 132kV Side	AVRMV	
	AVR Relay for 33kV Side	AVRLV	Front Panel
	<b>Input Output Module</b>	IO	Front Panel
<b>Mechanical Protection Flag Relays</b>			
			Refer Chapter 5.25.1
			Refer Chapter 5.12.6.4

Main Transformer Buchholz Trip	KTMB
HV Winding Temperature Trip	KTMHWT
LV Winding Temperature Trip	KTMLWT
Oil Temperature Trip	KTMOT
Buchholz Gas Trip	KTMBG
Tap Changer Oil Level Trip	KTTCOL
Tap Changer Oil Pressure Surge Trip	KTTCPST
Tap Changer Buchholz Trip	KTTCB
Main Transformer PRV Trip	KTMPR
Main Transformer Oil Level Minimum Trip	KTMOL
Tap Changer PRV Trip	KTTCPRT
Main Transformer Buchholz Alarm	KAMB
HV Winding Temperature Alarm	KAMHWT
LV Winding Temperature Alarm	KAMLWT
Oil Temperature Alarm	KAMOT
Tap Changer Oil Level Alarm	KATCOL
Main Transformer Oil Level Minimum Alarm	KAMOL
Tap Changer Buchholz Alarm	KATCB
Cooling Fan Motor MCB Trip	KAFMT
Cooling Fan Motor Thermal Overload	KAFOT
Cooling Fan Switched On	KAFON
Cooling Fan Switched Off	KAFOFF
OLTC Motor MCB Trip	KATCMT
Tap Change Incomplete	KATCI
OLTC in Local	KATCL
OLTC Motor Thermal Overload	KATCOT
Earthing Transformer Buchholz Trip	KTEB
Earthing Transformer PRV Trip	KTEPR
<b>Auxiliary Relays</b>	

Front Panel

Refer Chapter 5.22.3 If the transformer consists of three single phase banks there shall be relays on per phase basis. Then R phase relays' drawing reference shall contain a "R" at the end.

Transformer Meachanical Protection Operated	KTFMT	Inside the Panel (DIN Rail)	Refer Chapter 5.20.4. In the case of a transformer which consits of three single phase transformer banks there shall be three auxiliary relays on per phase basis.
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>DC MCBs</b>			
Transformer MV AVR Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Transformer LV AVR Supply	F111		
Transformer Meachanical Protection Supply	F102		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Terminal Blocks</b>			
AC Distribution	XAC	Inside the Panel (DIN Rail)	Refer Chapter 5.3. If the transformer consits of three single phase banks there shall be terminal bars for each phase of the transformer local control cubicles.
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
Low Voltage Panel	XLV		
HV Side Protection/Control Panel	XRP		
DFR Panel	XDFR		

Local Control Cubicle	XLCC
Medium Voltage Panel	XMV
Low Voltage Panel	XLV
Transformer Local Control Panel	XTLCC

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**Annexure 17 Panel Arrangement 132kV side of 220kV/132kV/33kV Transformer Air insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
	Bus 2 Core 2 VT MCB Healthy	KVT2BB2		
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>Discrepancy Switches</b>				
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4	
Bus 1 Isolator	DSQ1			

Bus 2 Isolator	DSQ2		
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>DC MCBs</b>			
Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Main 2, Lockout 2 Supply	F111		
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
Backup Control Supply	F131		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
Lamp Test for the Mimic	PBM		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2/Mimic	SSCTRL		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	
Socket for Synchronism Check Console	SYN	Front Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8

Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
DC F121	XDC121		
DC F122	XDC122		
DC F131	XDC131		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Low Voltage Panel	XLV		
High Voltage Panel	XHV		
Analogues from Bus Coupler Group 1	XIPA1		
Analogues from Bus Coupler Group 2	XIPA2		
Digitals from Bus Coupler Group 1	XIPD1		
Digitals from Bus Coupler Group 2	XIPD2		
DFR Panel	XDFR		
Marshalling Kiosk	XMK		
Transformer Local Control Panel	XTLCC		

	AVR Panel	XAVR		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>VT MCBs</b>			
	MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	MCB for VT Core 2	F402		
	MCB for VT Core 3	F403		
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
	Door Switch	SD	Inside Top of the Panel	
	<b>Terminal Blocks</b>			
	Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2			
Current Transformer Core 3	XCT3			
Current Transformer Core 4	XCT4			
Voltage Transformer Core 1	XVT1			
Voltage Transformer Core 2	XVT2			
Voltage Transformer Core 3	XVT3			

AC Distribution	XAC
DC Distribution	XDC
DC 101	XDC101
DC 111	XDC111
DC 121	XDC121
DC 131	XDC131
DC 132	XDC132
DC 133	XDC133
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Protection/Control Panel	XRP
AVR Panel	XAVR

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**Annexure 18 Panel Arrangement 132kV side of 220kV/132kV/33kV Transformer Gas insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and 5.9.3
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and 5.9.3
	Busbar Bay Unit	BBBU	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
Bus 2 Core 2 VT MCB Healthy	KVT2BB2			
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			
<b>DC MCBs</b>				
Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	

Main 2, Lockout 2 Supply	F111		
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit Supply	F121		
Busbar Bay Unit BI Supply	F122		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		

	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	DC F112	XDC112		
	DC F121	XDC121		
	DC F122	XDC122		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	Line Earth	XQ8		
	Line Isolator	XQ9		
	Low Voltage Panel	XLV		
	High Voltage Panel	XHV		
	Analogs from Bus Coupler Group 1	XIPA1		
	Analogs from Bus Coupler Group 2	XIPA2		
	Digitals from Bus Coupler Group 1	XIPD1		
	Digitals from Bus Coupler Group 2	XIPD2		
	DFR Panel	XDFR		
	Local Control Cubicle	XLCC		
	Transformer Local Control Panel	XTLCC		
	AVR Panel	XAVR		
<b>Local Control Cubicle</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		



Line Earth Motor Supply	F134		
Backup Control Supply	F141		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
MCB for VT Core 3	F403		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Line Isolator	DSQ9		
Earth Switch (Q51)	DSQ51		
Earth Switch (Q52)	DSQ52		
Earth Switch (Q53)	DSQ53		
Line Earth Switch (Q8)	DSQ8		
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			

Control Local/Remote	SSLCTRL	Front Panel	Refer Chapter 5.23.1
Interlock Bypassed/Not Bypassed	SSIB	Front Panel	Refer Chapter 5.23.1
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Current Transformer Core 4	XCT4		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
Voltage Transformer Core 3	XVT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102		
DC 121	XDC111		
DC 131	XDC112		
DC 132	XDC121		
DC 133	XDC133		
DC 134	XDC134		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Line Earth	XQ8		
Protection/Control Panel	XRP		
AVR Panel	XAVR		

**Annexure 19 Panel Arrangement 220kV/132kV Bus Coupler Air Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and
	Busbar Bay Unit Bus 1	BBBU1	Front Panel	Refer Chapters 5.7 and 5.14
	Busbar Bay Unit Bus 2	BBBU2	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
	Bus 2 Core 2 VT MCB Healthy	KVT2BB2		
	Circuit Breaker in Local	KCBL		
	Isolators in Local	KIL		
<b>DC MCBs</b>				
Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
Main 2, Lockout 2 Supply	F111			

Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit 1 Supply	F121		
Busbar Bay Unit 1 BI Supply	F122		
Busbar Bay Unit 2 Supply	F131		
Busbar Bay Unit 2 BI Supply	F132		
Backup Control Supply	F141		
Supply 1 for External Panels	F151		
Supply 2 for External Panels	F161		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
Lockout Reset	PBLR		
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	
AC Supply Socket	XPS	Inside the Panel	
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8

Door Switch	SD	Inside Top of the Panel	
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>Terminal Blocks</b>			
Bus 1 Current Transformer Core 1	XB1CT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Bus 1 Current Transformer Core 2	XB1CT2		
Bus 2 Current Transformer Core 1	XB2CT3		
Bus 2 Current Transformer Core 2	XB2CT4		
Bus 1 Voltage Transformer Core 1	XB1VT1		
Bus 1 Voltage Transformer Core 2	XB1VT2		
Bus 1 Voltage Transformer Core 3	XB1VT3		
Bus 2 Voltage Transformer Core 1	XB2VT1		
Bus 2 Voltage Transformer Core 2	XB2VT2		
Bus 2 Voltage Transformer Core 3	XB2VT3		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
DC F121	XDC121		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
Line Isolator	XQ9		
Earth Switch	XQ8		
Analogs from Bus Coupler Group 1	XIPA1		
Analogs from Bus Coupler Group 2	XIPA2		
Digitals from Bus Coupler Group 1	XIPD1		
Digitals from Bus Coupler Group 2	XIPD2		
DFR Panel	XDFR		
Marshalling Kiosk	XMK		

	External Panel Loop 1	XSP1		
	External Panel Loop 2	XSP2		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 1 Isolator Motor Supply	F133		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>VT MCBs</b>			
	MCB for Bus 1 VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	MCB for Bus 1 VT Core 2	F402		
	MCB for Bus 1 VT Core 3	F403		
	MCB for Bus 2 VT Core 1	F501		
	MCB for Bus 2 VT Core 2	F502		
	MCB for Bus 2 VT Core 3	F503		
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
	Door Switch	SD	Inside Top of the Panel	
	<b>Terminal Blocks</b>			
Bus 1 Current Transformer Core 1	XB1CT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3	
Bus 1 Current Transformer Core 2	XB1CT2			
Bus 2 Current Transformer Core 1	XB2CT3			
Bus 2 Current Transformer Core 2	XB2CT4			

Bus 1 Voltage Transformer Core 1	XB1VT1
Bus 1 Voltage Transformer Core 2	XB1VT2
Bus 1 Voltage Transformer Core 3	XB1VT3
Bus 2 Voltage Transformer Core 1	XB2VT1
Bus 2 Voltage Transformer Core 2	XB2VT2
Bus 2 Voltage Transformer Core 3	XB2VT3
AC Distribution	XAC
DC Distribution	XDC
DC 101	XDC101
DC 111	XDC102
DC 121	XDC111
DC 131	XDC112
DC 132	XDC121
DC 133	XDC133
DC 134	XDC134
DC 135	XDC135
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Protection/Control Panel	XRP

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**Annexure 20 Panel Arrangement 220kV/132kV Bus Coupler Gas Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Main 1 IED	Main 1	Front Panel	Refer Chapters 5.7 and
	Main 2 IED	Main 2	Front Panel	Refer Chapters 5.7 and
	Busbar Bay Unit Bus 1	BBBU1	Front Panel	Refer Chapters 5.7 and 5.14
	Busbar Bay Unit Bus 2	BBBU2	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	Busbar Lockout	K86BB		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>Auxiliary Relays</b>			
	Manual Close Command	KMC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus Coupler Closed	KBCC		
	Bus 1 Core 1 VT MCB Healthy	KVT1BB1		
	Bus 2 Core 1 VT MCB Healthy	KVT1BB2		
	Bus 1 Core 2 VT MCB Healthy	KVT2BB1		
Bus 2 Core 2 VT MCB Healthy	KVT2BB2			
Bus 1 VT MCB Healthy	KVTBB1			
Bus 2 VT MCB Healthy	KVTBB2			
Circuit Breaker in Local	KCBL			
Isolators in Local	KIL			



<b>DC MCBs</b>			
Main 1, Lockout 1 Supply, BB Lockout	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
Main 2, Lockout 2 Supply	F111		
Main 1 BI Supply	F102		
Main 2 BI Supply	F112		
Busbar Bay Unit 1 Supply	F121		
Busbar Bay Unit 1 BI Supply	F122		
Busbar Bay Unit 2 Supply	F131		
Busbar Bay Unit 2 BI Supply	F132		
Supply 1 for External Panels	F141		
Supply 2 for External Panels	F151		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR		Refer Chapter 5.23.2
<b>Selector Switches</b>			
Breaker Failure On/Off	SSBF	Front Panel	Refer Chapter 5.23.1
Control Main1/Main 2	SSCTRL		
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Bus 1 Current Transformer Core 1	XB1CT1		Refer Chapter 5.3

Bus 1 Current Transformer Core 2	XB1CT2
Bus 2 Current Transformer Core 1	XB2CT3
Bus 2 Current Transformer Core 2	XB2CT4
Bus 1 Voltage Transformer Core 1	XB1VT1
Bus 1 Voltage Transformer Core 2	XB1VT2
Bus 1 Voltage Transformer Core 3	XB1VT3
Bus 2 Voltage Transformer Core 1	XB2VT1
Bus 2 Voltage Transformer Core 2	XB2VT2
Bus 2 Voltage Transformer Core 3	XB2VT3
AC Distribution	XAC
DC Distribution	XDC
DC F101	XDC101
DC F102	XDC102
DC F111	XDC111
DC F112	XDC112
DC F121	XDC121
Busbar Bay Unit 2 Supply	XDC131
Busbar Bay Unit 2 BI Supply	XDC132
Supply 1 for External Panels	XDC141
Supply 2 for External Panels	XDC151
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Bus 1 Earth Switch	XQ11
Bus 2 Earth Switch	XQ12
Analogs from Bus Coupler Group 1	XIPA1
Analogs from Bus Coupler Group 2	XIPA2
Digitals from Bus Coupler Group 1	XIPD1
Digitals from Bus Coupler Group 2	XIPD2
DFR Panel	XDFR

Inside the Panel (DIN Rail)

	Local Control Cubicle	XLCC		
	External Panel Loop 1	XSP1		
	External Panel Loop 2	XSP2		
<b>Local Control Cubicle</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 1 Isolator Motor Supply	F133		
	Bus 1 Earth Switch Motor Supply	F134		
	Bus 2 Earth Switch Motor Supply	F135		
	Backup Control Supply	F141		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>Metering Equipment</b>			
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
	<b>VT MCBs</b>			
	MCB for Bus 1 VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	MCB for Bus 1 VT Core 2	F402		
	MCB for Bus 1 VT Core 3	F403		
	MCB for Bus 2 VT Core 1	F501		
	MCB for Bus 2 VT Core 2	F502		
	MCB for Bus 2 VT Core 3	F503		
<b>Heater</b>				
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7	
Temperature Controller	SH	Inside the Panel (DIN Rail)		
<b>Lamp Assembly</b>				

Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Discrepancy Switches</b>			
Circuit Breaker	DSQ0	Front Panel	Refer Chapter 5.23.4
Bus 1 Isolator	DSQ1		
Bus 2 Isolator	DSQ2		
Earth Switch (Q51)	DSQ51		
Earth Switch (Q52)	DSQ52		
Bus 1 Earth Switch	DSQ11		
Bus 2 Earth Switch	DSQ12		
<b>Sockets</b>			
Socket for Synchronism Check Console	SYN	Front Panel	Refer Chapter
<b>Push Buttons</b>			
Lamp Test for the Mimic	PBM	Front Panel	Refer Chapter 5.23.2
<b>Selector Switches</b>			
Control Local/Remote	SSLCTRL	Front Panel	Refer Chapter 5.23.1
Interlock Bypassed/Not Bypassed	SSIB	Front Panel	Refer Chapter 5.23.1
<b>Terminal Blocks</b>			
Bus 1 Current Transformer Core 1	XB1CT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Bus 1 Current Transformer Core 2	XB1CT2		
Bus 2 Current Transformer Core 1	XB2CT3		
Bus 2 Current Transformer Core 2	XB2CT4		
Bus 1 Voltage Transformer Core 1	XB1VT1		
Bus 1 Voltage Transformer Core 2	XB1VT2		
Bus 1 Voltage Transformer Core 3	XB1VT3		
Bus 2 Voltage Transformer Core 1	XB2VT1		
Bus 2 Voltage Transformer Core 2	XB2VT2		
Bus 2 Voltage Transformer Core 3	XB2VT3		
AC Distribution	XAC		
DC Distribution	XDC		

DC 101	XDC101
DC 111	XDC102
DC 121	XDC111
DC 131	XDC112
DC 132	XDC121
DC 133	XDC133
DC 134	XDC134
DC 135	XDC135
DC 141	XDC141
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Protection/Control Panel	XRP
Bus 1 Earth Switch	XQ11
Bus 2 Earth Switch	XQ12

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**Annexure 21 Panel Arrangement 220kV/132kV Bus bar protection**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection Panel	<b>Protection IEDs</b>			
	Central Unit	BBC	Front Panel	Refer Chapters 5.7 and 5.14
	<b>Station Alarm Devices</b>			
	Alarm Annunciator	AA	Front Panel	Refer Chapter 5.20.2
	Input Output Module	IO	Front Panel	Refer Chapter 5.20.1
	<b>DC MCBs</b>			
	Busbar Centrl Unit Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Alarm Annunciator Supply	F111		
	Input Output Module Supply	F121		
	Input Output Module BI Supply	F122		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel		

**Annexure 22 Panel Arrangement 33kV Transformer Incomer Air Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Control and Protection IED	BCPU	Front Panel	Refer Chapters 5.7 and
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Auxiliary Relays</b>			
	Bus Coupler Closed	KBCC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus 1 VT MCB Healthy	KVTBB1		
	Bus 2 VT MCB Healthy	KVTBB2		
	Circuit Breaker in Local	KCBL		
	Isolators in Local	KIL		
	<b>Flag Relays</b>			
	Circuit Breaker Common Alarm	KCBA	Front Panel	
	Breaker Fail Inter Trip	KBFP		
	<b>Metering Equipment</b>			
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
	<b>DC MCBs</b>			
	BCPU, Lockout 1 Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Lockout 2 Supply	F111		
	BCPU BI Supply	F102		
<b>AC MCBs</b>				
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
<b>Push Buttons</b>				

	Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
	<b>Sockets</b>			
	AC Supply Socket	XPS	Inside the Panel	Refer Chapter
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
	Door Switch	SD	Inside Top of the Panel	
	<b>Terminal Blocks</b>			
	Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
	Current Transformer Core 2	XCT2		
	Current Transformer Core 3	XCT3		
	Voltage Transformer Core 1	XVT1		
	Voltage Transformer Core 2	XVT2		
	AC Distribution	XAC		
	DC Distribution	XDC		
	DC F101	XDC101		
	DC F102	XDC102		
	DC F111	XDC111		
	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	DFR Panel	XDFR		
	External Panel Loop 1	XSP1		
	External Panel Loop 2	XSP2		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		



Isolator Control Supply	F121		
Circuit Breaker Motor Supply	F131		
Bus 1 Isolator Motor Supply	F132		
Bus 2 Isolator Motor Supply	F133		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102		
DC 121	XDC111		
DC 131	XDC112		
DC 132	XDC121		

DC 133	XDC133
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Protection/Control Panel	XRP

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**Annexure 23 Panel Arrangement 33kV Transformer Incomer Gas Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Control and Protection IED	BCPU	Front Panel	Refer Chapters 5.7 and
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Auxiliary Relays</b>			
	Bus Coupler Closed	KBCC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus 1 VT MCB Healthy	KVTBB1		
	Bus 2 VT MCB Healthy	KVTBB2		
	<b>Flag Relays</b>			
	Circuit Breaker Common Alarm	KCBA	Front Panel	
	Breaker Fail Inter Trip	KBFP		
	<b>Metering Equipment</b>			
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
	<b>DC MCBs</b>			
	BCPU, Lockout 1 Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Lockout 2 Supply	F111		
Main 1 BI Supply	F102			
Circuit Breaker Trip Circuit 1	F121			
Circuit Breaker Trip Circuit 2	F131			
Isolator Control Supply	F141			
Circuit Breaker Motor Supply	F151			
Bus 1 Isolator Motor Supply	F152			
Bus 2 Isolator Motor Supply	F153			

<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		
DC F112	XDC112		
DC F121	XDC121		

DC F131	XDC131
DC F141	XDC141
DC F151	XDC151
DC F152	XDC152
DC F153	XDC153
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
DFR Panel	XDFR
External Panel Loop 1	XSP1
External Panel Loop 2	XSP2

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**Annexure 24 Panel Arrangement 33kV Feeder Air Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Control and Protection IED	BCPU	Front Panel	Refer Chapters 5.7 and
	<b>Trip Lockout Relays</b>			
	Lockout 1	K86/1	Front Panel	Refer Chapter 5.22.2
	Lockout 2	K86/2		
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Auxiliary Relays</b>			
	Bus Coupler Closed	KBCC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus 1 VT MCB Healthy	KVTBB1		
	Bus 2 VT MCB Healthy	KVTBB2		
	Circuit Breaker in Local	KCBL		
	Isolators in Local	KIL		
	<b>Flag Relays</b>			
	Circuit Breaker Common Alarm	KCBA	Front Panel	
	Breaker Fail Inter Trip	KBFP		
	<b>Selector Switches</b>			
	Load Shedding On/Off	SSLS	Front Panel	Refer Chapter 5.23.1
	AR ON / OFF	SSAR		
	<b>Metering Equipment</b>			
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
	<b>DC MCBs</b>			
BCPU, Lockout Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
BCPU BI Supply	F102			
<b>AC MCBs</b>				

Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
Circuit Breaker	XQ0		
Bus Isolator 1	XQ1		
Bus Isolator 2	XQ2		
External Panel Loop 1	XSP1		
External Panel Loop 2	XSP2		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>		
	Circuit Breaker Trip Circuit 1	F101	Refer Chapter 5.23.3

Circuit Breaker Trip Circuit 2	F111	Inside the Panel (DIN Rail)	
Isolator Control Supply	F121		
Circuit Breaker Motor Supply	F131		
Bus 1 Isolator Motor Supply	F132		
Bus 2 Isolator Motor Supply	F133		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
AC Distribution	XAC		
DC Distribution	XDC		
DC 101	XDC101		
DC 111	XDC102		
DC 121	XDC111		
DC 131	XDC112		



DC 132	XDC121
DC 133	XDC133
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
Protection/Control Panel	XRP

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**Annexure 25 Panel Arrangement 33kV Feeder Gas Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Control and Protection IED	BCPU	Front Panel	Refer Chapters 5.7 and
	<b>Trip Lockout Relays</b>			
	Lockout	K86	Front Panel	Refer Chapter 5.22.2
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Auxiliary Relays</b>			
	Bus Coupler Closed	KBCC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus 1 VT MCB Healthy	KVTBB1		
	Bus 2 VT MCB Healthy	KVTBB2		
	<b>Selector Switches</b>			
	Load Shedding On/Off	SSLS	Front Panel	Refer Chapter 5.23.1
	AR ON / OFF	SSAR		
	<b>Flag Relays</b>			
	Circuit Breaker Common Alarm	KCBA	Front Panel	
	Breaker Fail Inter Trip	KBFP		
	<b>Metering Equipment</b>			
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
	<b>DC MCBs</b>			
BCPU, Lockout Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3	
BCPU BI Supply	F102			
Circuit Breaker Trip Circuit 1	F121			
Circuit Breaker Trip Circuit 2	F131			
Isolator Control Supply	F141			
Circuit Breaker Motor Supply	F151			

Bus 1 Isolator Motor Supply	F152		
Bus 2 Isolator Motor Supply	F153		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for VT Core 2	F402		
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Current Transformer Core 1	XCT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Current Transformer Core 2	XCT2		
Current Transformer Core 3	XCT3		
Voltage Transformer Core 1	XVT1		
Voltage Transformer Core 2	XVT2		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F111	XDC111		

DC F112	XDC112
DC F121	XDC121
DC F131	XDC131
DC F141	XDC141
DC F151	XDC151
DC F152	XDC152
DC F153	XDC153
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
External Panel Loop 1	XSP1
External Panel Loop 2	XSP2

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**Annexure 26 Panel Arrangement 33kV Bus Coupler/Bus Section Air Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Control and Protection IED	BCPU	Front Panel	Refer Chapters 5.7 and
	<b>Trip Lockout Relays</b>			
	Lockout	K86	Front Panel	Refer Chapter 5.22.2
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Auxiliary Relays</b>			
	Bus Coupler Closed	KBCC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus 1 VT MCB Healthy	KVTBB1		
	Bus 2 VT MCB Healthy	KVTBB2		
	Circuit Breaker in Local	KCBL		
	Isolators in Local	KIL		
	<b>Flag Relays</b>			
	Circuit Breaker Common Alarm	KCBA	Front Panel	
	Breaker Fail Inter Trip Bus 1	KBFPB1		
	Breaker Fail Inter Trip Bus 2	KBFPB2		
	<b>Metering Equipment</b>			
	Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>DC MCBs</b>			
	BCPU, Lockout 1 Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
BCPU BI Supply	F102			
Breaker Faikure Protection Supply 1	F161			

Breaker Failure Protection Supply 2	F162		
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Bus 1 Current Transformer Core 1	XB1CT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Bus 1 Current Transformer Core 2	XB1CT2		
Bus 2 Current Transformer Core 1	XB2CT1		
Bus 2 Current Transformer Core 2	XB2CT2		
Bus 1 Voltage Transformer Core 1	XB1VT1		
Bus 1 Voltage Transformer Core 2	XB1VT2		
Bus 2 Voltage Transformer Core 1	XB2VT1		
Bus 2 Voltage Transformer Core 2	XB2VT2		
AC Distribution	XAC		
DC Distribution	XDC		
DC F101	XDC101		
DC F102	XDC102		
DC F161	XDC161		
DC F162	XDC162		

	Circuit Breaker	XQ0		
	Bus Isolator 1	XQ1		
	Bus Isolator 2	XQ2		
	DFR Panel	XDFR		
	External Panel Loop 1	XSP1		
	External Panel Loop 2	XSP2		
<b>Marshalling Kiosk</b>	<b>DC MCBs</b>			
	Circuit Breaker Trip Circuit 1	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	Circuit Breaker Trip Circuit 2	F111		
	Isolator Control Supply	F121		
	Circuit Breaker Motor Supply	F131		
	Bus 1 Isolator Motor Supply	F132		
	Bus 2 Isolator Motor Supply	F133		
	<b>AC MCBs</b>			
	Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	<b>VT MCBs</b>			
	MCB for Bus 1 VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	MCB for Bus 1 VT Core 2	F402		
	MCB for Bus 2 VT Core 1	F501		
	MCB for Bus 2 VT Core 2	F502		
	<b>Heater</b>			
	Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
	Temperature Controller	SH	Inside the Panel (DIN Rail)	
	<b>Lamp Assembly</b>			
	Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
	Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>				
Current Transformer Core 1	XCT1		Refer Chapter 5.3	

Current Transformer Core 2	XCT2	Inside the Panel (DIN Rail)
Current Transformer Core 3	XCT3	
Voltage Transformer Core 1	XVT1	
Voltage Transformer Core 2	XVT2	
AC Distribution	XAC	
DC Distribution	XDC	
DC 101	XDC101	
DC 111	XDC102	
DC 121	XDC111	
DC 131	XDC112	
DC 132	XDC121	
DC 133	XDC133	
Circuit Breaker	XQ0	
Bus Isolator 1	XQ1	
Bus Isolator 2	XQ2	
Protection/Control Panel	XRP	

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**Annexure 27 Panel Arrangement 33kV Bus Coupler/Bus Section Gas Insulated Switchgear**

Panel	Equipment	Drawing Reference	Mounting Position	Remarks
Protection/ Control Panel	<b>Protection IEDs</b>			
	Control and Protection IED	BCPU	Front Panel	Refer Chapters 5.7 and
	<b>Trip Lockout Relays</b>			
	Lockout	K86	Front Panel	Refer Chapter 5.22.2
	<b>TCS Relays</b>			
	Trip Coil 1	K74-1	Front Panel	Refer Chapter 5.19
	Trip Coil 2	K74-2		
	<b>Auxiliary Relays</b>			
	Bus Coupler Closed	KBCC	Inside the Panel (DIN Rail)	Refer Chapter 5.22.4
	Bus 1 VT MCB Healthy	KVTBB1		
	Bus 2 VT MCB Healthy	KVTBB2		
	<b>Flag Relays</b>			
	Circuit Breaker Common Alarm	KCBA	Front Panel	
	Breaker Fail Inter Trip Bus 1	KBFPB1		
	Breaker Fail Inter Trip Bus 2	KBFPB2		
	<b>Network Equipment</b>			
	Ethernet Switch	ESW	Inside the Panel (DIN Rail)	Refer Chapter 5.24.3.10.7
	<b>DC MCBs</b>			
	BCPU, Lockout 1 Supply	F101	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
	BCPU BI Supply	F102		
	Circuit Breaker Trip Circuit 1	F121		
	Circuit Breaker Trip Circuit 2	F131		
	Isolator Control Supply	F141		
Circuit Breaker Motor Supply	F151			
Bus 1 Isolator Motor Supply	F152			
Bus 2 Isolator Motor Supply	F153			
Breaker Faikure Protection Supply 1	F161			

Breaker Failure Protection Supply 2	F162		
<b>Metering Equipment</b>			
Digital Measurement Centre	M	Front Panel	Refer Chapter 5.8.10
<b>AC MCBs</b>			
Heater/Lamp Supply	F201	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
<b>VT MCBs</b>			
MCB for Bus 1 VT Core 1	F401	Inside the Panel (DIN Rail)	Refer Chapter 5.23.3
MCB for Bus 1 VT Core 2	F402		
MCB for Bus 2 VT Core 1	F501		
MCB for Bus 2 VT Core 2	F502		
<b>Push Buttons</b>			
Lockout Reset	PBLR	Front Panel	Refer Chapter 5.23.2
<b>Sockets</b>			
AC Supply Socket	XPS	Inside the Panel	Refer Chapter
<b>Heater</b>			
Heating Element	EH	Inside bottom of the panel	Refer Chapter 5.23.7
Temperature Controller	SH	Inside the Panel (DIN Rail)	
<b>Lamp Assembly</b>			
Lamp	EL	Inside Top of the Panel	Refer Chapter 5.23.8
Door Switch	SD	Inside Top of the Panel	
<b>Terminal Blocks</b>			
Bus 1 Current Transformer Core 1	XB1CT1	Inside the Panel (DIN Rail)	Refer Chapter 5.3
Bus 1 Current Transformer Core 2	XB1CT2		
Bus 2 Current Transformer Core 1	XB2CT1		
Bus 2 Current Transformer Core 2	XB2CT2		
Bus 1 Voltage Transformer Core 1	XB1VT1		
Bus 1 Voltage Transformer Core 2	XB1VT2		
Bus 2 Voltage Transformer Core 1	XB2VT1		
Bus 2 Voltage Transformer Core 2	XB2VT2		
AC Distribution	XAC		

DC Distribution	XDC
DC F101	XDC101
DC F102	XDC102
DC F121	XDC121
DC F131	XDC131
DC F141	XDC141
DC F151	XDC151
DC F152	XDC152
DC F153	XDC153
DC F161	XDC161
DC F162	XDC162
Circuit Breaker	XQ0
Bus Isolator 1	XQ1
Bus Isolator 2	XQ2
DFR Panel	XDFR
External Panel Loop 1	XSP1
External Panel Loop 2	XSP2

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**Annexure 28 SAS Factory Acceptance Test Procedure**

Factory Acceptance Test (FAT) Procedures				
Substation Automation System				
No.	Device	Test	Description	Test which needs to carried out again after switch off Gateways
1	Workstation Computer No. 01	Verify Computer Specification	Verify Computer Serial Number	
			Verify Version of Operating System	
			Verify Hardware Configuration	
		Starting the Device	Start the computer and check screen for error messages	
		Time Synchronization	Check time zone and daylight saving under time settings	
			Compare Computer time with GPS Time Server Display	
			Start GPS Time Server Monitoring and Configuration Software in the Computer	
		Restricted Access Logical Volumes	Check access of DVD Drive on Administrator Login	
			Check access of USB Drive through all USB ports on Administrator Login	
			Check access of DVD Drive on Operator Login	
			Check access of USB Drive through all USB ports on Operator Login	
		Antivirus Software	Check the Antivirus software is updated	
		Remote Desktop Protocol	Try to connect Workstation Computer from test laptop	
Redundant Power Supply	Measure Voltage of Primary and Secondary Power Supplies			
	Check the operation of the computer when one power supply is turned off at a time			
2	Workstation Computer No. 02	Verify Computer Specification	Verify Computer Serial Number	
			Verify Version of Operating System	
			Verify Hardware Configuration	

		Starting the Device	Start the computer and check screen for error messages	
		Time Synchronization	Check time zone and daylight saving under time settings	
			Compare Computer time with GPS Time Server Display	
			Start GPS Time Server Monitoring and Configuration Software in the Computer	
		Restricted Access Logical Volumes	Check access of DVD Drive on Administrator Login	
			Check access of USB Drive through all USB ports on Administrator Login	
			Check access of DVD Drive on Operator Login	
			Check access of USB Drive through all USB ports on Operator Login	
		Antivirus Software	Check the Antivirus software is updated	
		Remote Desktop Protocol	Try to connect Workstation Computer from test laptop	
		Redundant Power Supply	Measure Voltage of Primary and Secondary Power Supplies	
			Check the operation of the computer when one power supply is turned off at a time	
3	Gateway No. 01	Verify Computer Specification	Verify Computer Serial Number	
			Verify Version of Operating System	
			Verify Hardware Configuration	
		Starting the Device	Start the computer and check screen for error messages	
		Time Synchronization	Check time zone and daylight saving under time settings	
			Compare Computer time with GPS Time Server Display	
			Start GPS Time Server Monitoring and Configuration Software in the Computer	
		Restricted Access Logical Volumes	Check access of DVD Drive on Administrator Login	
			Check access of USB Drive through all USB ports on Administrator Login	
			Check access of DVD Drive on Operator Login	
			Check access of USB Drive through all USB ports on Operator Login	
		Antivirus Software	Check the Antivirus software is updated	

		Remote Desktop Protocol	Try to connect Workstation Computer from test laptop	
		Redundant Power Supply	Measure Voltage of Primary and Secondary Power Supplies	
			Check the operation of the computer when one power supply is turned off at a time	
4	Gateway No. 02	Verify Computer Specification	Verify Computer Serial Number	
			Verify Version of Operating System	
			Verify Hardware Configuration	
		Starting the Device	Start the computer and check screen for error messages	
		Time Synchronization	Check time zone and daylight saving under time settings	
			Compare Computer time with GPS Time Server Display	
			Start GPS Time Server Monitoring and Configuration Software in the Computer	
		Restricted Access Logical Volumes	Check access of DVD Drive on Administrator Login	
			Check access of USB Drive through all USB ports on Administrator Login	
			Check access of DVD Drive on Operator Login	
			Check access of USB Drive through all USB ports on Operator Login	
		Antivirus Software	Check the Antivirus software is updated	
		Remote Desktop Protocol	Try to connect Workstation Computer from test laptop	
		Redundant Power Supply	Measure Voltage of Primary and Secondary Power Supplies	
			Check the operation of the computer when one power supply is turned off at a time	
5	SAS Cubicles	Visual Inspection	Check dimension and color of the panel as per the approved drawings	
			Check wiring and cables (Wiring Colors / Internal and External wiring / Terminals)	
			Check proper earthing of the panel	
			Check the mounting of Components (Computers, Gateways, Switches, Time Servers etc)	

			Check heater, Lamp, Power socket, Air filters and exhaust fans for their correct proper operation	
			Check for proper bolting, paint scratches, nameplates and stickers	
			Check rear and front door handle and lock arrangement	
			Check Gasket quality	
			Check rear and front door for opening and closing operation	
6	GPS Time Server	GPS Time Synchronization	Check the number of satellites connected	
		Starting the Device	Start the device and check for any error	
7	SAS Software on Workstation No. 1	Main Menu Picture	Check appearance of SAS Main Menu	
			Check operation of all Menu buttons	
		SAS Functions	Check project specific Functional Description for correct menu items	
			Verify toolbar configuration	
			Verify alarm window functionality	
			Verify process display short	
		General Interrogation	Check communication to attached devices	Yes
		Event Display	Compare functionality of Event Display to SAS Functional Description	Yes
		Alarm Display	Compare functionality of Alarm Display to SAS Functional Description	Yes
		Trend Display	Compare functionality of Trend Display to SAS Functional Description	Yes
		Measurement Reports	Verify reported measurements	Yes
			Inject sample measurement values	Yes
		Hot or Standby Operation	Verify System Status in SAS System Overview	Yes
			Change over operation by terminating SAS Software	Yes
			Change over operation by switch off the workstation	Yes
			Change over operation by disconnecting Ethernet connection of Workstation	Yes
		Overall Single Line Diagram	Verify Overall Single Line Diagram	Yes
		Single Voltage Level SLD	Verify 220 kV Single Line Diagrams	Yes
			Verify 132 kV Single Line Diagrams	Yes

			Verify 33 kV Single Line Diagrams	Yes
			Verify 11 kV Single Line Diagrams	Yes
		Bay Level SLD	Verify all Bay Level Single Line Diagrams	Yes
		System Supervision Display	Verify System Supervision Display	Yes
			Verify connection status of devices	Yes
		Bus bar Coloring	Verify bus bar Coloring of each Voltage levels	Yes
			Check operation of Dynamic bus bar Coloring	Yes
		User Management	Verify configuration, startup and its level of access of Restricted User	
			Verify configuration, startup and its level of access of Operator	
			Verify configuration, startup and its level of access of Engineer	
			Verify configuration, startup and its level of access of System Manager	
			Verify configuration, startup and its level of access of Administrator	
		Backup	Check the process of making backups of SAS Project	
			Check the process of making backups of the Workstation	
8	SAS Software on Workstation No. 2	Main Menu Picture	Check appearance of SAS Main Menu	
			Check operation of all Menu buttons	
		SAS Functions	Check project specific Functional Description for correct menu items	
			Verify toolbar configuration	
			Verify alarm window functionality	
			Verify process display short	
		General Interrogation	Check communication to attached devices	Yes
		Event Display	Compare functionality of Event Display to SAS Functional Description	Yes
		Alarm Display	Compare functionality of Alarm Display to SAS Functional Description	Yes
		Trend Display	Compare functionality of Trend Display to SAS Functional Description	Yes
		Measurement Reports	Verify reported measurements	Yes
			Inject sample measurement values	Yes
		Hot or Standby Operation	Verify System Status in SAS System Overview	Yes
			Change over operation by terminating SAS Software	Yes
			Change over operation by switch off the workstation	Yes



			Change over operation by disconnecting Ethernet connection of Workstation	Yes
		Overall Single Line Diagram	Verify Overall Single Line Diagram	Yes
		Single Voltage Level SLD	Verify 220 kV Single Line Diagrams	Yes
			Verify 132 kV Single Line Diagrams	Yes
			Verify 33 kV Single Line Diagrams	Yes
			Verify 11 kV Single Line Diagrams	Yes
		Bay Level SLD	Verify all Bay Level Single Line Diagrams	Yes
		System Supervision Display	Verify System Supervision Display	Yes
			Verify connection status of devices	Yes
		bus bar Coloring	Verify bus bar Coloring of each Voltage levels	Yes
			Check operation of Dynamic bus bar Coloring	Yes
		User Management	Verify configuration, startup and rights of Restricted User	
			Verify configuration, startup and rights of Operator	
			Verify configuration, startup and rights of Engineer	
			Verify configuration, startup and rights of System Manager	
			Verify configuration, startup and rights of Administrator	
		Backup	Check the process of making backups of SAS Project	
			Check the process of making backups of the Workstation	
9	Engineering Workstation	Starting the Device	Start the device and check for any error	
		Disturbance Recorder	Check manual upload of disturbance recorder data of IEDs	
			Check Automatic upload of disturbance recorder data of IEDs	
			Open disturbance recorder data of IEDs	
		Remote Parametrization	Check process of read and change parameters of IEDs	
10	Firewall	Firewall	Check external access to the SAS devices	
11	Gateway No. 01	Gateway Software	Check NSCC Communication Parameters	
			Check Control Authorization Handling	

			Check upstream communication	
			Check downstream communication	
		Hot or Standby Operation of NSCC Link	Verify data stream during switch over of links	
			Verify data stream during hot - hot operation of links	
12	RSTP Ring Network	Ethernet Switches	Start the device and check for any error	
			Check the quantity	
			Check the manufacture	
			Verify the specification	
		Ring Redundancy	Verify redundancy operation of RSTP Ring Network	

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Table with columns for equipment ID (AA1E1Q01FN2), IEC number (IEC61850), status (BI), description, address (AA1E1Q01FN2.LDX.PSCH2.EchoWeiOp.StVal), action (Reset), and count (1, 2). Includes events like 'EF WEI logic Trip', 'Line Differential Start', and 'Dist. Zone 1 Trip'.



















AA1E1Q01FN2	IEC61850	DB			Status of device	AA1E1Q01FN2.LDX.LPHD1.PhyHealth.StVal	Faulty	Ok	Warning	Not sampled	3	1
AA1E1Q01FN2	IEC61850	BI			Main-2 General Trip HV	AA1E1Q01FN2.LDX.PTRC1.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			Main-2 General Trip LV	AA1E1Q01FN2.LDX.PTRC3.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			Differential Blk. 2nd Har.	AA1E1Q01FN2.LDX.PHAR1.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Blk. 5th Har.	AA1E1Q01FN2.LDX.PHAR2.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Trip	AA1E1Q01FN2.LDX.PDIF1.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			Differential Trip L1	AA1E1Q01FN2.LDX.PDIF1.Op.phsA	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Trip L2	AA1E1Q01FN2.LDX.PDIF1.Op.phsB	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Trip L3	AA1E1Q01FN2.LDX.PDIF1.Op.phsC	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Open CT Alarm		Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Start	AA1E1Q01FN2.LDX.PDIF1.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Start L1	AA1E1Q01FN2.LDX.PDIF1.Str.phsA	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Start L2	AA1E1Q01FN2.LDX.PDIF1.Str.phsB	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Differential Start L3	AA1E1Q01FN2.LDX.PDIF1.Str.phsC	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Lo Imp REF Trip HV	AA1E1Q01FN2.LDX.PDIF2.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			Lo Imp REF Start HV	AA1E1Q01FN2.LDX.PDIF2.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Lo Imp REF Trip LV	AA1E1Q01FN2.LDX.PDIF3.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			Lo Imp REF Start LV	AA1E1Q01FN2.LDX.PDIF3.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			HV OC Trip	AA1E1Q01FN2.LDX.PTOC1.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			HV OC Trip R Phase	AA1E1Q01FN2.LDX.PTOC1.Op.phsA	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			HV OC Trip Y Phase	AA1E1Q01FN2.LDX.PTOC1.Op.phsB	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			HV OC Trip B Phase	AA1E1Q01FN2.LDX.PTOC1.Op.phsC	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			HV OC Start	AA1E1Q01FN2.LDX.PTOC1.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			HV OC Start R Phase	AA1E1Q01FN2.LDX.PTOC1.Str.phsA	Normal	Alarm				
AA1E1Q01FN2	IEC61850	BI			HV OC Start Y Phase	AA1E1Q01FN2.LDX.PTOC1.Str.phsB	Normal	Alarm				
AA1E1Q01FN2	IEC61850	BI			HV OC Start B Phase	AA1E1Q01FN2.LDX.PTOC1.Str.phsC	Normal	Alarm				
AA1E1Q01FN2	IEC61850	BI			LV OC Trip	AA1E1Q01FN2.LDX.PTOC3.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			LV OC Trip R Phase	AA1E1Q01FN2.LDX.PTOC3.Op.phsA	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			LV OC Trip Y Phase	AA1E1Q01FN2.LDX.PTOC3.Op.phsB	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			LV OC Trip B Phase	AA1E1Q01FN2.LDX.PTOC3.Op.phsC	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			LV OC Start	AA1E1Q01FN2.LDX.PTOC3.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			LV OC Start R Phase	AA1E1Q01FN2.LDX.PTOC3.Str.phsA	Normal	Alarm				
AA1E1Q01FN2	IEC61850	BI			LV OC Start Y Phase	AA1E1Q01FN2.LDX.PTOC3.Str.phsB	Normal	Alarm				
AA1E1Q01FN2	IEC61850	BI			LV OC Start B Phase	AA1E1Q01FN2.LDX.PTOC3.Str.phsC	Normal	Alarm				
AA1E1Q01FN2	IEC61850	BI			HV-SBEF Trip	AA1E1Q01FN2.LDX.PTOC4.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			HV-SBEF Start	AA1E1Q01FN2.LDX.PTOC4.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			HV EF protection Trip	AA1E1Q01FN2.LDX.PTOC5.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			HV EF protection Start	AA1E1Q01FN2.LDX.PTOC5.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			LV-SBEF Trip	AA1E1Q01FN2.LDX.PTOC6.Op.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			LV-SBEF Start	AA1E1Q01FN2.LDX.PTOC6.Str.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			OV Protection Trip	AA1E1Q01FN2.LDX.PTOV1.Str.general	Reset	Operated			1	1
AA1E1Q01FN2	IEC61850	BI			OV Protection Start	AA1E1Q01FN2.LDX.PTOV1.Op.general	Normal	Alarm			2	1
AA1E1Q01FN2	IEC61850	BI			Overexcitation prot. start	AA1E1Q01FN2.LDX.PVPH1.Str.general	Normal	Alarm			2	1

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Annexure 34 - 220kV or 132kV Bus coupler IED signal list for SAS

Table with columns: No, IED, Protocol, Process Object Type, Station Name, Bay Name, Device Name, Object Text, IEC Name, Event Text 1 (Bitvalue 00), Event Text 2 (Bitvalue 01), Event Text 3 (Bitvalue 10), Event Text 4 (Bitvalue 11), Alarm Class, History Enabled. It lists various signals for Main 1 Control, Measurements, Breaker, Disconnectors, and Earth Switch.









AA1E1Q05A1	IEC61850	BI		Transformer 2 Mechanical Protection Common Trip	AA1E1Q05A1.LDX.GGIO49.Ind1.StVal	Normal	Alarm				
AA1E1Q05A1	IEC61850	BI		DDR Fail	AA1E1Q05A1.LDX.GGIO50.Ind1.StVal	Normal	Alarm				
AA1E1Q05A1	IEC61850	BI		GPS Clock inside the DDR Panel Fail	AA1E1Q05A1.LDX.GGIO51.Ind1.StVal	Normal	Alarm				
AA1E1Q05A1	IEC61850	BI		GPS Clock inside the SAS Panel Fail	AA1E1Q05A1.LDX.GGIO52.Ind1.StVal	Normal	Alarm				

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AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 1 Trip	AA1H1Q01A1.LDX.PTUF1.Op.general	Reset	Operated				1	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 2 Trip	AA1H1Q01A1.LDX.PTUF2.Op.general	Reset	Operated				1	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 3 Trip	AA1H1Q01A1.LDX.PTUF3.Op.general	Reset	Operated				1	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 4 Trip	AA1H1Q01A1.LDX.PTUF4.Op.general	Reset	Operated				1	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 5 Trip	AA1H1Q01A1.LDX.PTUF5.Op.general	Reset	Operated				1	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 6 Trip	AA1H1Q01A1.LDX.PTUF6.Op.general	Normal	Alarm				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 1 Selected	AA1H1Q01A1.LDX.GGIO20.Ind1.StVal	Off	On				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 2 Selected	AA1H1Q01A1.LDX.GGIO21.Ind1.StVal	Off	On				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 3 Selected	AA1H1Q01A1.LDX.GGIO22.Ind1.StVal	Off	On				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 4 Selected	AA1H1Q01A1.LDX.GGIO23.Ind1.StVal	Off	On				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 5 Selected	AA1H1Q01A1.LDX.GGIO24.Ind1.StVal	Off	On				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage 6 Selected	AA1H1Q01A1.LDX.GGIO25.Ind1.StVal	Off	On				2	1
AA1H1Q01A1	IEC61850	BI			Load Shedding Stage switched off	AA1H1Q01A1.LDX.GGIO26.Ind1.StVal	Off	On				2	1
AA1E1Q01A1	IEC61850	BI			BFP Trip T2	AA1H1Q01A1.LDX.RBRF1.OpEx.general	Reset	Operated				1	1
AA1E1Q01A1	IEC61850	BI			BFP Trip T1	AA1H1Q01A1.LDX.RBRF1.OpIn.general	Reset	Operated				1	1
AA1E1Q01A1	IEC61850	BI			BFP Inter-Trip Received	AA1H1Q01A1.LDX.GGIO17.Ind1.StVal	Reset	Operated				1	1
AA1H1Q01A1	IEC61850	AI			Fault Loc. Dist. in km	AA1H1Q01A1.LDX.RFLO1.FltDiskm.mag						2	1
AA1H1Q01A1	IEC61850	AI			Fault Impedance	AA1H1Q01A1.LDX.RFLO1.FltImp.mag						2	1
AA1H1Q01A1	IEC61850	AI			Fault Current Phase L1	AA1H1Q01A1.LDX.RFLO1.FltPhsA.mag						2	1
AA1H1Q01A1	IEC61850	AI			Fault Current Phase L2	AA1H1Q01A1.LDX.RFLO1.FltPhsB.mag						2	1
AA1H1Q01A1	IEC61850	AI			Fault Current Phase L3	AA1E1Q01A1.LDX.RFLO1.FltPhsC.mag						2	1

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AA1H1Q01A1	IEC61850	BI			General Trip L2	AA1H1Q01A1.LDX.PTRC1.Op.phsB	Reset	Operated			1	1
AA1H1Q01A1	IEC61850	BI			General Trip L3	AA1H1Q01A1.LDX.PTRC1.Op.phsC	Reset	Operated			1	1
AA1H1Q01A1	IEC61850	BI			Directional Earth Fault Trip	AA1H1Q01A1.LDX.PTOC2.Op.general	Reset	Operated			1	1
AA1H1Q01A1	IEC61850	BI			Directional Earth Fault Start	AA1H1Q01A1.LDX.PTOC2.Str.general	Normal	Alarm			2	1
AA1H1Q01A1	IEC61850	BI			Directional Over Curernt Trip	AA1H1Q01A1.LDX.PTOC2.Op.general	Reset	Operated			1	1
AA1H1Q01A1	IEC61850	BI			Directional Over Curernt Start L1	AA1H1Q01A1.LDX.PTOC2.Str.phsA	Normal	Alarm			2	1
AA1H1Q01A1	IEC61850	BI			Directional Over Curernt Start L2	AA1H1Q01A1.LDX.PTOC2.Str.phsB	Normal	Alarm			2	1
AA1H1Q01A1	IEC61850	BI			Directional Over Curernt Start L3	AA1H1Q01A1.LDX.PTOC2.Str.phsC	Normal	Alarm			2	1
AA1E1Q01A1	IEC61850	BI			BFP Trip T2	AA1H1Q01A1.LDX.RBRF1.OpEx.general	Reset	Operated			1	1
AA1E1Q01A1	IEC61850	BI			BFP Trip T1	AA1H1Q01A1.LDX.RBRF1.OpIn.general	Reset	Operated			1	1
AA1E1Q01A1	IEC61850	BI			BFP Inter-Trip Received	AA1H1Q01A1.LDX.GGIO17.Ind1.StVal	Reset	Operated			1	1

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Protection												
AA1H1Q01A1	IEC61850	BI				Inverse Time Earth Fault Trip	AA1H1Q01A1.LDX.PTOC1.Op.general	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				Inverse Time Earth Fault Start	AA1H1Q01A1.LDX.PTOC1.Str.general	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				Inverse Time Over Currenrt Trip	AA1H1Q01A1.LDX.PTOC1.Op.general	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				Inverse Time Over Currenrt Start L1	AA1H1Q01A1.LDX.PTOC1.Str.phsA	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				Inverse Time Over Currenrt Start L2	AA1H1Q01A1.LDX.PTOC1.Str.phsB	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				Inverse Time Over Currenrt Start L3	AA1H1Q01A1.LDX.PTOC1.Str.phsC	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				General Trip	AA1H1Q01A1.LDX.PTRC1.Op.general	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				General Trip L1	AA1H1Q01A1.LDX.PTRC1.Op.phsA	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				General Trip L2	AA1H1Q01A1.LDX.PTRC1.Op.phsB	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				General Trip L3	AA1H1Q01A1.LDX.PTRC1.Op.phsC	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				Directional Earth Fault Trip	AA1H1Q01A1.LDX.PTOC1.Op.general	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				Directional Earth Fault Start	AA1H1Q01A1.LDX.PTOC1.Str.general	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				Directional Over Currenrt Trip	AA1H1Q01A1.LDX.PTOC1.Op.general	Reset	Operated		1	1
AA1H1Q01A1	IEC61850	BI				Directional Over Currenrt Start L1	AA1H1Q01A1.LDX.PTOC1.Str.phsA	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				Directional Over Currenrt Start L2	AA1H1Q01A1.LDX.PTOC1.Str.phsB	Normal	Alarm		2	1
AA1H1Q01A1	IEC61850	BI				Directional Over Currenrt Start L3	AA1H1Q01A1.LDX.PTOC1.Str.phsC	Normal	Alarm		2	1
AA1E1Q01A1	IEC61850	BI				BFP Trip T2	AA1H1Q01A1.LDX.RBRF1.OpEx.general	Reset	Operated		1	1
AA1E1Q01A1	IEC61850	BI				BFP Trip T1	AA1H1Q01A1.LDX.RBRF1.OpIn.general	Reset	Operated		1	1
AA1E1Q01A1	IEC61850	BI				BFP Inter-Trip Received	AA1H1Q01A1.LDX.GGIO17.Ind1.SVAl	Reset	Operated		1	1

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**Annexure 39 SAS Data set for 220kV 132kV Line Protection IEDs**

Data Set Name	Information
DS_Control	AA1E1Q01FN1.LDX.CSWI1.Pos
	AA1E1Q01FN1.LDX.CSWI1.SelOpn
	AA1E1Q01FN1.LDX.CSWI1.SelCls
	AA1E1Q01FN1.LDX.CSWI1.OpOpn
	AA1E1Q01FN1.LDX.CSWI1.OpCls
	AA1E1Q01FN1.LDX.CILO1.EnaCls
	AA1E1Q01FN1.LDX.CILO1.EnaOpn
	AA1E1Q01FN1.LDX.RSYN1.Rel
	AA1E1Q01FN1.LDX.GGIO6.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO7.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO8.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO9.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO10.Ind1.StVal
	AA1E1Q01FN1.LDX.CSWI2.Pos
	AA1E1Q01FN1.LDX.CSWI2.SelOpn
	AA1E1Q01FN1.LDX.CSWI2.SelCls
	AA1E1Q01FN1.LDX.CSWI2.OpOpn
	AA1E1Q01FN1.LDX.CSWI2.OpCls
	AA1E1Q01FN1.LDX.CILO2.EnaCls
	AA1E1Q01FN1.LDX.CILO2.EnaOpn
	AA1E1Q01FN1.LDX.CSWI3.SelOpn
	AA1E1Q01FN1.LDX.CSWI3.SelCls
	AA1E1Q01FN1.LDX.CSWI3.OpOpn
	AA1E1Q01FN1.LDX.CSWI3.OpCls
	AA1E1Q01FN1.LDX.CILO3.EnaCls
	AA1E1Q01FN1.LDX.CILO3.EnaOpn
	AA1E1Q01FN1.LDX.CSWI4.Pos
	AA1E1Q01FN1.LDX.CSWI4.SelCls
	AA1E1Q01FN1.LDX.CSWI4.OpOpn
	AA1E1Q01FN1.LDX.CSWI4.OpCls
	AA1E1Q01FN1.LDX.CILO4.EnaCls
	AA1E1Q01FN1.LDX.CILO4.EnaOpn
	AA1E1Q01FN1.LDX.CSWI5.Pos
	AA1E1Q01FN1.LDX.CSWI5.SelOpn
	AA1E1Q01FN1.LDX.CSWI5.SelCls
	AA1E1Q01FN1.LDX.CSWI5.OpOpn
	AA1E1Q01FN1.LDX.CSWI5.OpCls
	AA1E1Q01FN1.LDX.CILO5.EnaCls
	AA1E1Q01FN1.LDX.CILO5.EnaOpn
	AA1E1Q01FN1.LDX.CSWI6.Pos
	AA1E1Q01FN1.LDX.CSWI6.SelOpn
	AA1E1Q01FN1.LDX.CSWI6.SelCls
AA1E1Q01FN1.LDX.CSWI6.OpOpn	
AA1E1Q01FN1.LDX.CSWI6.OpCls	

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	AA1E1Q01FN1.LDX.CILO6.EnaCls
	AA1E1Q01FN1.LDX.CILO6.EnaOpn
	AA1E1Q01FN1.LDX.CSWI7.Pos
	AA1E1Q01FN1.LDX.CSWI7.SelOpn
	AA1E1Q01FN1.LDX.CSWI7.SelCls
	AA1E1Q01FN1.LDX.CSWI7.OpOpn
	AA1E1Q01FN1.LDX.CSWI7.OpCls
	AA1E1Q01FN1.LDX.CILO7.EnaCls
	AA1E1Q01FN1.LDX.CILO7.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1.general
DS_Meas	AA1E1Q01FN1.LDX.MMXU1.A.phsA
	AA1E1Q01FN1.LDX.MMXU1.A.phsB
	AA1E1Q01FN1.LDX.MMXU1.A.phsC
	AA1E1Q01FN1.LDX.MMXU2.PPV.phsAB
	AA1E1Q01FN1.LDX.MMXU2.PPV.phsBC
	AA1E1Q01FN1.LDX.MMXU2.PPV.phsCA
	AA1E1Q01FN1.LDX.MMXU3.TotW
	AA1E1Q01FN1.LDX.MMXU3.TotVar
	AA1E1Q01FN1.LDX.MMXU3.TotPF
	AA1E1Q01FN1.LDX.MMXU3.Hz
	AA1E1Q01FN1.LDX.MMTR1.TotWh
	AA1E1Q01FN1.LDX.MMTR1.TotVArh
	AA1E1Q01FN1.LDX.MMXU2.PhV.phsA
	AA1E1Q01FN1.LDX.MMXU2.PhV.phsB
	AA1E1Q01FN1.LDX.MMXU2.PhV.phsC
DS_Prot	AA1E1Q01FN1.LDX.RFLO1.FltDiskm
	AA1E1Q01FN1.LDX.PSCH2.Op
	AA1E1Q01FN1.LDX.PSCH2.TxPrm
	AA1E1Q01FN1.LDX.PSCH2.EchoWeiOp
	AA1E1Q01FN1.LDX.PSCH2.EchoWei
	AA1E1Q01FN1.LDX.GGIO37.Ind1
	AA1E1Q01FN1.LDX.PDIF1.Str
	AA1E1Q01FN1.LDX.GGIO38.Ind1
	AA1E1Q01FN1.LDX.PDIF1.Op
	AA1E1Q01FN1.LDX.PTOC1.Op
	AA1E1Q01FN1.LDX.PTOC1.Str
	AA1E1Q01FN1.LDX.PTOC1.Op
	AA1E1Q01FN1.LDX.PTOC1.Str
	AA1E1Q01FN1.LDX.PTRC1.Op
	AA1E1Q01FN1.LDX.PSCH1.Op
	AA1E1Q01FN1.LDX.PSCH1.TxPrm
	AA1E1Q01FN1.LDX.PSCH1.EchoWeiOp
	AA1E1Q01FN1.LDX.PSCH1.EchoWei
	AA1E1Q01FN1.LDX.GGIO36.Ind1
	AA1E1Q01FN1.LDX.PDIS1.Op
	AA1E1Q01FN1.LDX.PDIS1.Str

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	AA1E1Q01FN1.LDX.PDIS2.Op
	AA1E1Q01FN1.LDX.PDIS2.Str
	AA1E1Q01FN1.LDX.PDIS3.Op
	AA1E1Q01FN1.LDX.PDIS3.Str
	AA1E1Q01FN1.LDX.PDIS4.Op
	AA1E1Q01FN1.LDX.PDIS4.Str
	AA1E1Q01FN1.LDX.RPSB.BlkZn
	AA1E1Q01FN1.LDX.GGIO25.Ind1
	AA1E1Q01FN1.LDX.GGIO26.Ind1
	AA1E1Q01FN1.LDX.GGIO27.Ind1
	AA1E1Q01FN1.LDX.GGIO28.Ind1
	AA1E1Q01FN1.LDX.PSCH2.RxPrm1
	AA1E1Q01FN1.LDX.GGIO29.Ind1
	AA1E1Q01FN1.LDX.PSCH1.RxPrm1
	AA1E1Q01FN1.LDX.GGIO39.Ind1
	AA1E1Q01FN1.LDX.GGIO30.Ind1
	AA1E1Q01FN1.LDX.GGIO31.Ind1
	AA1E1Q01FN1.LDX.GGIO32.Ind1
	AA1E1Q01FN1.LDX.GGIO33.Ind1
	AA1E1Q01FN1.LDX.GGIO34.Ind1
	AA1E1Q01FN1.LDX.RREC1.OpCls
	AA1E1Q01FN1.LDX.GGIO35.Ind1
	AA1E1Q01FN1.LDX.RFLO1.FltImp.mag
	AA1E1Q01FN1.LDX.RFLO1.FltPhsA.mag
	AA1E1Q01FN1.LDX.RFLO1.FltPhsB.mag
	AA1E1Q01FN1.LDX.RFLO1.FltPhsC.mag
DS_Alarms	AA1E1Q01FN1.LDX.GGIO21.Ind1
	AA1E1Q01FN1.LDX.GGIO22.Ind1
	AA1E1Q01FN1.LDX.GGIO23.Ind1
	AA1E1Q01FN1.LDX.GGIO24.Ind1
	AA1E1Q01FN1.LDX.GGIO13.Ind1
	AA1E1Q01FN1.LDX.LPHD1.PhyHealth
	AA1E1Q01FN1.LDX.GGIO15.Ind1
	AA1E1Q01FN1.LDX.GGIO16.Ind1
	AA1E1Q01FN1.LDX.GGIO17.Ind1
	AA1E1Q01FN1.LDX.GGIO18.Ind1
	AA1E1Q01FN1.LDX.GGIO11.Ind1
	AA1E1Q01FN1.LDX.GGIO12.Ind1
	AA1E1Q01FN1.LDX.GGIO14.Ind1
	AA1E1Q01FN1.LDX.GGIO1.Ind1
	AA1E1Q01FN1.LDX.GGIO2.Ind1
	AA1E1Q01FN1.LDX.GGIO3.Ind1
	AA1E1Q01FN1.LDX.GGIO19.Ind1
	AA1E1Q01FN1.LDX.GGIO20.Ind1
	AA1E1Q01FN1.LDX.GGIO4.Ind1
	AA1E1Q01FN1.LDX.GGIO5.Ind1

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**Annexure 40 SAS Data set for 220kV side Protection IED of 220kV/132kV/LV Transformer**

Data Set Name	Information
DS_Control	AA1E1Q03FN1.LDX.CSWI1.Pos
	AA1E1Q03FN1.LDX.CSWI1.SelOpn
	AA1E1Q03FN1.LDX.CSWI1.SelCls
	AA1E1Q03FN1.LDX.CSWI1.OpOpn
	AA1E1Q03FN1.LDX.CSWI1.OpCls
	AA1E1Q03FN1.LDX.CILO1.EnaCls
	AA1E1Q03FN1.LDX.CILO1.EnaOpn
	AA1E1Q03FN1.LDX.RSYN1.Rel
	AA1E1Q03FN1.LDX.GGIO6.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO7.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO8.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO9.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO10.Ind1.StVal
	AA1E1Q03FN1.LDX.CSWI2.Pos
	AA1E1Q03FN1.LDX.CSWI2.SelOpn
	AA1E1Q03FN1.LDX.CSWI2.SelCls
	AA1E1Q03FN1.LDX.CSWI2.OpOpn
	AA1E1Q03FN1.LDX.CSWI2.OpCls
	AA1E1Q03FN1.LDX.CILO2.EnaCls
	AA1E1Q03FN1.LDX.CILO2.EnaOpn
	AA1E1Q03FN1.LDX.CSWI3.SelOpn
	AA1E1Q03FN1.LDX.CSWI3.SelCls
	AA1E1Q03FN1.LDX.CSWI3.OpOpn
	AA1E1Q03FN1.LDX.CSWI3.OpCls
	AA1E1Q03FN1.LDX.CILO3.EnaCls
	AA1E1Q03FN1.LDX.CILO3.EnaOpn
	AA1E1Q03FN1.LDX.CSWI4.Pos
	AA1E1Q03FN1.LDX.CSWI4.SelCls
	AA1E1Q03FN1.LDX.CSWI4.OpOpn
	AA1E1Q03FN1.LDX.CSWI4.OpCls
	AA1E1Q03FN1.LDX.CILO4.EnaCls
	AA1E1Q03FN1.LDX.CILO4.EnaOpn
	AA1E1Q03FN1.LDX.CSWI5.Pos
	AA1E1Q03FN1.LDX.CSWI5.SelOpn
	AA1E1Q03FN1.LDX.CSWI5.SelCls
	AA1E1Q03FN1.LDX.CSWI5.OpOpn
	AA1E1Q03FN1.LDX.CSWI5.OpCls
	AA1E1Q03FN1.LDX.CILO5.EnaCls
	AA1E1Q03FN1.LDX.CILO5.EnaOpn
	AA1E1Q03FN1.LDX.CSWI6.Pos
AA1E1Q03FN1.LDX.CSWI6.SelOpn	
AA1E1Q03FN1.LDX.CSWI6.SelCls	

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	AA1E1Q03FN1.LDX.CSWI6.OpOpn
	AA1E1Q03FN1.LDX.CSWI6.OpCls
	AA1E1Q03FN1.LDX.CILO6.EnaCls
	AA1E1Q03FN1.LDX.CILO6.EnaOpn
	AA1E1Q03FN1.LDX.CSWI7.Pos
	AA1E1Q03FN1.LDX.CSWI7.SelOpn
	AA1E1Q03FN1.LDX.CSWI7.SelCls
	AA1E1Q03FN1.LDX.CSWI7.OpOpn
	AA1E1Q03FN1.LDX.CSWI7.OpCls
	AA1E1Q03FN1.LDX.CILO7.EnaCls
	AA1E1Q03FN1.LDX.CILO7.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1_general
DS_Meas	AA1E1Q03FN1.LDX.MMXU1.A.phsA
	AA1E1Q03FN1.LDX.MMXU1.A.phsB
	AA1E1Q03FN1.LDX.MMXU1.A.phsC
	AA1E1Q03FN1.LDX.MMXU2.PPV.phsAB
	AA1E1Q03FN1.LDX.MMXU2.PPV.phsBC
	AA1E1Q03FN1.LDX.MMXU2.PPV.phsCA
	AA1E1Q03FN1.LDX.MMXU3.TotW
	AA1E1Q03FN1.LDX.MMXU3.TotVar
	AA1E1Q03FN1.LDX.MMXU3.TotPF
	AA1E1Q03FN1.LDX.MMXU3.Hz
	AA1E1Q03FN1.LDX.MMTR1.TotWh
	AA1E1Q03FN1.LDX.MMTR1.TotVArh
	AA1E1Q03FN1.LDX.MMXU2.PhV.phsA
	AA1E1Q03FN1.LDX.MMXU2.PhV.phsB
	AA1E1Q03FN1.LDX.MMXU2.PhV.phsC
DS_Prot	AA1E1Q03FN1.LDX.PTRC1.Op
	AA1E1Q03FN1.LDX.PTRC2.Op
	AA1E1Q03FN1.LDX.PTRC3.Op
	AA1E1Q03FN1.LDX.PHAR1.Str
	AA1E1Q03FN1.LDX.PHAR2.Str
	AA1E1Q03FN1.LDX.PDIF1.Op
	AA1E1Q03FN1.LDX.PDIF1.Str
	AA1E1Q03FN1.LDX.PDIF2.Op
	AA1E1Q03FN1.LDX.PDIF2.Str
	AA1E1Q03FN1.LDX.PDIF3.Op
	AA1E1Q03FN1.LDX.PDIF3.Str
	AA1E1Q03FN1.LDX.PTOC1.Op
	AA1E1Q03FN1.LDX.PTOC1.Str
	AA1E1Q03FN1.LDX.PTOC2.Op
	AA1E1Q03FN1.LDX.PTOC2.Str
	AA1E1Q03FN1.LDX.PTOC3.Op
	AA1E1Q03FN1.LDX.PTOC3.Str
	AA1E1Q03FN1.LDX.PTOC4.Op
	AA1E1Q03FN1.LDX.PTOC4.Str

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	AA1E1Q03FN1.LDX.PTOC5.Op
	AA1E1Q03FN1.LDX.PTOC5.Str
	AA1E1Q03FN1.LDX.PTOC6.Op
	AA1E1Q03FN1.LDX.PTOC6.Str
	AA1E1Q03FN1.LDX.PTOV1.Str
	AA1E1Q03FN1.LDX.PTOV1.Op
	AA1E1Q03FN1.LDX.PVPH1.Str
	AA1E1Q03FN1.LDX.PVPH1.Op
DS_Alarms	AA1E1Q03FN1.LDX.LPHD1.PhyHealth
	AA1E1Q03FN1.LDX.GGIO2.Ind1
	AA1E1Q03FN1.LDX.GGIO3.Ind1
	AA1E1Q03FN1.LDX.GGIO11.Ind1
	AA1E1Q03FN1.LDX.GGIO12.Ind1
	AA1E1Q03FN1.LDX.GGIO14.Ind1
	AA1E1Q03FN1.LDX.GGIO1.Ind1
	AA1E1Q03FN1.LDX.GGIO15.Ind1
	AA1E1Q03FN1.LDX.GGIO4.Ind1
	AA1E1Q03FN1.LDX.GGIO5.Ind1
	AA1E1Q03FN1.LDX.GGIO13.Ind1

**\* If the transformer is a single phase transformer there will be mechanical alarms per phase basis. Hence there shall be 3 separate datasets to limit the number of data.**

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**Annexure 41 SAS Data sets for IEDs in Transformer AVR Panel**

**1. AVR IED**

Data Set Name	Information
DS_AVR	AA1E1Q03A1.LDX.ATTC1.ParOp
	AA1E1Q03A1.LDX.ATTC1.Auto
	AA1E1Q03A1.LDX.ATTC1.TapChg
	AA1E1Q03A1.LDX.GGIO1.Ind1
	AA1E1Q03A1.LDX.GGIO2.Ind1
	AA1E1Q03A1.LDX.ATTC1.CtIV
	AA1E1Q03A1.LDX.ATTC1.BndCtr
	AA1E1Q03A1.LDX.ATTC1.CircA
	AA1E1Q03A1.LDX.GGIO3.Ind1
	AA1E1Q03A1.LDX.GGIO4.Ind1
	AA1E1Q03A1.LDX.GGIO5.Ind1
	AA1E1Q03A1.LDX.LPHD1.PhyHealth
	AA1E1Q03A1.LDX.GGIO6.Ind1
	AA1E1Q03A1.LDX.ATTC1.LTCBikAHi
	AA1E1Q03A1.LDX.ATTC1.LTCBikVHi
	AA1E1Q03A1.LDX.ATTC1.LTCBikVLo
	AA1E1Q03A1.LDX.GGIO1.Ind1
	AA1E1Q03A1.LDX.GGIO1.Ind1
	AA1E1Q03A1.LDX.ATTC1.EndPosR
	AA1E1Q03A1.LDX.ATTC1.EndPosL
	AA1E1Q03A1.LDX.ATCC1.ParErr
	AA1E1Q03A1.LDX.ATCC1.TapOpErr

**2. Alarm IED**

Data Set Name	Information
DS_Mech	AA1E1Q03A2.LDX.GGIO1.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO2.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO3.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO4.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO5.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO6.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO7.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO8.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO9.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO10.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO11.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO12.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO13.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO14.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO15.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO16.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO17.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO18.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO19.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO20.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO21.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO22.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO23.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO24.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO25.Ind1.StVal
	AA1E1Q03A2.LDX.GGIO26.Ind1.StVal

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**Annexure 42 SAS Data set for 132kV side Protection IED of 220kV 132kV LV Transformer**

Data Set Name	Information
DS_Control	AA1E1Q03FN1.LDX.CSWI1.Pos
	AA1E1Q03FN1.LDX.CSWI1.SelOpn
	AA1E1Q03FN1.LDX.CSWI1.SelCls
	AA1E1Q03FN1.LDX.CSWI1.OpOpn
	AA1E1Q03FN1.LDX.CSWI1.OpCls
	AA1E1Q03FN1.LDX.CILO1.EnaCls
	AA1E1Q03FN1.LDX.CILO1.EnaOpn
	AA1E1Q03FN1.LDX.RSYN1.Rel
	AA1E1Q03FN1.LDX.GGIO6.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO7.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO8.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO9.Ind1.StVal
	AA1E1Q03FN1.LDX.GGIO10.Ind1.StVal
	AA1E1Q03FN1.LDX.CSWI2.Pos
	AA1E1Q03FN1.LDX.CSWI2.SelOpn
	AA1E1Q03FN1.LDX.CSWI2.SelCls
	AA1E1Q03FN1.LDX.CSWI2.OpOpn
	AA1E1Q03FN1.LDX.CSWI2.OpCls
	AA1E1Q03FN1.LDX.CILO2.EnaCls
	AA1E1Q03FN1.LDX.CILO2.EnaOpn
	AA1E1Q03FN1.LDX.CSWI3.SelOpn
	AA1E1Q03FN1.LDX.CSWI3.SelCls
	AA1E1Q03FN1.LDX.CSWI3.OpOpn
	AA1E1Q03FN1.LDX.CSWI3.OpCls
	AA1E1Q03FN1.LDX.CILO3.EnaCls
	AA1E1Q03FN1.LDX.CILO3.EnaOpn
	AA1E1Q03FN1.LDX.CSWI4.Pos
	AA1E1Q03FN1.LDX.CSWI4.SelCls
	AA1E1Q03FN1.LDX.CSWI4.OpOpn
	AA1E1Q03FN1.LDX.CSWI4.OpCls
	AA1E1Q03FN1.LDX.CILO4.EnaCls
	AA1E1Q03FN1.LDX.CILO4.EnaOpn
	AA1E1Q03FN1.LDX.CSWI5.Pos
	AA1E1Q03FN1.LDX.CSWI5.SelOpn
	AA1E1Q03FN1.LDX.CSWI5.SelCls
	AA1E1Q03FN1.LDX.CSWI5.OpOpn
	AA1E1Q03FN1.LDX.CSWI5.OpCls
	AA1E1Q03FN1.LDX.CILO5.EnaCls
	AA1E1Q03FN1.LDX.CILO5.EnaOpn
	AA1E1Q03FN1.LDX.CSWI6.Pos
	AA1E1Q03FN1.LDX.CSWI6.SelOpn
	AA1E1Q03FN1.LDX.CSWI6.SelCls

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	AA1E1Q03FN1.LDX.CSWI6.OpOpn
	AA1E1Q03FN1.LDX.CSWI6.OpCls
	AA1E1Q03FN1.LDX.CILO6.EnaCls
	AA1E1Q03FN1.LDX.CILO6.EnaOpn
	AA1E1Q03FN1.LDX.CSWI7.Pos
	AA1E1Q03FN1.LDX.CSWI7.SelOpn
	AA1E1Q03FN1.LDX.CSWI7.SelCls
	AA1E1Q03FN1.LDX.CSWI7.OpOpn
	AA1E1Q03FN1.LDX.CSWI7.OpCls
	AA1E1Q03FN1.LDX.CILO7.EnaCls
	AA1E1Q03FN1.LDX.CILO7.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1_general
DS_Meas	AA1E1Q03FN1.LDX.MMXU1.A.phsA
	AA1E1Q03FN1.LDX.MMXU1.A.phsB
	AA1E1Q03FN1.LDX.MMXU1.A.phsC
	AA1E1Q03FN1.LDX.MMXU2.PPV.phsAB
	AA1E1Q03FN1.LDX.MMXU2.PPV.phsBC
	AA1E1Q03FN1.LDX.MMXU2.PPV.phsCA
	AA1E1Q03FN1.LDX.MMXU3.TotW
	AA1E1Q03FN1.LDX.MMXU3.TotVar
	AA1E1Q03FN1.LDX.MMXU3.TotPF
	AA1E1Q03FN1.LDX.MMXU3.Hz
	AA1E1Q03FN1.LDX.MMTR1.TotWh
	AA1E1Q03FN1.LDX.MMTR1.TotVArh
	AA1E1Q03FN1.LDX.MMXU2.PhV.phsA
	AA1E1Q03FN1.LDX.MMXU2.PhV.phsB
	AA1E1Q03FN1.LDX.MMXU2.PhV.phsC
DS_Prot	AA1E1Q03FN1.LDX.PTRC1.Op
	AA1E1Q03FN1.LDX.PTOC1.Op
	AA1E1Q03FN1.LDX.PTOC1.Str
	AA1E1Q03FN1.LDX.PTOC2.Op
	AA1E1Q03FN1.LDX.PTOC2.Str
DS_Alarms	AA1E1Q03FN1.LDX.LPHD1.PhyHealth
	AA1E1Q03FN1.LDX.GGIO2.Ind1
	AA1E1Q03FN1.LDX.GGIO3.Ind1
	AA1E1Q03FN1.LDX.GGIO11.Ind1
	AA1E1Q03FN1.LDX.GGIO12.Ind1
	AA1E1Q03FN1.LDX.GGIO14.Ind1
	AA1E1Q03FN1.LDX.GGIO1.Ind1
	AA1E1Q03FN1.LDX.GGIO15.Ind1
	AA1E1Q03FN1.LDX.GGIO4.Ind1
	AA1E1Q03FN1.LDX.GGIO5.Ind1
	AA1E1Q03FN1.LDX.GGIO13.Ind1

**\*If the transformer is a single phase transformer there will be mechanical alarms per phase basis. Hence there shall be 3 separate datasets to limit the number of data.**

**Annexure 43 SAS Data set for HV side Protection IED of HV LV 2WdgTransformer**

Data Set Name	Information
DS_Control	AA1E1Q01FN1.LDX.CSWI1.Pos
	AA1E1Q01FN1.LDX.CSWI1.SelOpn
	AA1E1Q01FN1.LDX.CSWI1.SelCls
	AA1E1Q01FN1.LDX.CSWI1.OpOpn
	AA1E1Q01FN1.LDX.CSWI1.OpCls
	AA1E1Q01FN1.LDX.CILO1.EnaCls
	AA1E1Q01FN1.LDX.CILO1.EnaOpn
	AA1E1Q01FN1.LDX.RSYN1.Rel
	AA1E1Q01FN1.LDX.GGIO6.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO7.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO8.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO9.Ind1.StVal
	AA1E1Q01FN1.LDX.GGIO10.Ind1.StVal
	AA1E1Q01FN1.LDX.CSWI2.Pos
	AA1E1Q01FN1.LDX.CSWI2.SelOpn
	AA1E1Q01FN1.LDX.CSWI2.SelCls
	AA1E1Q01FN1.LDX.CSWI2.OpOpn
	AA1E1Q01FN1.LDX.CSWI2.OpCls
	AA1E1Q01FN1.LDX.CILO2.EnaCls
	AA1E1Q01FN1.LDX.CILO2.EnaOpn
	AA1E1Q01FN1.LDX.CSWI3.SelOpn
	AA1E1Q01FN1.LDX.CSWI3.SelCls
	AA1E1Q01FN1.LDX.CSWI3.OpOpn
	AA1E1Q01FN1.LDX.CSWI3.OpCls
	AA1E1Q01FN1.LDX.CILO3.EnaCls
	AA1E1Q01FN1.LDX.CILO3.EnaOpn
	AA1E1Q01FN1.LDX.CSWI4.Pos
	AA1E1Q01FN1.LDX.CSWI4.SelCls
	AA1E1Q01FN1.LDX.CSWI4.OpOpn
	AA1E1Q01FN1.LDX.CSWI4.OpCls
	AA1E1Q01FN1.LDX.CILO4.EnaCls
	AA1E1Q01FN1.LDX.CILO4.EnaOpn
	AA1E1Q01FN1.LDX.CSWI5.Pos
	AA1E1Q01FN1.LDX.CSWI5.SelOpn
	AA1E1Q01FN1.LDX.CSWI5.SelCls
	AA1E1Q01FN1.LDX.CSWI5.OpOpn
	AA1E1Q01FN1.LDX.CSWI5.OpCls
	AA1E1Q01FN1.LDX.CILO5.EnaCls
	AA1E1Q01FN1.LDX.CILO5.EnaOpn
	AA1E1Q01FN1.LDX.CSWI6.Pos
	AA1E1Q01FN1.LDX.CSWI6.SelOpn
	AA1E1Q01FN1.LDX.CSWI6.SelCls
AA1E1Q01FN1.LDX.CSWI6.OpOpn	

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	AA1E1Q01FN1.LDX.CSWI6.OpCls
	AA1E1Q01FN1.LDX.CILO6.EnaCls
	AA1E1Q01FN1.LDX.CILO6.EnaOpn
	AA1E1Q01FN1.LDX.CSWI7.Pos
	AA1E1Q01FN1.LDX.CSWI7.SelOpn
	AA1E1Q01FN1.LDX.CSWI7.SelCls
	AA1E1Q01FN1.LDX.CSWI7.OpOpn
	AA1E1Q01FN1.LDX.CSWI7.OpCls
	AA1E1Q01FN1.LDX.CILO7.EnaCls
	AA1E1Q01FN1.LDX.CILO7.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1.general
DS_Meas	AA1E1Q01FN1.LDX.MMXU1.A.phsA
	AA1E1Q01FN1.LDX.MMXU1.A.phsB
	AA1E1Q01FN1.LDX.MMXU1.A.phsC
	AA1E1Q01FN1.LDX.MMXU2.PPV.phsAB
	AA1E1Q01FN1.LDX.MMXU3.TotW
	AA1E1Q01FN1.LDX.MMXU3.TotVar
	AA1E1Q01FN1.LDX.MMXU3.TotPF
	AA1E1Q01FN1.LDX.MMXU3.Hz
	AA1E1Q01FN1.LDX.MMTR1.TotWh
	AA1E1Q01FN1.LDX.MMTR1.TotVArh
DS_Prot	AA1E1Q01FN1.LDX.PTRC1.Op
	AA1E1Q01FN1.LDX.PTRC2.Op
	AA1E1Q01FN1.LDX.PTRC3.Op
	AA1E1Q01FN1.LDX.PHAR1.Str
	AA1E1Q01FN1.LDX.PHAR2.Str
	AA1E1Q01FN1.LDX.PDIF1.Op
	AA1E1Q01FN1.LDX.PDIF1.Str
	AA1E1Q01FN1.LDX.PDIF2.Op
	AA1E1Q01FN1.LDX.PDIF2.Str
	AA1E1Q01FN1.LDX.PDIF3.Op
	AA1E1Q01FN1.LDX.PDIF3.Str
	AA1E1Q01FN1.LDX.PTOC1.Op
	AA1E1Q01FN1.LDX.PTOC1.Str
	AA1E1Q01FN1.LDX.PTOC2.Op
	AA1E1Q01FN1.LDX.PTOC2.Str
	AA1E1Q01FN1.LDX.PTOC3.Op
	AA1E1Q01FN1.LDX.PTOC3.Str
	AA1E1Q01FN1.LDX.PTOC4.Op
	AA1E1Q01FN1.LDX.PTOC4.Str
	AA1E1Q01FN1.LDX.PTOC5.Op
	AA1E1Q01FN1.LDX.PTOC5.Str
	AA1E1Q01FN1.LDX.PTOC6.Op
	AA1E1Q01FN1.LDX.PTOC6.Str
	AA1E1Q01FN1.LDX.PTOV1.Str
	AA1E1Q01FN1.LDX.PTOV1.Op

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	AA1E1Q01FN1.LDX.PVPH1.Str
	AA1E1Q01FN1.LDX.PVPH1.Op
DS_Alarms	AA1E1Q01FN1.LDX.LPHD1.PhyHealth
	AA1E1Q01FN1.LDX.GGIO2.Ind1
	AA1E1Q01FN1.LDX.GGIO3.Ind1
	AA1E1Q01FN1.LDX.GGIO11.Ind1
	AA1E1Q01FN1.LDX.GGIO12.Ind1
	AA1E1Q01FN1.LDX.GGIO14.Ind1
	AA1E1Q01FN1.LDX.GGIO1.Ind1
	AA1E1Q01FN1.LDX.GGIO15.Ind1
	AA1E1Q01FN1.LDX.GGIO4.Ind1
	AA1E1Q01FN1.LDX.GGIO5.Ind1
	AA1E1Q01FN1.LDX.GGIO13.Ind1

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**Annexure 44 SAS Data set for 220kV 132kV Bus Coupler Protection IED**

Data Set Name	Information
DS_Control	AA1E1Q05FN1.LDX.CSWI1.Pos
	AA1E1Q05FN1.LDX.CSWI1.SelOpn
	AA1E1Q05FN1.LDX.CSWI1.SelCls
	AA1E1Q05FN1.LDX.CSWI1.OpOpn
	AA1E1Q05FN1.LDX.CSWI1.OpCls
	AA1E1Q05FN1.LDX.CILO1.EnaCls
	AA1E1Q05FN1.LDX.CILO1.EnaOpn
	AA1E1Q05FN1.LDX.RSYN1.Rel
	AA1E1Q05FN1.LDX.GGIO6.Ind1.StVal
	AA1E1Q05FN1.LDX.GGIO7.Ind1.StVal
	AA1E1Q05FN1.LDX.GGIO8.Ind1.StVal
	AA1E1Q05FN1.LDX.GGIO9.Ind1.StVal
	AA1E1Q05FN1.LDX.GGIO10.Ind1.StVal
	AA1E1Q05FN1.LDX.CSWI2.Pos
	AA1E1Q05FN1.LDX.CSWI2.SelOpn
	AA1E1Q05FN1.LDX.CSWI2.SelCls
	AA1E1Q05FN1.LDX.CSWI2.OpOpn
	AA1E1Q05FN1.LDX.CSWI2.OpCls
	AA1E1Q05FN1.LDX.CILO2.EnaCls
	AA1E1Q05FN1.LDX.CILO2.EnaOpn
	AA1E1Q05FN1.LDX.CSWI3.SelOpn
	AA1E1Q05FN1.LDX.CSWI3.SelCls
	AA1E1Q05FN1.LDX.CSWI3.OpOpn
	AA1E1Q05FN1.LDX.CSWI3.OpCls
	AA1E1Q05FN1.LDX.CILO3.EnaCls
	AA1E1Q05FN1.LDX.CILO3.EnaOpn
	AA1E1Q05FN1.LDX.CSWI4.Pos
	AA1E1Q05FN1.LDX.CSWI4.SelCls
	AA1E1Q05FN1.LDX.CSWI4.OpOpn
	AA1E1Q05FN1.LDX.CSWI4.OpCls
	AA1E1Q05FN1.LDX.CILO4.EnaCls
	AA1E1Q05FN1.LDX.CILO4.EnaOpn
	AA1E1Q05FN1.LDX.CSWI5.Pos
	AA1E1Q05FN1.LDX.CSWI5.SelOpn
	AA1E1Q05FN1.LDX.CSWI5.SelCls
	AA1E1Q05FN1.LDX.CSWI5.OpOpn
	AA1E1Q05FN1.LDX.CSWI5.OpCls
	AA1E1Q05FN1.LDX.CILO5.EnaCls
	AA1E1Q05FN1.LDX.CILO5.EnaOpn
	AA1E1Q05FN1.LDX.CSWI6.Pos
AA1E1Q05FN1.LDX.CSWI6.SelOpn	
AA1E1Q05FN1.LDX.CSWI6.SelCls	
AA1E1Q05FN1.LDX.CSWI6.OpOpn	

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	AA1E1Q05FN1.LDX.CSWI6.OpCls
	AA1E1Q05FN1.LDX.CILO6.EnaCls
	AA1E1Q05FN1.LDX.CILO6.EnaOpn
	AA1E1Q05FN1.LDX.CSWI7.Pos
	AA1E1Q05FN1.LDX.CSWI7.SelOpn
	AA1E1Q05FN1.LDX.CSWI7.SelCls
	AA1E1Q05FN1.LDX.CSWI7.OpOpn
	AA1E1Q05FN1.LDX.CSWI7.OpCls
	AA1E1Q05FN1.LDX.CILO7.EnaCls
	AA1E1Q05FN1.LDX.CILO7.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1.general
DS_Meas	AA1E1Q05FN1.LDX.MMXU1.A.phsA
	AA1E1Q05FN1.LDX.MMXU1.A.phsB
	AA1E1Q05FN1.LDX.MMXU1.A.phsC
	AA1E1Q05FN1.LDX.MMXU2.PPV.phsAB
	AA1E1Q05FN1.LDX.MMXU2.PPV.phsBC
	AA1E1Q05FN1.LDX.MMXU2.PPV.phsCA
	AA1E1Q05FN1.LDX.MMXU4.PPV.phsAB
	AA1E1Q05FN1.LDX.MMXU4.PPV.phsBC
	AA1E1Q05FN1.LDX.MMXU4.PPV.phsCA
	AA1E1Q05FN1.LDX.MMXU3.TotW
	AA1E1Q05FN1.LDX.MMXU3.TotVar
	AA1E1Q05FN1.LDX.MMXU3.TotPF
	AA1E1Q05FN1.LDX.MMXU3.Hz
	AA1E1Q05FN1.LDX.MMTR1.TotWh
	AA1E1Q05FN1.LDX.MMTR1.TotVarh
	AA1E1Q05FN1.LDX.MMXU2.PhV.phsA
	AA1E1Q05FN1.LDX.MMXU2.PhV.phsB
	AA1E1Q05FN1.LDX.MMXU2.PhV.phsC
	AA1E1Q05FN1.LDX.MMXU4.PhV.phsA
	AA1E1Q05FN1.LDX.MMXU4.PhV.phsB
	AA1E1Q05FN1.LDX.MMXU4.PhV.phsC
DS_Prot	AA1E1Q03FN1.LDX.PTRC1.Op
	AA1E1Q03FN1.LDX.PTOC1.Op
	AA1E1Q03FN1.LDX.PTOC1.Str
	AA1E1Q03FN1.LDX.PTOC2.Op
	AA1E1Q03FN1.LDX.PTOC2.Str
DS_Alarms	AA1E1Q05FN1.LDX.LPHD1.PhyHealth
	AA1E1Q05FN1.LDX.GGIO15.Ind1
	AA1E1Q05FN1.LDX.GGIO16.Ind1
	AA1E1Q05FN1.LDX.GGIO11.Ind1
	AA1E1Q05FN1.LDX.GGIO12.Ind1
	AA1E1Q05FN1.LDX.GGIO14.Ind1
	AA1E1Q05FN1.LDX.GGIO1.Ind1
	AA1E1Q05FN1.LDX.GGIO19.Ind1
	AA1E1Q05FN1.LDX.GGIO2.Ind1

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AA1E1Q05FN1.LDX.GGIO3.Ind1
AA1E1Q05FN1.LDX.GGIO17.Ind1
AA1E1Q05FN1.LDX.GGIO18.Ind1
AA1E1Q05FN1.LDX.GGIO4.Ind1
AA1E1Q05FN1.LDX.GGIO5.Ind1
AA1E1Q05FN1.LDX.GGIO13.Ind1

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**Annexure 45 SAS Data sets for IEDs in 220kV 132kV Bus Bar Protection panel**

**1. BB Protection Central IED**

Data Set Name	Information
DS_Prot	AA1E1Q05FP1.LDX.RBRF1.Str
	AA1E1Q05FP1.LDX.RBRF2.Str
	AA1E1Q05FP1.LDX.RBRF3.Str
	AA1E1Q05FP1.LDX.RBRF4.Str
	AA1E1Q05FP1.LDX.RBRF5.Str
	AA1E1Q05FP1.LDX.GGIO3.Ind1
	AA1E1Q05FP1.LDX.GGIO8.Ind1
	AA1E1Q05FP1.LDX.GGIO9.Ind1
	AA1E1Q05FP1.LDX.GGIO10.Ind1
	AA1E1Q05FP1.LDX.GGIO11.Ind1
	AA1E1Q05FP1.LDX.GGIO12.Ind1
	AA1E1Q05FP1.LDX.GGIO13.Ind1
	AA1E1Q05FP1.LDX.GGIO14.Ind1
	AA1E1Q05FP1.LDX.PDIF1.Op
	AA1E1Q05FP1.LDX.RBRF.OpEx
	AA1E1Q05FP1.LDX.RBRF.OpIn
	AA1E1Q05FP1.LDX.GGIO1.Ind1
	AA1E1Q05FP1.LDX.GGIO2.Ind1
	AA1E1Q05FP1.LDX.GGIO3.Ind1
	AA1E1Q05FP1.LDX.GGIO4.Ind1
	AA1E1Q05FP1.LDX.GGIO5.Ind1
	AA1E1Q05FP1.LDX.GGIO6.Ind1
	AA1E1Q05FP1.LDX.GGIO7.Ind1
	AA1E1Q05FP1.LDX.PTOC1.Op
	AA1E1Q05FP1.LDX.PTOC2.Op
	AA1E1Q05FP1.LDX.PTOC1.Str
	AA1E1Q05FP1.LDX.PTOC2.Str

**2. Station Alarm IED**

Data Set Name	Information
DS_Alarms	AA1E1Q05A1.LDX.GGIO1.Ind1
	AA1E1Q05A1.LDX.GGIO2.Ind1
	AA1E1Q05A1.LDX.GGIO3.Ind1
	AA1E1Q05A1.LDX.GGIO4.Ind1
	AA1E1Q05A1.LDX.GGIO5.Ind1
	AA1E1Q05A1.LDX.GGIO6.Ind1
	AA1E1Q05A1.LDX.GGIO7.Ind1
	AA1E1Q05A1.LDX.GGIO8.Ind1
	AA1E1Q05A1.LDX.GGIO9.Ind1
	AA1E1Q05A1.LDX.GGIO10.Ind1
	AA1E1Q05A1.LDX.GGIO11.Ind1
	AA1E1Q05A1.LDX.GGIO12.Ind1
	AA1E1Q05A1.LDX.GGIO13.Ind1
	AA1E1Q05A1.LDX.GGIO14.Ind1
	AA1E1Q05A1.LDX.GGIO15.Ind1
	AA1E1Q05A1.LDX.GGIO16.Ind1
	AA1E1Q05A1.LDX.GGIO17.Ind1
	AA1E1Q05A1.LDX.GGIO18.Ind1
	AA1E1Q05A1.LDX.GGIO19.Ind1
	AA1E1Q05A1.LDX.GGIO20.Ind1
	AA1E1Q05A1.LDX.GGIO21.Ind1
	AA1E1Q05A1.LDX.GGIO22.Ind1
	AA1E1Q05A1.LDX.GGIO23.Ind1
	AA1E1Q05A1.LDX.GGIO24.Ind1
	AA1E1Q05A1.LDX.GGIO25.Ind1
	AA1E1Q05A1.LDX.GGIO26.Ind1
	AA1E1Q05A1.LDX.GGIO27.Ind1
	AA1E1Q05A1.LDX.GGIO28.Ind1
	AA1E1Q05A1.LDX.GGIO29.Ind1
	AA1E1Q05A1.LDX.GGIO30.Ind1
	AA1E1Q05A1.LDX.GGIO31.Ind1
	AA1E1Q05A1.LDX.GGIO32.Ind1
	AA1E1Q05A1.LDX.GGIO33.Ind1
	AA1E1Q05A1.LDX.GGIO34.Ind1
	AA1E1Q05A1.LDX.GGIO35.Ind1
	AA1E1Q05A1.LDX.GGIO36.Ind1
	AA1E1Q05A1.LDX.GGIO37.Ind1
	AA1E1Q05A1.LDX.GGIO38.Ind1
	AA1E1Q05A1.LDX.GGIO39.Ind1
	AA1E1Q05A1.LDX.GGIO40.Ind1
	AA1E1Q05A1.LDX.GGIO41.Ind1

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	AA1E1Q05A1.LDX.GGIO42.Ind1
	AA1E1Q05A1.LDX.GGIO43.Ind1
	AA1E1Q05A1.LDX.GGIO44.Ind1
	AA1E1Q05A1.LDX.GGIO45.Ind1
	AA1E1Q05A1.LDX.GGIO46.Ind1
	AA1E1Q05A1.LDX.GGIO47.Ind1
	AA1E1Q05A1.LDX.GGIO48.Ind1
	AA1E1Q05A1.LDX.GGIO49.Ind1
	AA1E1Q05A1.LDX.GGIO50.Ind1
	AA1E1Q05A1.LDX.GGIO51.Ind1.StVal
	AA1E1Q05A1.LDX.GGIO52.Ind1.StVal

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**Annexure 46 SAS Data set for LV Feeder Protection IED**

Data Set Name	Information
DS_Control	AA1H1Q01FN1.LDX.CSWI1.Pos
	AA1H1Q01FN1.LDX.CSWI1.SelOpn
	AA1H1Q01FN1.LDX.CSWI1.SelCls
	AA1H1Q01FN1.LDX.CSWI1.OpOpn
	AA1H1Q01FN1.LDX.CSWI1.OpCls
	AA1H1Q01FN1.LDX.CILO1.EnaCls
	AA1H1Q01FN1.LDX.CILO1.EnaOpn
	AA1H1Q01FN1.LDX.RSYN1.Rel
	AA1H1Q01FN1.LDX.GGIO6.Ind1
	AA1H1Q01FN1.LDX.GGIO7.Ind1
	AA1H1Q01FN1.LDX.GGIO8.Ind1
	AA1H1Q01FN1.LDX.GGIO9.Ind1
	AA1H1Q01FN1.LDX.GGIO10.Ind1
	AA1H1Q01FN1.LDX.CSWI2.Pos
	AA1H1Q01FN1.LDX.CSWI2.SelOpn
	AA1H1Q01FN1.LDX.CSWI2.SelCls
	AA1H1Q01FN1.LDX.CSWI2.OpOpn
	AA1H1Q01FN1.LDX.CSWI2.OpCls
	AA1H1Q01FN1.LDX.CILO2.EnaCls
	AA1H1Q01FN1.LDX.CILO2.EnaOpn
	AA1H1Q01FN1.LDX.CSWI3.SelOpn
	AA1H1Q01FN1.LDX.CSWI3.SelCls
	AA1H1Q01FN1.LDX.CSWI3.OpOpn
	AA1H1Q01FN1.LDX.CSWI3.OpCls
	AA1H1Q01FN1.LDX.CILO3.EnaCls
	AA1H1Q01FN1.LDX.CILO3.EnaOpn
	AA1H1Q01FN1.LDX.CSWI4.Pos
	AA1H1Q01FN1.LDX.CSWI4.SelCls
	AA1H1Q01FN1.LDX.CSWI4.OpOpn
	AA1H1Q01FN1.LDX.CSWI4.OpCls
	AA1H1Q01FN1.LDX.CILO4.EnaCls
	AA1H1Q01FN1.LDX.CILO4.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1.general
DS_Meas	AA1H1Q01FN1.LDX.MMXU1.A.phsA
	AA1H1Q01FN1.LDX.MMXU1.A.phsB
	AA1H1Q01FN1.LDX.MMXU1.A.phsC
	AA1H1Q01FN1.LDX.MMXU2.PPV.phsAB
	AA1H1Q01FN1.LDX.MMXU2.PPV.phsBC
	AA1H1Q01FN1.LDX.MMXU2.PPV.phsCA
	AA1H1Q01FN1.LDX.MMXU3.TotW
	AA1H1Q01FN1.LDX.MMXU3.TotVar
	AA1H1Q01FN1.LDX.MMXU3.TotPF
	AA1H1Q01FN1.LDX.MMXU3.Hz

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	AA1H1Q01FN1.LDX.MMTR1.TotWh	
	AA1H1Q01FN1.LDX.MMTR1.TotVArh	
	AA1H1Q01FN1.LDX.MMXU2.PhV.phsA	
	AA1H1Q01FN1.LDX.MMXU2.PhV.phsB	
	AA1H1Q01FN1.LDX.MMXU2.PhV.phsC	
DS_Prot	AA1H1Q01A1.LDX.PTOC1.Op	
	AA1H1Q01A1.LDX.PTOC1.Str	
	AA1H1Q01A1.LDX.PTOC1.Op	
	AA1H1Q01A1.LDX.PTRC1.Op	
	AA1H1Q01A1.LDX.PTOC1.Op	
	AA1H1Q01A1.LDX.PTOC1.Str	
	AA1H1Q01A1.LDX.PTOC1.Op	
	AA1H1Q01A1.LDX.PTUF1.Op	
	AA1H1Q01A1.LDX.PTUF2.Op	
	AA1H1Q01A1.LDX.PTUF3.Op	
	AA1H1Q01A1.LDX.PTUF4.Op	
	AA1H1Q01A1.LDX.PTUF5.Op	
	AA1H1Q01A1.LDX.PTUF6.Op	
	AA1H1Q01A1.LDX.GGIO20.Ind1	
	AA1H1Q01A1.LDX.GGIO21.Ind1	
	AA1H1Q01A1.LDX.GGIO22.Ind1	
	AA1H1Q01A1.LDX.GGIO23.Ind1	
	AA1H1Q01A1.LDX.GGIO24.Ind1	
	AA1H1Q01A1.LDX.GGIO25.Ind1	
	AA1H1Q01A1.LDX.GGIO26.Ind1	
	AA1H1Q01A1.LDX.RBRF1.OpEx	
	AA1H1Q01A1.LDX.RBRF1.Opln	
	AA1H1Q01A1.LDX.GGIO17.Ind1	
	AA1H1Q01A1.LDX.RFLO1.FltDiskm.mag	
	AA1H1Q01A1.LDX.RFLO1.FltImp.mag	
	AA1H1Q01A1.LDX.RFLO1.FltPhsA.mag	
	AA1H1Q01A1.LDX.RFLO1.FltPhsB.mag	
	AA1E1Q01A1.LDX.RFLO1.FltPhsC.mag	
	DS_Alarms	AA1H1Q01A1.LDX.LPHD1.PhyHealth
		AA1H1Q01A1.LDX.GGIO15.Ind1
		AA1H1Q01A1.LDX.GGIO16.Ind1
		AA1H1Q01A1.LDX.GGIO19.Ind1
AA1H1Q01A1.LDX.GGIO20.Ind1		
AA1H1Q01A1.LDX.GGIO11.Ind1		
AA1H1Q01A1.LDX.GGIO12.Ind1		
AA1H1Q01A1.LDX.GGIO1.Ind1		
AA1H1Q01A1.LDX.GGIO18.Ind1		
AA1H1Q01A1.LDX.GGIO13.Ind1		
AA1H1Q01A1.LDX.GGIO14.Ind1		
AA1H1Q01A1.LDX.GGIO2.Ind1		
AA1H1Q01A1.LDX.GGIO3.Ind1		

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**Annexure 47 SAS Data set for Transformer LV Protection IED**

Data Set Name	Information
DS_Control	AA1H1Q01FN1.LDX.CSWI1.Pos
	AA1H1Q01FN1.LDX.CSWI1.SelOpn
	AA1H1Q01FN1.LDX.CSWI1.SelCls
	AA1H1Q01FN1.LDX.CSWI1.OpOpn
	AA1H1Q01FN1.LDX.CSWI1.OpCls
	AA1H1Q01FN1.LDX.CILO1.EnaCls
	AA1H1Q01FN1.LDX.CILO1.EnaOpn
	AA1H1Q01FN1.LDX.RSYN1.Rel
	AA1H1Q01FN1.LDX.GGIO6.Ind1
	AA1H1Q01FN1.LDX.GGIO7.Ind1
	AA1H1Q01FN1.LDX.GGIO8.Ind1
	AA1H1Q01FN1.LDX.GGIO9.Ind1
	AA1H1Q01FN1.LDX.GGIO10.Ind1
	AA1H1Q01FN1.LDX.CSWI2.Pos
	AA1H1Q01FN1.LDX.CSWI2.SelOpn
	AA1H1Q01FN1.LDX.CSWI2.SelCls
	AA1H1Q01FN1.LDX.CSWI2.OpOpn
	AA1H1Q01FN1.LDX.CSWI2.OpCls
	AA1H1Q01FN1.LDX.CILO2.EnaCls
	AA1H1Q01FN1.LDX.CILO2.EnaOpn
	AA1H1Q01FN1.LDX.CSWI3.SelOpn
	AA1H1Q01FN1.LDX.CSWI3.SelCls
	AA1H1Q01FN1.LDX.CSWI3.OpOpn
	AA1H1Q01FN1.LDX.CSWI3.OpCls
	AA1H1Q01FN1.LDX.CILO3.EnaCls
	AA1H1Q01FN1.LDX.CILO3.EnaOpn
	AA1H1Q01FN1.LDX.CSWI4.Pos
	AA1H1Q01FN1.LDX.CSWI4.SelCls
	AA1H1Q01FN1.LDX.CSWI4.OpOpn
	AA1H1Q01FN1.LDX.CSWI4.OpCls
	AA1H1Q01FN1.LDX.CILO4.EnaCls
	AA1H1Q01FN1.LDX.CILO4.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1.general
DS_Meas	AA1H1Q01FN1.LDX.MMXU1.A.phsA
	AA1H1Q01FN1.LDX.MMXU1.A.phsB
	AA1H1Q01FN1.LDX.MMXU1.A.phsC
	AA1H1Q01FN1.LDX.MMXU2.PPV.phsAB
	AA1H1Q01FN1.LDX.MMXU2.PPV.phsBC
	AA1H1Q01FN1.LDX.MMXU2.PPV.phsCA
	AA1H1Q01FN1.LDX.MMXU3.TotW
	AA1H1Q01FN1.LDX.MMXU3.TotVar
	AA1H1Q01FN1.LDX.MMXU3.TotPF
	AA1H1Q01FN1.LDX.MMXU3.Hz

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	AA1H1Q01FN1.LDX.MMTR1.TotWh
	AA1H1Q01FN1.LDX.MMTR1.TotVarh
	AA1H1Q01FN1.LDX.MMXU2.PhV.phsA
	AA1H1Q01FN1.LDX.MMXU2.PhV.phsB
	AA1H1Q01FN1.LDX.MMXU2.PhV.phsC
DS_Prot	AA1H1Q01A1.LDX.PTOC1.Op
	AA1H1Q01A1.LDX.PTOC1.Str
	AA1H1Q01A1.LDX.PTOC1.Op
	AA1H1Q01A1.LDX.PTRC1.Op
	AA1H1Q01A1.LDX.PTOC1.Op
	AA1H1Q01A1.LDX.PTOC1.Str
	AA1H1Q01A1.LDX.PTOC1.Op
	AA1H1Q01A1.LDX.PTUF1.Op
	AA1H1Q01A1.LDX.PTUF2.Op
	AA1H1Q01A1.LDX.PTUF3.Op
	AA1H1Q01A1.LDX.PTUF4.Op
	AA1H1Q01A1.LDX.PTUF5.Op
	AA1H1Q01A1.LDX.PTUF6.Op
	AA1H1Q01A1.LDX.RBRF1.OpEx
	AA1H1Q01A1.LDX.RBRF1.Opln
	AA1H1Q01A1.LDX.GGIO17.Ind1
DS_Alarms	AA1H1Q01A1.LDX.LPHD1.PhyHealth
	AA1H1Q01A1.LDX.GGIO15.Ind1
	AA1H1Q01A1.LDX.GGIO16.Ind1
	AA1H1Q01A1.LDX.GGIO19.Ind1
	AA1H1Q01A1.LDX.GGIO20.Ind1
	AA1H1Q01A1.LDX.GGIO11.Ind1
	AA1H1Q01A1.LDX.GGIO12.Ind1
	AA1H1Q01A1.LDX.GGIO1.Ind1
	AA1H1Q01A1.LDX.GGIO18.Ind1
	AA1H1Q01A1.LDX.GGIO13.Ind1
	AA1H1Q01A1.LDX.GGIO14.Ind1
	AA1H1Q01A1.LDX.GGIO2.Ind1
	AA1H1Q01A1.LDX.GGIO3.Ind1

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**Annexure 48 SAS Data set for LV Bus Coupler Protection IED**

Data Set Name	Information
DS_Control	AA1H1Q01FN1.LDX.CSWI1.Pos
	AA1H1Q01FN1.LDX.CSWI1.SelOpn
	AA1H1Q01FN1.LDX.CSWI1.SelCls
	AA1H1Q01FN1.LDX.CSWI1.OpOpn
	AA1H1Q01FN1.LDX.CSWI1.OpCls
	AA1H1Q01FN1.LDX.CILO1.EnaCls
	AA1H1Q01FN1.LDX.CILO1.EnaOpn
	AA1H1Q01FN1.LDX.RSYN1.Rel
	AA1H1Q01FN1.LDX.GGIO6.Ind1
	AA1H1Q01FN1.LDX.GGIO7.Ind1
	AA1H1Q01FN1.LDX.GGIO8.Ind1
	AA1H1Q01FN1.LDX.GGIO9.Ind1
	AA1H1Q01FN1.LDX.GGIO10.Ind1
	AA1H1Q01FN1.LDX.CSWI2.Pos
	AA1H1Q01FN1.LDX.CSWI2.SelOpn
	AA1H1Q01FN1.LDX.CSWI2.SelCls
	AA1H1Q01FN1.LDX.CSWI2.OpOpn
	AA1H1Q01FN1.LDX.CSWI2.OpCls
	AA1H1Q01FN1.LDX.CILO2.EnaCls
	AA1H1Q01FN1.LDX.CILO2.EnaOpn
	AA1H1Q01FN1.LDX.CSWI3.SelOpn
	AA1H1Q01FN1.LDX.CSWI3.SelCls
	AA1H1Q01FN1.LDX.CSWI3.OpOpn
	AA1H1Q01FN1.LDX.CSWI3.OpCls
	AA1H1Q01FN1.LDX.CILO3.EnaCls
	AA1H1Q01FN1.LDX.CILO3.EnaOpn
	AA1H1Q01FN1.LDX.CSWI4.Pos
	AA1H1Q01FN1.LDX.CSWI4.SelCls
	AA1H1Q01FN1.LDX.CSWI4.OpOpn
	AA1H1Q01FN1.LDX.CSWI4.OpCls
	AA1H1Q01FN1.LDX.CILO4.EnaCls
	AA1H1Q01FN1.LDX.CILO4.EnaOpn
	AA1H1Q01FN1.LDX.CSWI5.Pos
	AA1H1Q01FN1.LDX.CSWI5.SelOpn
	AA1H1Q01FN1.LDX.CSWI5.SelCls
	AA1H1Q01FN1.LDX.CSWI5.OpOpn
	AA1H1Q01FN1.LDX.CSWI5.OpCls
	AA1H1Q01FN1.LDX.CILO5.EnaCls
	AA1H1Q01FN1.LDX.CILO5.EnaOpn
	AA1E1Q01FN1.LDX.GAPC1.Op1.general
DS_Meas	AA1H1Q01A1.LDX.MMXU1.A.phsA
	AA1H1Q01A1.LDX.MMXU1.A.phsB

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	AA1H1Q01A1.LDX.MMXU1.A.phsC
	AA1H1Q01A1.LDX.MMXU2.PPV.phsAB
	AA1H1Q01A1.LDX.MMXU2.PPV.phsBC
	AA1H1Q01A1.LDX.MMXU2.PPV.phsCA
	AA1H1Q01A1.LDX.MMXU3.TotW
	AA1H1Q01A1.LDX.MMXU3.TotVar
	AA1H1Q01A1.LDX.MMXU3.TotPF
	AA1H1Q01A1.LDX.MMXU3.Hz
	AA1H1Q01A1.LDX.MMTR1.TotWh
	AA1H1Q01A1.LDX.MMTR1.TotVARh
	AA1H1Q01A1.LDX.MMXU2.PhV.phsA
	AA1H1Q01A1.LDX.MMXU2.PhV.phsB
	AA1H1Q01A1.LDX.MMXU2.PhV.phsC
DS_Prot	AA1H1Q01A1.LDX.PTOC1.Op
	AA1H1Q01A1.LDX.PTOC1.Str
	AA1H1Q01A1.LDX.PTOC1.Op
	AA1H1Q01A1.LDX.PTRC1.Op
	AA1H1Q01A1.LDX.RBRF1.OpEx
	AA1H1Q01A1.LDX.RBRF1.OpIn
	AA1H1Q01A1.LDX.GGIO17.Ind1
DS_Alarms	AA1H1Q01A1.LDX.LPHD1.PhyHealth
	AA1H1Q01A1.LDX.GGIO15.Ind1
	AA1H1Q01A1.LDX.GGIO16.Ind1
	AA1H1Q01A1.LDX.GGIO19.Ind1
	AA1H1Q01A1.LDX.GGIO20.Ind1
	AA1H1Q01A1.LDX.GGIO11.Ind1
	AA1H1Q01A1.LDX.GGIO12.Ind1
	AA1H1Q01A1.LDX.GGIO1.Ind1
	AA1H1Q01A1.LDX.GGIO18.Ind1
	AA1H1Q01A1.LDX.GGIO13.Ind1
	AA1H1Q01A1.LDX.GGIO14.Ind1
	AA1H1Q01A1.LDX.GGIO2.Ind1
	AA1H1Q01A1.LDX.GGIO3.Ind1

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**CHAPTER 6 - POWER LINE CARRIER , FIBRE OPTIC COMMUNICATION SYSTEM  
AND SCADA EQUIPMENT**

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## **CHAPTER 6- POWER LINE CARRIER OPTICAL FIBRE EQUIPMENT AND SCADA EQUIPMENT**

### **6.1 GENERAL**

#### **6.1.1 Description of the Scheme**

##### **Communication System**

The existing communication system of the Employer comprises of PLC (Power Line Carrier) links, which operates over the HV transmission network, and Fibre Optic links ,which operates over the OPGW and Under Ground fibre optic cable.

The communication system provides communications channels for the following:

- (1) Party Line Telephone System
- (2) Administrative Telephone System
- (3) Supervisory Control and Data Acquisition (SCADA) System
- (4) Tele-protection signalling facilities
- (5) Computer WAN connectivity

For all Communication equipment including power line carrier, fibre optic equipment and SCADA equipment, the Bid shall comprise the system design, supply and delivery of equipment to the sites. Installation, testing and commissioning of the equipment shall be done by qualified engineers from the manufactures of the equipment.

#### **6.1.2 Overall Power Line Carrier System**

The Power Line Carrier Equipment for speech and tele-signalling channels is required under this Contract for communication between substations via HV transmission line circuits.

The power line carrier equipment to be supplied under the Contract shall be used in conjunction with the existing power line carrier system. Any equipment or device required to ensure compatibility with the existing systems shall be supplied.

Since the implementation of the communication program will be in stages, the Bidder shall propose a power line carrier system, which permits systematic and orderly expansion in the future. The PLC equipment shall be furnished completely wired for the required channel capacity.

The design of PLC equipment shall be compatible with the existing one, from operation viewpoints.

The PLC shall provide at least 2 channels for speech and data for each circuit. The power line carrier terminal shall consist of a single carrier communication circuit equipped with transmit/receive high frequency terminals of independent/single side band type. The carrier circuit shall be coupled to the power lines as detailed in Chapter 6.2.3. All plant i.e. line traps, coupling capacitors and HF coupling devices shall operate on the HV system with characteristics specified in Chapter 6.2.

The carrier circuit shall be of the multi-purpose type and shall provide speech, tele-protection and tele-control, tele-signalling facilities etc.

The carrier frequencies will be notified to the successful Bidder.

### 6.1.3 Fibre Optic Communication System

The Fibre Optic (FO) communication system is gradually replacing the current PLC network due to frequency congestion and limited channel capacity of the PLC. The fibre optic network is based on SDH (STM-1) with transmission capacity of 155 Mbit/s.

The Fibre Optic multiplexers to be supplied under the Contract shall be possible to connect in STM-1 level with the existing Fibre Optic multiplexers in the system. Any equipment or device required to ensure compatibility with the existing systems shall be supplied. The Fibre Optic Equipment shall be furnished completely wired for the required channel capacity.

### 6.1.4 Party Line Telephone System

This system is a dedicated non-switched telephone system, which is exclusively used for system control purposes. The system comprises of master station equipment at the system control centre and terminal equipment at all power stations and grid substations.

Eight lines, each having multiple stations connected on 4-wire basis, are arranged in a star configuration at the master station. The system has two telephone consoles at master station for communication with other stations. The selection of a particular station is done by selecting of the line on which the station is connected, and dialling a 3 digit number from any one of the consoles. The system sends DTMF dialling signals on the selected line and a decoder at each terminal equipment on that line will try to decode the numbers. Finally the terminal equipment which is programmed for the correct number will ring the telephone attached. The branching of connection path for the different station on the same line is through a 4-way bridging amplifier supported in the terminal equipment having 4 AF ports. One of the three ports is used for the local telephone. The number of branching directions can be extended by adding more 4-way bridging amplifiers to the existing bridge. As an example, by connecting 2 bridging amplifiers together using one port from each, the total number of ports can be increased to six.

In Fibre Optic Communication system the function of the 4-way bridging amplifier is integrated into the fibre optic multiplexer.

### 6.1.5 Administrative Telephone System

The administrative Telephone System provides voice communications between any other substation and generating stations connected to the Sri Lanka HV transmission system.

Existing Private Automatic Telephone exchanges at grid substations and power stations are interconnected via four wire (4W) analog trunks with E & M signaling or via digital trunks where fibre optic links available between the stations.

This system uses closed numbering scheme that means the same number is dialled from any extension to obtain a given extension.

### 6.1.6 Teleprotection System

The teleprotection system is provided for satisfactory operation of the grid substations. The carrier (or Fibre Optic) teleprotection equipment will be used to provide, with maximum security, the rapid, two-way transmission of a trip command between adjacent substations connected by a high voltage transmission(or OPGW) line.

The power line carrier terminals or optical fibre links will be used as the transmission path for signal transmission of protection relaying

### 6.1.7 Overall SCADA System

The existing SCADA system includes the Master Station hardware at the National Control Centre of the Employer and Remote Terminal Units and/or Gateways of Substation Automation System at Power Stations and Grid Substations. The Master Station equipment is a Dual Computer System “MicroSCADA”, Windows XP Professional based SCADA System, supplied by M/s ABB Power Automation Ltd., Switzerland.

There is an ongoing project named System Control Center Modernization Project (SCCMP) for the implementation of a new system control center at Sri Jayawardanapura. The new Master station equipment will be a dual SCADA/EMS server system “e-terra” , based on Windows 8/Linux operating system supplied by M/s. Alstom Grid S.A.S. ,India.

This SCADA system is used for monitoring and controlling of the power generation and transmission network of the Employer.

The SCADA equipment to be supplied under this Contract shall be used in conjunction with the new SCADA system.

## 6.2 PLC SYSTEM EQUIPMENT AND DEVICES

### 6.2.1 PLC Equipment

#### 6.2.1.1 General

The equipment to be provided shall have been constructed on a modular basis and shall be mounted within an indoor panel. The equipment shall operate from -48 Volt DC batteries as specified in Chapter 4. The terminal shall employ full static circuitry techniques of the plug-in type.

The design and performance requirements to be met by the power line carrier terminal bays shall be such that they may be for the transmission of any combination of the following types of information.

- (i) Speech for telephone communication
- (ii) Telephone signalling
- (iii) Teleprotection signalling – 2 (Permissive Tripping)
- (iv) Teleprotection signalling – 2 (Direct Tripping)
- (v) Data Transmission (Broad band and narrow band data)

The equipment shall be suitable for operation at all times when the ambient temperature in which the cubicle is located is between 0°C and + 45°C. Bidders shall clearly detail any methods of ventilation which they will provide to meet this service requirement.

The Bidder shall show clearly the methods of transmission used. Bidders shall clearly show whether there are any limitations in paralleling their systems on the same power line with their own or other manufacturer's equipment and detail the necessary frequency spacing.

Bidders shall state clearly and show in the form of frequency allocation plan the available channels in line with ITU-T (former CCITT) recommendations.

The method of transmission may include the transmission of reduced carrier in order to synchronize the two ends of the link and Bidders shall state clearly how synchronizing is achieved. The virtual carrier frequency shall not vary by more than +/- 20 Hz and the frequency difference, in a pair of terminals, between the voice frequency signal applied to the transmit end and that received at the receive end shall not exceed 2 Hz.

The Peak Envelope Power (PEP) of the PLC terminal shall be stated and shall be sufficient to ensure the signal/noise ratio specified hereunder.

The nominal impedance at the carrier frequency output shall be 75 ohms (unbalanced) and provision shall be made for terminating the output in an appropriate dummy load. The return loss within the nominal carrier frequency band in the transmit direction shall not be less than 12 dB.

Bidders shall state clearly the maximum line attenuation permissible to achieve a signal to noise ratio at all times greater than 26 dB. This figure should be normally better than 35 dB. Bidders shall provide calculations detailing coupling equipment, tee points, and line attenuation losses etc., to show that the proposed equipment will meet this requirement.

The level of spurious emission shall be clearly stated in the Technical Particulars and Guarantees.

#### **6.2.1.2 Speech channels**

Circuit shall be suitable for connection to a 4 wire telephone exchange and shall be compatible with the existing exchange equipment.

The preferred methods of telephone signalling shall be to utilize the same VF signalling channel as the AGC pilot tone in order to conserve above speech bandwidth. Other methods shall be clearly explained by Bidders.

All speech and VF signal input and output circuit shall be balanced and have a nominal impedance of 600 ohms. The return loss within the effectively transmitted frequency band shall not be less than 14 dB.

Telephone facilities shall be provided at each end of the link using a handset together with an audible form of calling and a lamp.

Specification of speech channel shall be as follows

**Analog speech**

## Telephony services

Depending on configuration either:

- Point to point hot line / 2 wire remote subscriber / 4 wire remote subscriber
- 4 wire PAX connection with E&M signaling
- 2/4 wire PAX connection with E&M signaling and hybrid control
- Transit mode for E&M wire
- Service phone (available once per AF channel)

## Speech low-pass filter cut-off frequency

– 2.0 kHz to 3.4 kHz, programmable in steps of 200 Hz, limited by AF channel bandwidth

## Signaling

DTMF and decadic

## Speech limiter

+3 dBm0

## Speech compandor

According to ITU-T G.162; configurable to “Off” or “On” (either permanent or enabled/disabled via control input)

**Digital speech**

## Telephony services

Depending on configuration either:

- Point to point hot line / 2 wire remote subscriber / 4 wire remote subscriber
- 4 wire PAX connection with E&M signaling
- Services phone (available once per terminal)

## Number of digital speech channels

Up to 16, multiplexed in broadband modem

## Speech low-pass filter cut-off frequency

2.0 kHz to 3.4 kHz, programmable in steps of 200 Hz

## Signaling

DTMF and decadic

## Modes

Voice and FAX 4.8 kbps (automatic FAX detection)

## Data rate

5.3 or 6.3 kbps, programmable

**6.2.1.3 Data Service  
Broadband data**

Application	Transmission of high-speed / high capacity data in bandwidth of 2 kHz, 4 kHz or higher
Transmission bandwidth	2, 4, 6, 8, 12, 16, 20, 24, 28, 32 kHz
Programmable data rates	9.6, 11, 12, 14.4, 16, 19.2, 24, 28.8, 32, 36, 38.4, 40, 48, 56, 64, 72, 76.8, 80, 96, 112, 128, 144, 153.6, 160, 192, 224, 256, 288, 307.2, 320 kbps

**Narrowband data**

Application	Data transmission in bandwidth of less than 4 kHz, in point-point or point-multipoint applications (e.g polling SCADA)
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**Data Ports**

**V.11 ports**

Number of V.11/X.24 ports	1 or 2 (option), depending on configuration
---------------------------	---

**V.24 ports**

Number of V.24/RS-232 ports	2 or 6 (option), depending on configuration;
Data rates	For broadband 1200, 2400, 4800, 9600 or 19200 bps For narrowband: 1200, 2400, 4800, 9600 bps

**G.703.1 port**

Number of G.703.1 ports	1
Data rate	64 kbps

**LAN port**

Number of LAN ports	1
Connector	10/100 BaseT (STP): shielded RJ-45
Physical layer	Auto or manual negotiation (full/half duplex and 10/100 Mbps)



Link layer	Conforms to IEEE 802.3 / Ethernet II
LAN services	Bridging / IP routing, SNMP, HMI over LAN

#### 6.2.1.4 Receivers

The method of automatic gain control used by Bidders shall ensure that in the case of a + 30 dB change in carrier frequency signal level within the regulation range, the change in voice frequency receive levels of both speech, data and teleprotection signals shall be less than + 1.0 dB. A receive level low alarm shall be given some 6 dB above the receiver fail alarm which will occur when the receiver has failed completely.

#### 6.2.1.5 Service Conditions

The set noise generated within the terminals shall comply with IEC 60495 as shall the cross talk attenuation between speech, data and teleprotection signalling channels.

Bidders shall state clearly the type of modulation used for the speech, data and teleprotection channels.

The level of spurious emission shall be clearly stated in the Technical Particulars.

The equipment shall operate to its stated performance with a variation in power supply of -10% to +15% and remain operational with an increase of power supply voltage of up to 20% of the nominal value.

#### 6.2.1.6 Voltage withstand

The equipment shall be designed to withstand satisfactorily the following insulation tests:

- (i) 2 kV AC, r.m.s. 50Hz applied for one minute
  - Between all terminals (other than earth terminals) connected together and all metallic parts intended to be earthed in service.
  - Between the output contact terminals with the contacts closed, and all the remaining terminals connected together.
  - Between all electrical circuits of the equipment not intended to be connected together in service, except where an earthed barrier exists between the circuits or where the circuits have mating contacts between them.
- (ii) 1kV AC r.m.s. 50 Hz applied for one minute across each output contact in the open position. When the carrier frequency terminals are not isolated from earth they shall be capable of withstanding an impulse voltage of 3 kV 1.2/50  $\mu$ s applied between each terminal and earth.

The equipment shall not be subject to interference by the presence of electrical noise generated by circuit breaker or isolator switching operations. The bandwidth of such noise extends from 10 kHz to at least 1 MHz and can peak to 1,200 volts at the coaxial termination. Limiting diodes of the avalanche type should be provided at the HF cubicle terminals in order to limit this voltage to 400 volts peak to peak.

### 6.2.1.7 Test facilities and alarms

The equipment shall have clearly designated test point on the modules on which adjustments are required together with test points on modules having normal reference points. It shall be possible to mount a bay transmission measuring set or equivalent instrument in the sub rack to which the various test points can be connected to achieve wide band measurements. The equipment shall also have a variable level 800 Hz oscillator for injection of test tone when commissioning or maintenance work is performed on the bay. The minimum requirement for alarm lamps to be provided on the bay is “Receiver Fail”, “Transmitter Fail”, and voltage free changeover contacts shall be provided to initiate remote and supervisory “Carrier fail” alarms.

Supervisory facilities shall be provided for monitoring the HF output amplifier current, the AGC voltage and the cubicle supply voltage. An abnormal condition in any of these quantities shall close two normally open electrically isolated contacts, one of which illuminates the cubicle alarm lamp.

### 6.2.1.8 Mechanical details

There shall be good access to panel terminals to which all external cabling shall be connected. There shall be a suitable gland plate fitted near the base of the panel and all cables shall be provided with glands. Inside the base of the panel, there shall be a substantial earthing terminal to which the substation earth and all internal cubicle earthing shall be connected.

The cabinets shall provide ventilation, where necessary, for purposes of cooling. However the use of a ventilating fan is not encouraged due to dust accumulation. If use of a fan is unavoidable, it should be controlled by a thermostatic switch so that operating time is limited to a bare minimum. All ventilation openings shall be covered by stainless steel mesh, and the entire cabinet shall be insect and rodent proof.

All modules shall be identified as to their shelf location and shall use coded key slots in the edge connectors, or similar means, in order that modules cannot be plugged into the wrong position.

The panel shall be clearly labelled as to the bay designation and all alarm lamps shall also be clearly labelled. There shall be at least one external cubicle alarm lamp, which will indicate internal fault conditions when the panel doors are closed.

## 6.2.2 Line traps

The rated current and the rated rupturing capacity of the line traps shall be as stated in the Scope of works. The value of coil inductance shall be 0.2 milliHenries although other values will be considered. The line traps shall be broadband tuned over the assigned bandwidth within the frequency range of 50-500 kHz by use of a tuning device, which shall be arranged to permit interchange without removing the line trap. The line trap shall have a protective device, which utilizes non-linear resistor type arrestors (IEC 60099-1), and the nominal discharge current shall be 5 kA. The line trap shall be completed with bird barrier and other necessary accessories.

Bidder shall be expected to demonstrate that their line traps meet the test recommended in IEC 60353 - Line Traps. Measurement of temperature rise, short time current ratings and impulse voltage may be in the form of type tests. Measurement of blocking impedance and insertion loss shall be done on routine tests and individual test figures for each trap shall be submitted.

All line traps shall be provided with clearly visible rating plates which shall include the rated continuous current in amperes, rated short time current in kilo-amperes and duration in seconds, rated coil inductance in milliHenries, rated power frequency in hertz, and total mass in kilograms.

The tuning device shall similarly include the frequency band in kilohertz, and the rated impulse level of the protective device in kilovolts.

Line traps shall be mounted on the top of capacitor voltage transformer and coils shall be coated with the insulation materials.

The blocking band of the line traps will be notified to the successful Bidder.

### 6.2.3 HF coupling devices

The high frequency coupling units (line matching and protection units) shall comply with IEC 60481 and shall be suitable for mounting on the structure of the capacitor voltage transformers. The filters shall be suitable for outdoor use in the climatic conditions specified in Chapter 1.5 and shall have weatherproof door seals together with breather holes to avoid condensation.

The units shall have an earthing switch. Clear indication of the ON/OFF position of this switch shall be indicated. The terminal of the filter, which shall be connected directly to the substation grounding system, shall be clearly designated.

The coupling device shall meet in full the safety and protection requirements of IEC 60481 Coupling Devices for Power Line Carrier Systems.

The coupling unit shall be suitable for a tuning range of 50-500 kHz and the composite loss over the range shall not be greater than 2 dB. The line side and equipment side return losses shall be preferably not less than 12 dB over the available bandwidth of the filter. The line side impedance of the device shall be suitable for the range 350-400 ohms for phase to phase coupling whilst the nominal equipment side impedance shall preferably be 75 ohms (unbalanced). In any case both shall match the impedance of the PLC transmitter/receiver units to be provided. The device shall be fitted with a rating plate, which shall include the peak envelope power and the available bandwidth or working range.

Bidders shall demonstrate that their equipment complies with the following tests:

- (a) Drain coil
  - (i) Measurements of impedance at power frequency.
  - (ii) Current carrying capacity at power frequency 1 amp r.m.s. continuous and 50 amps r.m.s. for 0.2 seconds.
- (b) Power frequency voltage tests on the isolation transformer of 5 kV r.m.s. for one minute between each coil and earth, and between each coil and screen.
- (c) Composite loss at several frequencies within the working range of the filter.
- (d) Return loss at several frequencies within the working range of the filter.

The CVTs and the coupling capacitors shall have a minimum rated capacitance of 2,000 pF per phase, which is specified in Chapter 2 of this Specification.

#### 6.2.4 Coaxial cable

Bidders shall quote a unit rate for 100 meters of HF coaxial cable suitable for connecting between the coupling filters and the indoor high frequency units. The cable shall preferably have a characteristic impedance to match the HF coupling units and the PLC transmitter/receiver units. The cable shall be armoured, PE insulated and have a PVC outer sheath. It shall be suitable for installation in the cable trenches and pipes if required.

Bidders shall clearly show the make up of the cable, together with details of the cable's mechanical and electrical characteristics. Bidders shall also state the test voltage/time with which their cable complies.

### 6.3 FIBRE OPTIC COMMUNICATION SYSTEM

This part of the Specification covers the general design, manufacture, assembly, and testing in the Contractor's workshops as well as delivery, erection, commissioning, testing of the equipment and trial operation of the fibre optic telecommunication system.

The optical fibre cables or OPGW shall be with 24 optical fibres (single mode). Optical fibres shall be used to establish the telecommunication channels with all required functions for SCADA, Telephone, Teleprotection and other data transmission as per Specification.

To achieve the necessary availability for the overall telecommunication network, redundancy shall be established by means of main and backup links for most FO links by installation of a fibre-optic ring. The Contractor shall ensure that there will be no single point of failure of connections in the fibre-optic network. The failure of one equipment shall not prevent the use of any other that has not failed.

The fibre-optic telecommunication systems shall be supervised and controlled by the communication branch.

The telecommunication system is used to transfer the following signals:

- party line telephone system (PLTS)
  - -4-wire voice without E&M
- administrative telephone system
  - 4-wire voice with E&M
  - FXS and FXO
  - Digital Trunk Lines
- supervisory control and data acquisition (SCADA) network
- teleprotection signalling facilities (distance protection)
- differential protection
- computer Wide Area Network (WAN)

Additional facilities are envisaged for future, and the system shall be capable of expansion to provide the following features:

- teleconferencing and remote video monitoring
- connection to an SDH transport network with higher transmission capacities.

The digital protection relays will be connected to the 64 kbit/s interface of the add/drop multiplexer sending/receiving of protection inter-tripping signals.

Telephone equipment (2 wire subscriber) for voice communication will be connected to the access multiplexer at the 64 kbit/s channel. Partly line telephone system PLTS will be connected to the access multiplexer. A 64 kbit/s channel will be provided on the access multiplexer for the connection of SCADA system.

### 6.3.1 Overall fibre optic system

The Fibre Optic Equipment to be supplied under the Contract shall be used in conjunction with the existing power line carrier system. Any equipment or device required to ensure compatibility with the existing systems shall be supplied. Since the implementation of the communication program will be in stages, the Bidder shall propose fibre Optic Equipment, which permits systematic and orderly expansion in the future. The Fibre Optic Equipment shall be furnished completely wired for the required channel capacity.

The new fibre optic network shall be based on SDH (STM-1). The system will have a transmission capacity of at least 155 Mbit/s.

### 6.3.2 System Requirements

The offered equipment shall be in compliance with all facilities existing and or provided by others and their capabilities, also future demands beyond the actual capacity shall be considered within the scope of this project.

It is required that the Bidder submits, together with the technical description of the equipment proposals for:

- expansion/conversion of transmission equipment for higher multiplexer levels and combined use for public services on telephone and facsimile
- attenuation plan based on actually offered fibre optic cables
- incorporation of the supplied equipment into the existing telecommunication network.

#### 6.3.2.1 System Performance

Overall mean equivalent bit error rate (BER) of the fibre optic telecommunication system between any two end terminals shall not be worse than  $10^{-9}$  under normal operating conditions. The typical error rate for each traffic path shall be stated. System performance monitoring shall be in accordance with the requirements of ITU Recommendations G 826. The automatic switch-over to standby transmitter criterion shall be  $BER > 10^{-9}$ . Switching shall also be possible manually for maintenance. The switch-over reaction time shall be less than 10 milliseconds. The fibre optic telecommunication system shall include provision for overcoming impairments caused

by transmission delays. The system shall have a transmission delay of not more than 1250  $\mu$ -second at no zero phase condition. The maximum signal transmission time of the fibre optic telecommunication system over any fibre optic links shall not exceed 2 milliseconds. Details of the performance of the proposed fibre optic telecommunication system shall be stated in the Bid.

### **6.3.2.2 System Availability**

The availability of the fibre optic telecommunication system shall be greater than 99.9 per cent. This availability shall be maintained regardless of the number of repeaters. Detailed calculations of the system availability or system reliability with details of the mean time between failures (MTBF) and the mean time to repair (MTTR) for the proposed fibre optic telecommunication system and sub-assemblies shall be included in the Bid. MTTR for equipment shall exclude reporting and travelling time. The bidder shall clearly state at which temperature the given MTBF is calculated. Hot-standby (an east/west) redundant configuration for ensuring minimum down time in case of equipment failure shall be provided. The optical line terminal equipment shall operate with dual transmitter and receiver, with automatic changeover to the opposite transmitter and receiver, should the one link fail, for each direction of transmission. Any failure of the operating transmitter shall produce automatic switch-changeover to the standby transmitter and indication of an alarm.

### **6.3.2.3 System Design Calculation**

The Contractor shall carry out system design calculations for each transmission link to ensure the fibre optic communication system meets the requirements of this Specification. The calculations shall include both a 'worst case' and a 'typical case' design loss calculations, using the respective maximum and average attenuation predicted for each component in the system. The "worst case" shall be designed to determine the worst case dispersion coefficient. Utilising the transmitter central wave length ranges such as 1310 nm and 1550 nm the fibre's dispersion characteristic (and its range of tolerance) shall be considered, and the "worst case" mis-match between the laser and fibre shall be determined with the working condition of path attenuation of at least 36 dB.

The design loss calculation should include the following parameters, but not limited to:

- (a) Transmitter power
- (b) Receiver sensitivity
- (c) System design penalties (dispersion power penalty)
- (d) Margin for age degradation and temperature
- (e) Connector loss
- (f) Maximum installed cable loss

System performance calculations shall include a minimum of 9 dB optical attenuation margin to cater for system degradation with temperature and time. Preliminary system design calculations shall be included in the Bid. Detailed calculations shall be submitted during the detail design stage for the approval of the Employer and the Engineer.

### 6.3.3 Main Equipment Design

The FO Equipments shall be suitable for a transmission capacity of min. 155 Mbit/s.

The optical fibres shall comply with ITU-T G.652.D standard.

The equipment to be provided shall be suitable for use in the HV substations environment, especially the protection and telecontrol interfaces shall be capable of withstanding insulation/EMC/ESD applicable tests required by following standards:

Protection: IEC 60255-4/5/6 (22-1/2/3/4) class 111

IEC 61000

IEC 60834-1

Telecontrol: IEC 60255-4/5/6 class 11/111

IEC 61000

IEC 60870-1/2/3/4

### 6.3.6 Data Communication

The SAS links, communication and signalling functions shall be connected to the multiplexers to be provided in the substations.

Multiplexers shall provide fault information to the Network Management System (NMS). Fault information in this system shall be used for reconfiguration and re-routing of the communication circuit.

The contractor shall be responsible of making all connections between the various items of equipment.

Data from the Substation Automation System (SAS) at the substation shall be coded for the transmission to the SCC either on polling request from the SCC data acquisition. The SCADA system shall make scan requests to the SAS tele-metered by it for the most current status and/or analogue data.

The Contractor shall be responsible for the provision of all signalling transmission equipment for through transmission, to ensure satisfactory operation over the specified transmission media.

The Contractor shall also rearrange existing and/or supply and install new cables at various sites, as necessary, to complete all telecommunication circuits.

All necessary software and programming tools shall be supplied, which are required for configuration and maintenance of the supplied equipment.

### 6.3.7 Fibre optic equipment

#### 6.3.7.1 General

The contractor shall provide all optical fibre cables in the areas of the substations including all required termination equipment as required for the telecommunication functions specified elsewhere in detail. Descriptions of the cables and termination equipment shall be furnished with the bids. As a minimum, the descriptions shall

include all relevant information including the glass manufacturer, fibre grade, optical characteristics, the cable configuration and mechanical Specifications.

All fibre-installed as a part of this contract shall have a minimum life of 30 years from the date of final acceptance.

### **6.3.7.2 Patch cords**

The patch cords will be used for the interconnections of the approach cables with the respective optical terminal equipment. The optical fibre of the patch cords and approach cable shall be fusion spliced and protected in an approved type terminal box. Insertion loss shall not exceed 0.5 dB and return loss shall not be less than 35 dB. The patch cord with optical connectors and flexible corrugated tubes shall be supplied by the “equipment contractor”. The “patch panel side connector” of the patch cord shall be FC/PC. The “equipment side connector” of the patch cord depends on the fibre optic multiplexer.

The patch panel shall be supplied by the OPGW/OFAC supplier.

### **6.3.7.3 Fibre optic terminals**

#### **6.3.7.3.1 General**

The same equipment shall be used as a terminal, for through connections (transit, repeater) and as add-drop multiplexer with integrated optical transmission modules. Conference for voice channels and point –multipoint function for data signals shall be possible. The equipment shall be of fully modular design, based on a single 19” shelf.

Transport facilities shall include optical and electrical STM-1 aggregate interfaces (155Mbit/s), 8 Mbit/s PDH optical interfaces and 2 Mbit/s HDSL interfaces all integratable together in the same 19” subrack.

The platform shall have means to cross-connect, drop and insert VC 12 (with termination), 2 Mbit/s G. 703 unframed signals, 2 Mbit/s G. 704 framed signals and individual 64 kbit/s timeslots. Path protection on VC 12, 2 Mbit/s and 64 kbit/s shall be supported.

For operational networks it shall be suitable for operation in substations with harsh environment with high electromagnetic interference, be highly reliable and provide secure communications for real time signals such as voice, SCADA, teleprotection and status/control signals.

It shall comply with the latest ITU-T standards and be able to be interconnected with telecommunication equipment. Each network element shall be manageable from the NMS at National System Control Center. Each network element shall be manageable from a control centre and there shall be means to supervise external/existing equipment as well.

In order to adapt transmission to higher bit rates, the equipment shall allow the integration into STM-4 or STM 16 networks by adding higher order SDH equipment.

Modules for the following user signals shall be available as plug-in units for the platform:

- analogue subscriber interfaces: subscriber and exchange side
- 4-wire E&M voice interface



- 4 wire partyline telephone system (Voice conference facility shall be integrated in the multiplexer)
  - G. 703, 64 kbit/s data interface
  - Data interface X.24/V.11 (RS.422), Nx64kbit/s data interface
  - Data interface V.36 (RS-449), Nx64kbit/s data interface (V.10)
  - Data interface V.35, Nx64kbit/s data interface
- Data interface V.24/V.28 (RS-232)
- 0.6kbps,1.2kbps,2.4kbps,4.8kbps,9.6kbps,19.2kbps,38.4kbps,48kbps,56k bps
- LAN Interface 10/100 Base T Ethernet with VLAN, L2 Switching and L3 routing Facilities.
  - ISDN U interface
  - Alarm collection interface
  - Teleprotection command interface
  - Optical protection relay interface
  - Binary signal (status and control) interface
  - 2 Mbit/s electrical interface for unframed signals according to ITU-T G. 703 and framed signals according to G. 703/4
  - E1 interface for digital voice trunks and other data applications
  - External equipment connecting RS 232 ports

The equipment shall provide the following aggregate interfaces:

- SDH:  
STM-1 (155 Mbit/s) optical 2 port interface for medium and long distances, with automatic laser shut down.

The equipment shall operate from -48 Volt DC supply. as specified in Chapter 4. The equipment shall be suitable for operation at all times when the ambient temperature in which the cubicle is located at between 0°C and +45°C. Bidders shall clearly detail any methods of ventilation which they will provide to meet this service requirement.

### 6.3.7.3.2 SDH Multiplexer

All digital multiplexers shall be equipped with interfaces for external clock synchronization based on the relevant ITU-T recommendations by a separate signal. Synchronization shall also be possible via an embedded feeder signal. Also The Multiplexer should support the redundant Power Supply interface. Furthermore the multiplexers shall be furnished with an internal clock. The synchronization shall be done by a GPS signal. The SDH multiplexer shall perform all necessary electrical to optical conversions and vice versa. Laser transmitters shall be temperature stabilized and shall for safety reasons, be switched off in the event of fibre rupture. All individual main units shall be equipped with local status and alarm indicators.

The transceiver characteristics shall be as specified below:

Optical wavelength:	1550 nm or 1310 nm
Optical source:	Laser
Optical source life span:	better than 15 years
Optical fibre type:	Single mode comply with ITU-T G.652.D standard
Optical connectors:	Type LC-PC
Jitter performance:	ITU recommendation G. 823 etc.

This interface shall transmit 155Mb/s. It shall be available with 1550 nm laser or 1310 nm laser. The laser shall be switched off if the port is not used. The interface shall be capable of working with a path attenuation of at least 36 db.

### **1+1 Path protection**

The equipment shall provide means to protect VC12, 2 Mbit/s etc. channels. The protection shall be end to end from one interface to the other. It shall switch automatically from the main channel to the standby channel if a path has switched to its standby route because the main route is disturbed this shall be indicated with an alarm. The switching shall be done within the multiplexer without using the Network Management System.

### **1+1 Section protection**

The equipment shall provide means to protect STM-1 (MSP), 8 Mbit/s connections. It shall be possible to use two independent links: one as the main and the other as the standby. The system shall automatically switch to the standby connection and generate an alarm if the main connection is disturbed.

### **Network topology**

It shall be possible to build point to point -, linear-, ring-, T, and meshed networks.

### **Synchronization**

The kit shall be synchronisable with an external clock, with connected 2048 Mbit/s signals and/or with internal oscillator. The synchronization shall be configurable and it shall be possible to distribute the synchronization to other equipment as well. The system shall have means to switch to select the synchronization source as well as means to prevent the system from switching synchronization loops. The equipment shall be capable select the synchronization source by means of the SSM (Synchronization Status Messaging) feature according to ITU-T G. 704 or priority based.

### **Alarms**

Each module shall supervise its functions and shall have an alarm-indication LED on its front. All alarms shall be collected by the SCC. Each node shall be capable to collect up to 50 external alarms.

### **Test loops**

The equipment shall provide means to loop signals on 64 kBits/s level as well as on 2 Mbit/s level. It shall indicate an alarm if a loop is activated. It shall have the possibility to determine the time after which an activated loop is switched back.

### 6.3.7.3.3 Access Multiplexer

The digital multiplexer should be universal, software controlled, and be equipped with various interfaces to connect tributary channels such as voice, protection and data signals to aggregate signals such as 2 Mb/s HDSL lines, G.703, G.704 electrical streams and optical interfaces. It should provide means to drop and insert 64 kB/s signals into 2 MB/s streams and have the possibilities of path-protection on 64 kB/s channels. It shall be suitable for operation in harsh environments with electromagnetic interference and have a high reliability and security. After commissioning at least 30% spare channel capacity shall be available on each transmission section (both for main and backup systems).

For transmission of protection signals the multiplexers shall be equipped with special interfaces ensuring electromagnetic compatibility according to IEC 60255-4: Pulse 1kV (1.2/50 ms) and Isolation 2 kV DC (0.5J/1 min). The protection signals shall be transferred using dedicated fibres or priority channels or bypassing the multiplexing level. In case of detection of transmission failures operation for protection signalling shall be blocked.

All multiplexers shall have interfaces for connection of control, monitoring, protection signalling and utility communication/telephone equipment if necessary. Ethernet access shall provide for local and remote management of the Multiplexer. The equipment offered shall have a proven track record in the power utility field. It shall comply with the latest ITU-T recommendations and be able to be interconnected with other standard telecommunication equipment. As the equipment will carry tele-protection signals for safe operation of transmission lines, signal delay problems associated with digital systems shall be addressed and maintained within acceptable limits under all conditions. All equipment in the network shall be managed from a control centre. The equipment shall be equipped with a ringer generator if 2 Wire subscriber interfaces are used. The following interface modules shall be available:

- 2 wire subscriber interface
- 2 wire exchange interface
- 4-wire E&M interface
- Digital voice trunk interface
- 64 kB/s X.24/X.11 interfac
- 10/100 Base T Ethernet Interface
- V.24/V.28 data interface
- RS 232/V.24 data polling interface (for SCADA)
- V.35 date interface
- ISDN U interface
- Alarm interface
- Teleprotection interface (permissive, blocking and direct tripping)
- Differential protection relay interface
- Binary indication interface
- Analogue measuring interface

The equipment shall have the following aggregate interfaces:

- 2 MB/s G. 703, G.704 interface
- 2 MB/s HDSL interface

#### 6.3.7.3.3.1 Two Wire subscriber interface (FXS & FXO)

The module shall provide several interfaces to connect analogue subscribers to the system with the following functions:

- pulse dialing
- tone dialing (DTMF)
- earth key function
- polarity reversal
- indication of busy lines

The following parameters shall be configurable by software:

- Input voice level                    -5 to + 4 dBr
- Output voice level                    -7.5 to –1 dBr

#### 6.3.7.3.3.2 4-Wire interface (VF interface)

This interface shall provide several voice channels with a bandwidth of 300 Hz. 3.4 kHz and 2 signalling channels (M->E, M'->E") per voice channel. Each interface shall be configurable to operate with or without CAS. With CAS it shall use the a and b bits for the two signalling channels.

The level shall be software adjustable within the following range:

Input:                                    +7.5 .. –16 dBr

Output:                                   +7.0 .. –16 dBr

#### 6.3.7.3.3.3 RS 232 V.24/V.28 data polling interface (for IEC 101 SCADA)

It shall provide one or more full duplex channels between an unlimited numbers of locations using only one 64 kbps time slot. Transmission shall be activated on receipt of an RTS (Ready to Send) signal from DTE equipment. The transmission rate for single channel operation is up to 9.6 kbps.

#### 6.3.7.3.3.4 Tele-protection interface

The interface shall provide up to four independent, bi-directional transfer trip functions over a single time slot. Applicable teleprotection schemes include Direct Transfer Trip, Permissive Overreaching Transfer Trip, Permissive Under-reaching Transfer Trip, Directional Comparison Blocking and Directional Comparison Unblocking. The interface shall allow the user to independently set trip hold timers, input de-bounce timers, pre-trip timers etc., other features shall include channel delay measurement, a sequence of events log, an adjustable alarm timer delay, channel addressing for prevention of wrong trips.

#### System performance

Operate time (back-to-back):        3 ms (solid-state)

Dependability: 99.9%  
 Security:  $1 \times 10^{-22}$

All four functions occupy a single 64 kb time slot

### Operational mode

Full duplex (transmit and receive)

### Programmable functions

Trip hold: 3-256 ms (1 ms increment)  
 Input de-bounce: 100  $\mu$  s  
 Output form: normal/invert  
 Alarm timer (delay): 0-2.5 s (10 ms increment)  
 Pre-trip timer 3-16 ms (1 ms increment)  
 Blocking: Enable/Disable

### Optically isolated inputs

Operating voltage range:  
 48 Vdc 38-60 Vdc  
 125 Vdc 88-150 Vdc  
 250 Vdc 200-280 Vdc

### Solid-state outputs

Maximum continuous output current: 1A  
 Maximum open circuit voltage: 280 Vdc  
 Maximum turn on delay: 100  $\mu$  s

### Optional relay outputs

Maximum continuous output current: 2A (inductive)  
 Maximum open circuit voltage 280Vdc  
 Maximum operate time: 5 ms

#### 6.3.7.3.3.5 10/100 Base T Ethernet Interface

The interface shall provide minimum four numbers of 10/100 Base T Ethernet ports with VLAN, L2 switching and L3 routing facilities.

#### 6.3.7.4 Alarms

As a minimum the equipment should detect at least the following fault conditions:

- Failure of power supply
- Loss of incoming signal
- Loss of frame alignment
- Alarm Indication Signal (AIS) received from the remote equipment at the input of the demultiplexer
- Excessive error rate

### 6.3.7.5 Factory Testing

The factory test shall include following tests:

1. Source output Power Tests
2. Bit Error Rate (BER) Test
3. Electrical Signal Test - signal power and shape
4. Jitter Test - Jitter accommodation and tolerance
5. Current and voltage test
6. Voltage variation tests
7. Remote loop back test
8. All Ones test
9. Alarm verification
10. Switching verification (for multiplexers requiring redundancy)
11. Transmission time delay measurement
12. Noise and cross-talk measurement
13. Clock frequency measurement

## 6.4 PARTYLINE TELEPHONE SYSTEM / HOTLINE TELEPHONE SYSTEM

### 6.4.1 Party Line Telephone Terminal Equipment

#### 6.4.1.1 General

This shall comprise of following functional units which are plug in type modules.

- (i) 4-way bridge amplifier
- (ii) Selective Party Line Telephone with Integrated Decoder

The equipment shall have been constructed on a modular basis with module plugging into 482 mm shelves and shall be mountable within the PLC terminal equipment panels. The equipment shall operate from -48V DC supply used for the PLC equipment.

#### 6.4.1.2 4-Way Bridging Amplifier:

This module shall have been designed to interconnect PLC links on a 4-wire basis and shall have 4 ports for the AF signal connections. Each signal path from the input of one port to the output of another port shall have its individual gain control potentiometer which shall be accessible from the front of the unit and identified by two figures indicating input and output port.

The input and output impedances of the ports shall be 600 ohms +/- 10% and the frequency response over 300 Hz to 5000Hz shall be +/- 1 dB.

The maximum input level shall be + 6 dBm and the maximum output level shall be + 16 dBm. The supply voltage shall be -48V DC.

In Fibre Optic Communication system the function of the 4-way bridging amplifier is integrated into the fibre optic multiplexer.

### 6.4.1.3 Selective Party Line Telephone set with Integrated Decoder

#### **DTMF DECODER:**

Call No: 1...4 Digits (Programmable)  
Inter digit Time: 5 OR 10 Sec. or More

#### **DTMF RECEIVER:**

##### **Frequencies (Q23):**

Low Group: 697, 770, 852, 941 Hz  
High Group: 1209, 1336, 1477, 1633 Hz

##### **Input Level:**

Each tone minimum :  $\geq -27\text{dBm}$   
Each tone maximum :  $\leq +3\text{dBm}$

##### **Tone Duration:**

Must accept :  $\geq 40\text{ms}$   
Must reject :  $\leq 20\text{ms}$

#### **DTMF SENDER**

Summated level :  $-9\text{dBm}$   
Tone burst duration: 50ms

#### **TELEPHONE INTERFACE**

##### **AC-Level:**

Speech Input :  $-3.0\text{dBr}$ ,  $600\Omega$   
Speech output :  $-3.5\text{dBr}$ ,  $600\Omega$   
Echo attenuation :  $> 20\text{dB}$   
Long earth balance attenuation :  $> 55\text{dB}$

##### **Ring Back Tone:**

Level with  $600\Omega$  termination:  $-15\text{dBm}$ ,  $425\text{Hz}$

##### **Ringling:**

Type of ringing : 1/4 sec, 0.5/0.5/0.5/3.5 sec, or continuous  
(Programmable)

**NOTE: Ringling Buzzer volume sufficiently high enough to hear in nosy environment (E.g. Diesel Power Stations) otherwise contact provision for external buzzer must be provided.**

Ring back Time : 15, 30, 60 Sec or unlimited (programmable)

#### **GENERAL SPECIFICATION**

##### **POWER SUPPLY**

Input Voltage: 21.....70Vdc  
Input current :  $\leq 20\text{mA}$

## CONNECTIONS

Telephone connection: RJ12 Plug (3m long) and wall mounting jack

External Buzzer contact: RJ12 Plug (3m long) and wall mounting jack

### 6.4.2 Hot Line Telephone System

The Party Line Telephone System will be gradually replaced by the 2-wire Hotline Telephone System with the implementation of the System Control Center Modernization Project (SCCMP).

The Hotline telephones for all the grid substations and power stations will be provided by the four main PABXs installed at National System Control Center, Laxapana Power Station, Kotmale Power Station and Kotugoda Grid Substation.

The hotline telephone for each station will be extended via digital subscriber lines from the nearest main PABXs of that station.

## 6.5 ADMINISTRATIVE TELEPHONE SYSTEM

### 6.5.1 Private Automatic Telephone Exchange

#### 6.5.1.1 General

A private Automatic Telephone Exchange (PAX) will be required at substations as detailed in the Technical particulars and Guarantees. The PAX will be connected to the power line carrier or to *ADM Multiplexer* so as to provide voice communications between any other substation/generating stations connected to the Sri Lanka HV transmission system. The existing automatic telephone equipment at the Employer's substations is a combined automatic local exchange and a transit exchange which has a closed numbering system that means the same number is dialled from any extension to obtain a given extension.

Any equipment supplied under this Contract must be compatible with the existing automatic telephone equipment.

#### 6.5.1.2 PAX facilities

The PAX shall combine the capabilities of an automatic local exchange and an automatic long distance transit exchange to provide a switched speech communication network with other substations. All calls shall be set up on a fully automatic basis by using a rotary dial or a push button keypad. Connections shall be released when either party clears the call, with busy tone being returned to the party last to clear.

The PAX shall employ at least 5 digit closed numbering scheme.

The Contractor shall be responsible for and take adequate steps to ensure satisfactory speech level and quality under all conditions likely to be encountered on the system. The advent of spurious noise on lines or cable used for communications purposes shall, regardless of the source of noise, not cause disconnection of established calls.

Particular care shall be taken in the design of communication equipment to ensure that calls are not disconnected due to operation of high voltage switchgear.

All telephone instruments supplied under this Contract shall be one piece combined sets of a type approved for use in major public telephone systems, in respect of design, quality and performance.

The system shall fulfil the following requirements:



- (i) Compatibility with the existing systems
- (ii) The PAX shall be able to be connected to the existing telephone network of the CEB through digital trunks.
- (iii) Further expandability with introduction of network groups and other configurations
- (iv) Connection facilities to other transmission links than PLC and for compandors (Radio, cable, optic fibre system).
- (v) Individual call code for each subscriber, max. 5 digits
- (vi) Ring-back signal to the calling subscriber
- (vii) Housing in standard 19" racks
- (viii) Power supply by -48 V DC
- (ix) Required Interfaces

Digital trunk lines with which support both Channel Associated Signaling functionality and Common Channel Signaling functionality to connect other Exchanges.

Digital Line Interface offers 2 wire digital extensions , which support both 1B and 2B modes.

Private 2 –wire exchange interfaces

Analog 2-wire line circuits for standard telephone sets.

2-wire analog public network interfaces. (Central Office Trunks)

- (x) Microprocessor control with easy and flexible programming and reprogramming, solid state switching or cross point or crossbar design
- (xi) Local, long distance and through connection operation
- (xii) Transit calls not limiting internal calls
- (xiii) Dialling both DTMF (Dual Tone Multi Frequency) and Pulse.
- (xiv) Break in facility ( Priority calls) - Some selected extensions shall be able to break into established connection by dialling a predetermined code.
- (xv) The facility to provide short codes for dialling frequently used destinations (Abbreviated numbering).
- (xvi) Call forwarding facility. Calls made for an extension can be automatically rerouted to an alternative destination. It can be an internal number, an operator, an external destination etc.
- (xvii) Hotline facility. The system can be able to establish a connection to a predefined destination number when the handset is lifted. The destination number can be an internal or an external number.

- (xviii) Multi-Party calls facility. This facility should allow more than 2 parties & maximum at least 8 parties to be connected together.
- (xix) Priority Access to Routes and Trunks. This facility allows specific extensions to use reserved trunk routes. A separate route table can be defined in priority extensions.
- (xx) Data connection should be prevented from being interrupted (break-in, listen in or call waiting tone)
- (xxi) Facilities shall be provided for remote configuration and monitoring of the PAX from the National System Control Center via Ethernet access.

### 6.5.1.3 PAX equipment

The PAX equipment shall be housed in insect and vermin proof, free standing metal cabinet.

PAX shall be provided complete with a cubicle mounting Main Distribution Frame (MDF) of crone type connector bars with necessary line isolation links.

#### (i) Existing PAX and PLC equipment

The existing PAX equipment used for communications on the most of Sri Lanka HV transmission lines are made by Siemens – Albis and Phillips.

Equipment conforms to the ITU-T (former CCITT) Recommendations.

#### (ii) New PAX equipment

The new PAX equipment shall conform to the ITU-T (former CCITT) Recommendations, and shall be easily connected to the existing telephone system.

Following equipment shall be provided with PAX,

- Standard 2 wire telephone sets with both pulse and tone dialling facility.
- Digital telephone sets with DTMF dialling including relevant drivers and accessories.

#### 6.5.1.3.1 PAX power supply

The PAX must be capable of operation while the HV transmission lines are closed down. This will require the PAX to be supplied from a battery and battery charger. The battery voltage shall be a nominal -48 V DC and this battery which shall also supply the PLC system is specified in Chapter 6.2.

## 6.6 TELEPROTECTION SYSTEM

### 6.6.1 General

The carrier (*or Fibre Optic*) teleprotection equipment will be used to provide, with maximum security, the rapid, two-way transmission of a trip command between adjacent substations connected by a high voltage transmission(*or OPGW*) line. All line protection relays to be supplied, are specified in Chapter 5. The teleprotection equipment supplied under this contract shall guarantee the smooth operation of the protection scheme specified in Chapter 5. In this case, necessary interfacing equipment such as interposing relays shall also be supplied.

The equipment shall employ full solid state circuitry except for output tripping, alarm and flagging auxiliaries. The teleprotection equipment shall be of modular construction and shall be mounted in the power line carrier panels.

### 6.6.2 Signalling Conditions

Each teleprotection unit shall allow the independent of at least four separate trip signals. They shall comprise of two permissive/blocking commands and two direct tripping commands.

The equipment shall provide full duplex operation on *fibre optic* media or via the single side band power line carrier equipment. The equipment shall include a send and receive channel and shall include a line noise monitoring feature which shall function so as to block the trip signal in the event of excessive line noise.

Under normal operating conditions when there is no trip or permissive relaying command present, a guard frequency tone shall be transmitted. This frequency shall be used for channel supervision. When a trip command is given to the transmitter, this frequency shall undergo a frequency shift resulting in a trip command frequency tone being transmitted with raised output power of the PLC transmitter (modulation boosting *in PLC*).

The trip command from the protection relay is normally a short duration signal. In the event a continuous trip command is sent by the relay, a timer shall be built-in to the panel to disable this signal after a predetermined time.

The Bid shall clearly state the precautions taken in the design of their receivers to safeguard the trip output against the presence of noise in the VF channel.

The offer shall also show that the signal-to-noise ratio for worst case combination of attenuation and noise on the line due to weather conditions and line faults shall be adequate to ensure positive operation of the line protection relaying channel.

The transmission time, dependability and security of trip commands shall comply with Section 19, of IEC 60834-1 (1988) and 60834-2 (1993).

### 6.6.3 Alarms

An alarm shall be issued on failure of guard signal for a continuous period of 2 seconds. However there shall not be any fleeting operational output prior to the alarm conditions being given.

The alarm output shall persist for a minimum period of 100 milliseconds and the operational output shall be prevented until the alarm output condition is removed.

A separate low level alarm shall be given but not prevent operation when the input signal level drops by 6 dB from normal. Bidders shall state the level at which the receiver will cease to function. This level shall be at least 10 dB below normal.

Voltage free contacts shall be provided for remote alarm purposes suitable for operation at voltage of the Substation general Battery Bank.

#### **6.6.4 Test Facilities**

Test points shall be provided on the front surface to enable the maintenance personnel to check equipment under operating conditions. This testing shall in no way disturb the equipment or cause mal-operation of the circuit breaker. Errors committed by maintenance personnel in the use of these test points shall in no way lead to the destruction or damage of the equipment. Proper operation of the equipment shall be indicated by the use of lamps.

A suitable test/normal switch shall be provided with a visual indication to show that the trip output circuitry is disconnected and functional tests can be safely performed on the equipment.

Tripping shall in no way be blocked or limited during tests to maintain full protection of the HV lines.

Loop tests shall be possible from any station without the need of personnel at the opposite station. The test shall be carried out such that a tripping test signal will be transmitted from the testing station and automatically returned via the distant station. The proper operation of the transmission loops shall be indicated by the stepping of counters.

#### **6.6.5 Protection interface**

The input/output interface to the protection equipment shall be by means of relays and the input/output rack wiring shall be carefully segregated from other shelf/panel wiring. The input relays shall be operated by voltage free contacts of the HV protection equipment.

The isolation requirements of the protection interface shall be 2 kV r.m.s.

### **6.7 SCADA SYSTEM EQUIPMENT AND DEVICES**

#### **6.7.1 General Description**

The contractor shall be responsible for the design and supply of all equipment such that the complete functioning with the rest of the SCADA system is guaranteed. This will include manufacture, testing at factory, packing, freight, insurance and delivery to sites, testing at site, commissioning test etc.

All equipment must correctly interface with one another and also with the existing plant.

## 6.7.2 The SCADA System

### 6.7.2.1 Master Station at National System Control Center- Kolonnawa

The Master Station equipment is a Dual Computer System “MicroSCADA”, Windows XP Professional based SCADA System, supplied by M/s ABB Power Automation Ltd., consisting of the following:

- Hardware : HP xw4600 Workstation/160GB\_HDD/2GB RAM/2\*19” LCD Monitors
- Simpack ICP2432 PCI Board to connect INDUCTIC 33/41 RTUs and IEC 60870 – 5 – 101 RTUs/Gateways connect through Voice Frequency FSK via Analogue PLC Equipment
- Control “RocketPort” PCI series multiport serial card for the IEC 60870-5-101 protocol RTUs and to connect Gateways of the automated control systems in Grid Substations and Power Stations.
- Meinberg GPS167PC Receiver.
- ABB NSK5 Modems for each Part System.

The existing Part Systems communicate with the Master Station using INDUCTIC 33/41 and IEC 60870 – 5 – 101 Protocols. (See relevant Drawings in Section 6)

#### (a) Stations with Indactic 33/41 protocol

There are five part systems and multiple stations (RTUs) are connected to each part system. Each station of each part system is connected by a data channel of 200 baud to the Master Station using a frequency above 2 kHz, of the voice channels of the Power Line Carrier equipment.

Frequency Shift Keying (FSK) modems are included in the RTUs and at the Master Station.

#### (b) Stations with IEC 60870-5-101

- There are two part systems and multiple stations (RTUs and Gateways) are connected to each part system. Each station of each part system is connected to master station as follows
  - Data channel of 1200bps baud rates using the bandwidth above 2kHz and 9600bps baud rates using the 0- 4kHz bandwidth through Voice Frequency FSK via PLC Equipment.

- 1200bps and 9600bps baud rates through Direct Digital Link via Fibre Optic Equipment

### 6.7.2.2 Master Station at New System Control Center – Sri Jayewardenepura

The Master Station equipment will be a dual SCADA/EMS server system “e-terra”, based on Windows 8/Linux operating system supplied by M/s. Alstom Grid S.A.S.

The system will consist of

#### Dual SCADA/EMS servers

- Hardware: HP DL 580G7 workstation/500GB-SATA HDD/4 GB RAM.

#### Dual Application Servers

- Hardware: HP DL 580G7 workstation/500GB-SATA HDD/4 GB RAM.

#### Dual FEP Servers

- Hardware: HP DL 580G7 workstation/500GB-SATA HDD/4 GB RAM

#### Dual Terminal Servers

##### (a) Stations with IEC 60870-5-101

RTUs/Gateways with IEC60870-5-101 protocol connect to the Master Station via dual terminal servers and dual FEP servers at the speed of 9600 bps (through Direct Digital link via Fiber Optic Equipment).

##### (b) Stations with IEC 60870-5-104

RTUs/Gateways with IEC60870-5-104 protocol connect to the Master Station directly via dual FEP servers (through Fiber Optic Equipment).

### 6.7.3 Remote Terminal Units (RTU) and SCADA Gateways

#### 6.7.3.1 General

The contractor shall be responsible for the design and supply of all equipment such that the complete functioning with the rest of the SCADA system is guaranteed.

All equipment must correctly interface with one another and also with the existing plant. The provided Remote Terminal Units and the Gateways should have the facility to integrate to the present SCADA Master Station without interfering to the existing system and subsequently to the New SCADA Master station at NSCC with the completion of New System Control Center. The RTU/Gateway also should communicate with the Regional Control Center in future.

#### 6.7.3.2 Components of the System

##### a) Remote Terminal Units

- I Remote Terminal Unit.
- II Interposing relays, (if necessary) for indications as given in signal list.
- III Interposing relays, (if necessary) for commands as given in signal list.
- IV Transducers for analog measurands as given in signal list.

**b) Gateways**

- I. One No. of Gateway unit.
- II. Two Nos. of IEC 101 output ports and two Nos. of IEC 104 output ports with redundancy for the Gateway (One port for System Control Centre and one port for Regional control Centre).

**6.7.3.3 Detailed Specifications of RTU/Gateway****(a) RTU**

The equipment provided shall be of a modular design capable of being readily expanded by adding more input/output modules. The analogue measurands and state indications are fed via Transducers and Interposing relays to the RTUs

The equipment shall be reliable. Input voltage shall be -48V DC (+20% -15%) The RTU shall communicate with remote control centres via IEC60870-5-101 and IEC60870-5-104 .

**(b) Gateway**

The gateway shall be an industrial grade computer with redundant, uninterruptable power supply units.. PC based gateways which contains moving parts will not be accepted. The gateway should be designed for a life of 20 years. The gateway shall communicate with remote control centres via IEC60870-5-101 and IEC60870-5-104 .

**General specification**

The RTU/Gateway Shall Communicate with MicroSCADA” Windows XP based SCADA System at present and it should capable to connect Windows 7, Linux and Windows 8 based SCADA Systems for the Future requirement.

The following inputs/outputs should be available:

**Digital input**

- Single indications
- Double indications
- Binary Coded Decimal or parallel inputs
- Pulse accumulator or counter input
- 1 ms resolution of events, accuracy: +/- 1 ms
- Debouncing filters
- DC input voltage: 24..220V

**Analogue input**

- Unipolar and bipolar measurements
- Current input: 4 to 20 mA

- Resolution: 12 bits
- Accuracy: +/- 0.05%

### Command outputs

- Single commands
- Double commands
- Set point commands
- Select (check) before execute commands

#### 6.7.3.3.1 Communication:

Communication protocol of RTU/Gateway with the Master station will be IEC 60870-5-101 and IEC 60870 – 5 – 104.

RTU/Gateway shall be able to communicate over the following available transmission media:

-(a) for IEC 60870 – 5 – 101

1. Voice Frequency FSK via Analogue PLC Equipment.
2. Direct Digital Link via Digital PLC Equipment.
3. Direct Digital Link via Fibre Optic Equipment

The interface should be RS232.

Baud rate and other RS232 related parameters should be configurable.

Possible baud rates shall include 1.2kbps and 9.6kbps.

(b) for IEC 60870 – 5 – 104

Direct Digital Link via Ethernet Data Interface of Fibre Optic Equipment

#### 6.7.3.3.2 Communication Ports:

- 02 Nos. of RS 232 ( V.24) serial ports with redundancy ( i.e. Minimum 04 Nos. ports).
- 02 Nos. of 10/100 Mbps Ethernet (electrical) ports with redundancy (i.e. minimum 04 Nos. ports).

( for communication of SCADA to System Control Centre and Regional Control Centre).

All the ports shall be surge protected.

#### 6.7.3.3.3 Mechanical Details of Equipment

The equipment listed under clause 6.7.3.3(a), items I, II, III & IV and 6.7.3.3 (b), items I & II shall be housed in enclosed cabinets, which are insect and vermin proof. All external



cables shall pass through a cable gland plate, at base of cabinet. Each cable shall have a separate gland mounted on this plate.

All modules shall be identified as to their location and function, and shall employ coded key slots, or similar means, so that, modules cannot be plugged in the wrong position.

#### 6.7.3.3.4 Alarms and Indications

Alarms and indications shall be installed on all relevant equipment. The major alarms shall be so wired that they are visible with the cabinet door closed. Voltage free contacts shall be provided to relay these indications to a remote point. The contractor shall provide a list of alarms available, with the offer.

#### 6.7.3.4 Schedule of Tests at Works

- ii. Construction check
- iii. High voltage test
- iv. Insulation resistance measurement
- v. Temperature rise test (Certification of type test may be accepted)
- vi. Power consumption measurement
- vii. Operation tests (both Simulation and actual operation)
- viii. Redundancy Verification Tests
- ix. Others

#### 6.7.3.5 Environmental

Operating temperature 0 .. +55 °C

Relative humidity 5.....95 (non-condensing) according to DIN 40040 Class F

#### 6.7.3.6 External Wiring

All control and instrument panel will be wired with cable having flame retardant insulation and outer sheaths.

The wiring of all indications and controls will be done using multi-stranded, 1.5 mm<sup>2</sup> copper. However for Current Transformer Secondary wiring side, since transducers will have to be wired in series, the wiring will be of 2.5 mm<sup>2</sup> or 4.0 mm<sup>2</sup> copper (where the distances are long) in order to reduce burden.

The multi-core cables supplied shall be made up of fine strands of plain copper wire with PVC based insulation and an outer sheath of PVC. Any filler used to make a circular compact cable shall be non-hygroscopic.

The armoured cable shall be similar in construction, but with a galvanized wire armour and an outer PVC sheath.

The nominal operating voltage of cables shall be 300 V between core and earth 500 V between cores. This rating shall be stamped on the outer sheath of cable.

The cores of control cables shall be identified by means of numerals printed at regular intervals throughout the length of the core.

Armoured cable will be used between marshalling kiosk and outdoor equipment.

All control and power cables shall include a green/yellow protective core in addition to the specified number of cores.

All material required for installation work such as, cable glands, numbering systems, cable ties, terminals etc. should be provided with 10% extra.

## 6.8 COMPUTER WAN CONNECTIVITY

Separate LAN networks are to be established within CEB communication network as follows

IEC 104 SCADA Network for National System Control Center.

Management Information System Network (administrative application) for Information Technology Branch,

Digital Disturbance Recorder network for Protection Development Branch,

Network connecting each grid substation for Protection Maintenance Branch.

Network connecting each grid substation to a Regional Control Center (Four regional control centers are to be established) for Operation and Maintenance branch. CCTV camera information is required to be transmitted over this.

Network for transmitting energy meter readings of each grid substation to a centralized location for Energy Marketing Branch.

For IEC 104 SCADA network, a separate interface with minimum 4 Nos. Ethernet ports (10/100 Base T) shall be provided. All the above networks shall work independently. A user of one network shall not be able to access another network. For all other IT requirements an interface with minimum five Nos. Ethernet ports (100/1000 base T) with VLAN and L2 switching facilities shall be available in the Multiplexer.

## 6.9 SCHEDULE OF TEST AT WORKS

The following minimum tests shall be carried out at the contractor's plant in the presence of the Engineer and the Employer. The tests shall comply with this Specification and approved documents by the Engineer.

- (a) PLC equipment
  1. Inspection of construction
  2. High voltage test
  3. Measurement of insulation resistance
  4. Carrier frequency characteristics test
  5. Measurement of output level
  6. Audio frequency characteristics test

7. Impedance characteristics test
  8. A.G.C. characteristics test
  9. Measurement of equipment noise
  10. Measurement of distortion factor
  11. Ringer characteristics test
  12. Power consumption test
  13. Temperature characteristics test
- (b) PAX
1. Construction and Dimension check
  2. Operation check
- (c) PLTS
1. Construction and Dimension check
  2. Operation check
- (d) Signalling and Tele-protection equipment
- 1 Construction and Dimension check
  - 2 Impedance characteristics
  - 3 Frequency stability
  - 4 Measurement of output level
  - 5 Operation test
- (e) Line Traps
- 1 Mechanical inspection
  - 2 Impedance/Frequency characteristics
  - 3 Tapping loss
  - 4 Impulse withstand voltage test of main and tuning device without protective device
  - 5 AC spark over voltage of lightning arrestor
  - 6 Impulse spark over voltage of lightning arrestor
  - 7 Temperature rise test (Certificate of type test may be accepted)
- Data of type test shall be submitted with the test report.
- (f) Coaxial Cable and Cord
- 1 Insulation resistance measurement
  - 2 High voltage test
  - 3 Measurement of conductor resistance
  - 4 Measurement of attenuation loss

- 5 Impedance characteristics test
- (g) Coupling Devices
- 1 Construction and dimension check
  - 2 High voltage test
  - 3 Impulse voltage test (certificate of type test may be accepted)
  - 4 Temperature rise test ((certificate of type test may be accepted)
  - 5 Measurement of attenuation loss
- (h) SCADA System and RTU/Gateway
- 1 Construction check
  - 2 High voltage test
  - 3 Insulation resistance measurement
  - 4 Temperature rise test (Certification of type test may be accepted)
  - 5 Power consumption measurement
  - 6 Operation tests (both Simulation and actual operation )
  - 7 Redundancy Verification Tests
  - 8 Interoperability list for the RTU/Gateway shall be submitted with the test reports

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**CHAPTER 7 - EARTHING SYSTEMS, ELECTRODES AND CONNECTIONS**

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## **CHAPTER 7 - EARTHING SYSTEMS, ELECTRODES AND CONNECTIONS**

### **7.1 GENERAL**

The earthing of all equipment and the provision of earthing systems, electrodes and connections shall be in accordance with the recommendations in the “Guide for safety in Substation Grounding” IEEE No. 80 and the requirements of this Chapter.

Steelworks and supporting structures shall be bonded and earthed to the substation earthing system. Earth connections shall be made approximately 250 mm above the top of the finished foundation level. Connections shall be made also to the earth terminals of operating mechanisms, control cubicles and marshalling kiosks.

Except where the earth connection is bonded to the steelwork, insulated clamps shall be provided for supporting the earthing connection to high level equipment and the earth screen.

There shall be an extension of the earth bar system into the substation buildings for connecting to indoor switchgear, control, relay and ancillary equipment.

All necessary studs, connectors and earth bars shall be provided to permit the connection of each switchboard, motor or other electrical equipment supplies under the Contract to the substation general earthing system. The provision for earthing shall be such that no reliance is to be placed on the conductivity of metal to metal joints without the use of special connectors however lightning arresters must be directly connected to the earthing grid.

All external connections line (i.e. PSTN line, etc.) should be connect via a surge protective device.

### **7.2 EXTENT OF WORK**

The Contract includes the Complete design of the substation earthing system including, connections of Plant supplied under this Contract to the main earthing system and all Site Tests as specified in this specification.

The main earth system shall be installed prior to the construction of the building, transformer and equipment foundations.

The Contractor will be required to prepare installation drawings and schedules of material to be provided. These drawings and schedules shall be submitted to the Engineer for approval together with calculations of step, touch and mesh potentials.

The contractor shall connect the new earthing grid to the existing earthing grids. The Engineer shall approve the position at which the connections are made and the number of connections.

### **7.3 DESIGN OF EARTHING SYSTEMS**

The grounding system shall be designed according to the guidelines given in the latest IEEE Standard 80.

The site shall be provided with earth grid of buried conductors designed for an earth fault current specified in chapter 1 for duration of 1 second, keeping the step and touch voltages within the limits as recommended in the guide IEEE std. 80.

The design of earth grid over the area occupied by out door switchgear and associated apparatus shall be based on a maximum grid spacing of 10m x 5m.

The Contractor shall carry out Site tests of the ground resistivity not later than one month after the award of the Contract and his final design of the earthing system shall be submitted and approved prior to foundation excavation works.

Earthing points shall be provided by the Contractor such that the combined resistance of the earth grid and earthing points does not exceed 1 ohm, however combined resistance shall be considered for acceptance provided that the conditions recommended above are satisfied. It is the Contractor's responsibility to provide design calculations.

Basically, the earthing system in the substations shall consist of:

- earthing mesh underneath the building
- foundation earth of the building
- earthing ring around the building
- buried earthing mesh in the open yard area of the substation.

For controlling the potential and for protection against excessive contact-potentials, for the earthing ring around the building, the copper cable must be laid at a distance of 1 m and a depth of 0.6 m around the switchgear building and be connected to the grid earth conductors.

Inside the substation, bare copper strips must be installed on the walls. From the inner earthing ring the connections to the switchgear, cable trays, vertical cable runs, steelwork, etc. are to be made using bare stranded copper conductor. All the electrical equipment, frames and mechanical apparatus must be fitted with earthing screws and studs.

The copper conductors can be laid and fixed on the cable trays and vertical runs for AC power cables. Where this is not possible, earthing conductor supports are to be provided.

All concrete reinforcement bars should be connected to the earthing system electrically by welding or compression connectors.

The spacing of the earthing mesh in the outer substation area will be determined by means of earthing calculation. The maximum spacing shall, however, not exceed the 5mx10m.

The inside earthing ring of the building has to be connected at every 20m with the outdoor earthing system.

The lighting columns of the external lighting system are to be connected with separate lead-coated copper conductors to the outdoor earthing grid.

Earthing rods will be provided as necessary in order not to exceed the required combined earthing resistance. The final design of the earthing system will be based on the earthing system measurements to be carried out after award of contract.

The star points on the HV side of the transformers must be connected to the central earthing installation where they are earthed directly. The frames of the electric apparatus and the lightning installations have to be connected to the earthing system.

## 7.4 CONSTRUCTION OF EARTH GRIDS

The earth grids shall be of hard drawn high conductivity copper conductor, and shall be installed at a depth of 600 mm below the ground level. After the construction of footings and foundations the area shall be backfilled.

Connections for the transformer neutrals shall be provided.

## 7.5 EARTHING POINTS

The number of earthing points shall be verified by Site earth resistivity tests after the letting of the Contract.

Earthing points:

Each will consist of at least 15mm diameter copper rod electrodes, driven into undisturbed soil. Each electrode will be complete with approved non-ferrous clamps for the connection of earthing conductors and with a hardened steel tip and cap driving by means of a power hammer.

Test link chambers and covers for each earthing point are to be provided and the Contractor for the approval of the Engineer shall submit a drawing showing the proposed arrangement.

## 7.6 CONNECTIONS OF EARTHING POINTS AND SYSTEM NEUTRALS

The electrodes of an earthing point shall be connected to the test link and there shall be duplicate conductors from each test link to the earth grid.

Any neutral points for high voltage systems within the substation will have duplicate connections to earth grid.

Conductors interconnecting the electrodes to a test link and between the test links and the earth grid will have a cross-sectional area of not less than 150 sq. mm. There will be at least two connections from each steel support etc. to the earth grid. Duplicate connections may be in the form of rings.

Earthing conductors will be of soft annealed high conductivity copper stranded in accordance with Table 4 in BS.6346. Earthing conductors will normally be buried directly in the ground but where necessary they may be cleated to walls, fixed to cable racks or laid in the cable trenches as convenient.

## 7.7 EARTHING OF EQUIPMENT

The frames of all electrical apparatus and the bases of all structural steelwork shall be connected by branches running to a group of equipment. All isolator bases, earth terminals and earthing switches, neutral current transformers shall be connected to the earth grid. An earth electrode, which may be part of the grid, shall be provided as near as practicable to each set of surge arresters.

The connections to the steel structures from main earth mat shall be of soft annealed copper conductors. If the connections to the steel structures are bolted, the maximum allowable temperature of the conductors shall be consider as 250°C.

Earthing of 12 kV/36 kV switchgear room shall be properly performed with copper strip, which enable connection to the equipment installed in and linked to main grid with more than two wires.



## 7.8 JOINTING AND BONDING

Connections to plant and equipment shall be made using the earthing terminals specified in the Contract. Where a strip has to be drilled to fit an earth terminal the hole shall not be greater than half the width of the strip.

Joints in earthing strip shall employ chemical welding or high compression joints or clamps.

## 7.9 AFTER INSTALLATION TESTING FOR EARTHING SYSTEM

### 7.9.1 General Requirements

The purpose of earthing system testing is to verify the earthing system. Following purposes shall be served by the testing;

- Earthing system operates according to the design.
- Structures and equipment, are bonded together and to the earth grid with a sufficiently low series impedance.
- Hazardous step, touch and transfer voltages do not exist within and outside the substation during fault conditions.
- To check whether, sufficient number of earthing points provided to eliminate the build-up of any static or induced voltages.
- To identify any problems and rectify.

### 7.9.2 Electrical Continuity Test

A high current ( $\geq 1$  Amp) DC continuity test and visual inspection shall be carried out to verify all equipment and exposed metal work within the substation is appropriately bonded to the earth grid.

Following must be considered as part of this process;

- A high current DC continuity test must be injected by means of a four (4) wire micro-ohmmeter, with reference to a central reference point in the substation.
- The earth connections must be visually inspected to verify the connection is in good condition.
- The inspection must check that the minimum number of earth connections are present.
- The substation fence must be inspected for earth integrity of bonds and tested for continuity. Where the fence/boundary wall is known to be intentionally isolated from the earth grid the test must confirm this isolation.

All joints installed above ground and inside ground will have continuity readings to a common source (the neutral point of the solidly earthed power transformer) as follows.

- DC resistance not exceeding  $5 \text{ m}\Omega$  for assets that could become directly or indirectly energised will be required.
- For substations with overhead HV supply, DC continuity of the fence earth terminations must be below  $5 \text{ m}\Omega$ . For substations connected with all underground HV supply, DC continuity readings for fence earth terminations below  $20 \text{ m}\Omega$  are acceptable.
- Joints for non-fault current carrying conductors shall have DC resistance not exceeding  $20 \text{ m}\Omega$ .

Continuity readings shall be recorded in the test report.

### 7.9.3 Grid Resistance Measurement

Ground grid resistance shall be measured using fall-of-potential method specified in IEEE 81-2012 standard. The current probe is generally placed at distance at least five (5) times (preferably greater than ten (10) times) the largest diameter of the earthing system.

The ground grid resistance shall be less than one ohm ( $1\Omega$ ).

### 7.9.4. Step and Touch Voltage Measurement

A substation ground grid is designed to limit step and touch voltages on and around the yard within the tolerable limits. The step and touch potential shall be verified by the measurements.

Measurement of touch voltages shall include structure touch voltage, mesh touch voltage, fence touch voltage, gate touch voltage, station transferred touch voltage and remote transferred touch voltage.

To inject the test current, the current probe is generally placed at a distance at least five (5) times (preferably greater than ten (10) times) the largest diameter of the earthing system. Test procedure specified in IEEE 81 shall be followed.

The measured touch and step voltages shall be compared with the tolerable voltages as defined by IEEE 80 standard. If required ground grid improvements shall be proposed to improve the step and touch voltage.

### 7.9.5. Current Split Measurement

Split Factor value in design calculation shall be validate by the current split measurements.

The testing shall be carried out considering the guide in IEEE 81-2012 standard.

## CHAPTER 8 - POWER AND CONTROL CABLES

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## **CHAPTER 8 - POWER AND CONTROL CABLES**

### **8.1 GENERAL**

This Chapter of the Specification applies to single core and multi-core dielectric insulated power cables and control cables. Polyvinyl Chloride (PVC) insulated cables shall generally be supplied for conductor cross-sections smaller or equal to 16 mm<sup>2</sup>. Cross-linked polyethylene (XLPE) cables shall be generally supplied for larger cross-section than 16 mm<sup>2</sup>.

### **8.2 L.V. 1000V DIELECTRIC POWER CABLES**

#### **8.2.1 Conductors**

Conductors smaller to 2.5 mm<sup>2</sup> shall consist of solid annealed copper. They shall comply with IEC 60228, 60229, 60287 and 60811. Non-circular stranded conductors shall be pre-spiralled and compacted. Conductors of cross-section area equal or larger than 2.5mm<sup>2</sup> shall be of stranded copper.

#### **8.2.2 Insulation**

Insulation shall be in accordance with IEC 60502 Clause 4.

#### **8.2.3 Laying-Up**

Laying-up of multi-core cables shall be in accordance with BS 5467 Clause 9.

#### **8.2.4 Fillers**

Where fillers are necessary to make a circular compact cable, for PVC insulated cable they shall be of PVC, for XLPE cable they shall be of PVC or cross-linked polyethylene. Textile and other hygroscopic materials are not permitted.

#### **8.2.5 Core Identification**

The cores shall be colour identified in accordance with IEC 60227-1.

#### **8.2.6 Voltage Identification**

The PVC outer sheath shall be embossed 'ELECTRIC CABLES' followed by the voltage, in accordance with Clause 15.2 of BS. 5467.

#### **8.2.7 Screening**

Copper screens shall comply to Clause 8 of the IEC 60502-1 .

#### **8.2.8 Armour**

Armour bedding on multi-core cables shall comply with IEC 60502-1 Clause 12 and steel wire armour with Clause 11.

#### **8.2.9 Oversheath**

PVC outer covering type 9 shall be in accordance with IEC 60502 Clause 12.

### 8.2.10 Jointing

Jointing of LV cable is not permitted.

### 8.2.11 Sealing and Drumming

Immediately after the cable laying and testing, both end of the cable shall be sealed against the ingress of moisture, dirt and insects. The end projecting from the drum shall be similarly sealed and adequately protected against mechanical damage during handling.

### 8.2.12 Jointing Accessories

Jointing accessories for stranded copper conductor cables shall be designed for indentation ferrules. Solid aluminium conductors may be jointed with soldered ferrule. Conductor temperature during the soldering process shall be carefully monitored as not to exceed the maximum insulation temperature stated in the Technical particulars and Guarantees.

## 8.3 PVC INSULATED CONTROL CABLES

### 8.3.1 Scope

This part of the Chapter is for control cables with stranded copper conductors, PVC insulated, shielded if required and PVC sheathed overall. The cable design shall generally be in accordance with IEC 60228 & IEC 60287.

### 8.3.2 Conductors

Conductors shall be of plain copper and have a cross sectional area of 2.5 mm<sup>2</sup> made up of 50/0.25mm strands or 4mm<sup>2</sup> made up of 56/0.30mm strands. Copper conductors shall meet the requirements of IEC 60028.

### 8.3.3 Laying Up

Multi-core control cables shall contain one of the following standard numbers of cores - 4, 7, 12, 27, 37 & 48. For control cables having more than seven cores, the direction of lay shall alternate for each successive layer. A PTP binder tape 0.013mm thick applied over the laid up cores may be used at the discretion of the manufacturer.

### 8.3.4 Fillers

Where fillers are necessary to make circular compact PVC insulated cable, they shall be of PVC. Textile and other hygroscopic materials are not permitted.

### 8.3.5 Core Identification

The cores of control cables shall be identified in accordance with IEC 60227-1. When numerals are used, they shall be printed in black on the white core insulation at intervals not greater than 75mm throughout the length of the core. The print shall be permanent and not easily removed.

### 8.3.6 Voltage Identification

The PVC outer sheath of control cables shall be embossed with the legend "ELECTRIC LV CONTROL CABLE". The letter shall be raised and consist of upright block characters in accordance with the requirements of BS 6346.

### 8.3.7 Jointing Accessories

Details of the jointing method shall be given by the Contractor with the jointing accessory designs.

Jointing of control cables is normally not permitted but in exceptional circumstances may be allowed subject to the Engineer's approval.

In these cases stranded copper conductors may be jointed together by crimped type ferrules and the single wires to be insulated by heat shrinkable tubes, which shall also be applied as an overall sheath for the jointed cable.

### 8.3.8 Armour

Armour bedding on multi-core cables shall comply with IEC 60502 Clause 6.6 and steel wire armour with Clause 11.

### 8.3.9 Oversheath

PVC outer covering shall be in accordance with IEC 60502.

## 8.4 POLYETHYLENE INSULATED TELEPHONE TYPE CABLES

### 8.4.1 Design

Telephone type multipair underground type and catenary type cables shall be of the filled type and shall have plain copper conductors insulated with polyethylene, armoured (underground type) and shall be sheathed overall with PVC. They shall be suitable for internal and external use in a tropical climate. Catenary type cables shall be suitable for an induced voltage up to 15kV.

### 8.4.2 Conductors

Each conductor shall consist of a single annealed copper wire, to IEC 60228 in so far as applicable for plain annealed copper wires and shall have a standard diameter of.

Underground type cable - 0.9mm

Catenary type cable - 1.38mm

The DC resistance per km of each conductor in the finished cable at 20<sup>0</sup> C shall not exceed 29.67 ohms and 13.61 ohms respectively.

### 8.4.3 Insulation

The conductor insulation shall be of extruded polyethylene type 03 in accordance with IEC 60881-4. The radial thickness of insulation shall be:

0.80mm +/- 0.14 for both catenary type cables.

The insulation thickness shall be determined in accordance with Clause 18 of BS 6346.

### 8.4.4 Identification of Cores

The cable shall be made with twin twisted pairs. Cores shall be clearly colour identified as per attached Table 1.

#### **8.4.5 Twinning and Laying Up**

The insulated conductors shall be uniformly twisted together in pairs with a right hand lay. The length of lay shall not exceed 150mm and the lays of pairs which are adjacent within the finished cable shall differ in length and shall be so chosen that cross talk is as small as possible. In the case of two pair cables, the cores shall be laid in quad formation.

#### **8.4.6 Fillers**

Where Fillers are necessary for the satisfactory laying up of the cable pairs, they shall be of Polyethylene. Textile fillers are prohibited.

#### **8.4.7 Binders**

A polyethylene terephthalate (PTP) tape having a thickness of not less than 0.013mm shall be applied as an open helix over the centre cores if more than one pair and over each successive layer except the out layer over which the tape shall be applied with a 50 per cent overlap.

#### **8.4.8 Bedding**

Cables shall be provided with a bedding of extruded polyethylene type 03C in accordance with BS 6234. The armour bedding of underground type cables shall have a radial thickness in accordance with Table 2. The bedding thickness of catenary type cables shall be 1.8mm.

#### **8.4.9 Armour (Underground Type Cables Only)**

The armour shall consist of one layer of galvanised steel or aluminium wires complying with the requirements of BS EN 10257 Part 1 and BS 2627 (condition H68) where appropriate. The size of armour wires shall be in accordance with Table 2.

#### **8.4.10 Screening (Catenary Type Cables Only)**

A screen consisting of a helical lapping of aluminium tape, which shall be, electrically continuous, shall be applied with a thirty percent overlap over the polyethylene bedding. The aluminium tape shall be 0.08mm thick and for cables of five pairs or more, of a width not exceeding the diameter of the laid up pairs plus 6mm tolerance. Alternatively, two tapes each applied with a gap not exceeding 3mm and breaking joint, or a polyethylene/aluminium laminate tape applied longitudinally may be used.

#### **8.4.11 Oversheath (Underground Type Cables Only)**

The outer protective covering shall consist of an extruded PVC compound shall be type TM 1 and coloured black in accordance with BS 6746. The sheath radial thickness shall comply with Table 2 and shall be determined in accordance with Clause 19 of BS 6346.

#### **8.4.12 Integral Suspension String (Catenary Type Cables Only)**

Catenary type cables shall incorporate an integral suspension strand which shall be of galvanised wire to BS 183 (Grade 1150), 7./1.25mm for cables with a diameter not exceeding 20mm and 7/1.60mm for cables having a greater diameter. The oversheath shall be PVC type TM1, coloured over the cable cores and the suspension wire to form



a dumbbell cross section with a suitable dimensioned web for each size of cable. Dimensions to be supplied in Technical Particulars and Guarantees.

#### 8.4.13 Identification of Manufacturer

The PVC oversheath shall be embossed with the name of the manufacturer and year of manufacture followed by

ELECTRIC CABLE - TELE

Embossing shall comply with Clause 14.2 of BS 5346.

#### 8.4.14 Cable Lengths

The cables shall be supplied in drum lengths of not less than 500m unless shorter lengths are specified or are required to complete a specific order.

#### 8.4.15 Jointing and Terminating Accessories

Straight through jointing accessories for telephone type control cables shall be designed or the accommodation of crimped ferrules.

Straight through jointing of short cable lengths is normally not permitted but, in exceptional circumstances, may be allowed subject to the Engineer's approval.

### 8.5 TABLES

#### 8.5.1 Telephone Type Cables – Colour Code

2 pair (quad) cables - Blue, Orange, Green, Brown (on order of rotation)

1	-	Black/Blue	26	White /Yellow
2	-	Black/Orange	27	White /Violet
3	-	Black/Green	28	Blue/ Red
4	-	Black/Brown	29	Blue /Yellow
5	-	Black/Gray	30	Blue /Violet
6	-	Blue/White	31	Green /Red
7	-	Blue/Orange	32	Green/Yellow
8	-	Blue/ Green	33	Green/ Violet
9	-	Blue/ Brown	34	Red/ Gray
10	-	Blue/ Gray	35	Red/Orange
11	-	Orange/ White	36	Red /Yellow
12	-	Orange/ Green	37	Red/ Brown
13	-	Orange/ Brown	38	Red/ Violet
14	-	Orange/ Gray	39	Gray /Yellow
15	-	Green/ White	40	Gray /Violet
16	-	Green/ Brown	41	Orange/Yellow
17	-	Green /Gray	42	Orange/Violet
18	-	Brown /White	43	Yellow /Brown

19	-	Brown /Gray	44	Yellow /Violet
20	-	Gray /White	45	Brown/Violet
21	-	Black /White	46	Turquoise/Black
22	-	Black/ Red	47	Turquoise /Blue
23	-	Black/ Yellow	48	Turquoise /Red
24	-	Black/ Violet	49	Turquoise/Orange
25	-	White/Red	50	Turquoise /Yellow

75 pair cables - Pairs 1 to 50 plus 1 to 25 inclusive.

100 pair cables - Pairs 1 to 50 plus 1 to 50 inclusive.

Information Copy - Not for Bidding

### 8.5.2 Telephone Type Cables

Number of Pairs	*Thickness of Armour Bedding mm	Size of Armour Wires mm	Thickness of Outer PVC Sheath mm
2	0.8	0.9	1.3
5	1.0	0.9	1.4
10	1.1	1.25	1.5
15	1.2	1.25	1.6
20	1.2	1.25	1.6
25	1.3	1.6	1.7
30	1.4	1.6	1.7
40	1.4	1.6	2.8
50	1.6	1.6	1.9
75	1.7	2.0	2.0
100	1.9	2.0	2.2

\* minimum average value

### 8.6 12 KV AND 36 KV POWER CABLES AND TERMINATIONS

#### 8.6.1 General requirements

(a) 36 kV power cables are required as follows:

Single core XLPE insulated copper conductor cables shall be rated for 800A for connection between transformer secondary terminals and 36 kV switchgear (if specified in Scope of Work) and 400A for connection between 36kV switchgear and 33 kV overhead line gantry.

(b) 12 kV power cables are required as follows:

Single core XLPE insulated copper conductor cables (3 in parallel) shall be rated for 2400A in total for connection between transformer secondary terminals and 12 kV switchgear.

The current capacity shall be for the following operating conditions:

- Ground temperature at 1 m depth of cover 25<sup>0</sup> C
- Maximum conductor temperature XLPE 90<sup>0</sup> C
- Maximum conductor temperature XLPE 250<sup>0</sup> C  
(Short circuit)
- Average Thermal resistivity of soil 1.20 Km/W

### 8.6.1.1 Construction of cross-linked polyethylene insulated cables

The technical requirements of the XLPE Insulated underground cables shall be in accordance with the following.

#### Design

The cable shall be designed to a maximum operating temperature of 90°C and a maximum short circuit temperature of 250 °C.

#### Conductor

Conductor shall be Circular Compacted Plain Annealed Copper Conductors of Class 2 as per BS EN / IEC 60228. Resistance of each conductor should be as per as per BS EN / IEC 60228.

#### Conductor Screen

Conductor screen shall be extruded Semi-conducting Compound type. The extruded layer shall be continuous and shall cover the surface of the conductor completely. The Conductor Screen shall be applied in the same operation as the insulation and shall be fully bonded to the insulation. Volume resistivity Shall not exceed 500 Ω.m at 90 °C when measured in accordance with Annex J of BS 6622:2007 or Annex D of IEC 60502-2:2014 as applicable.

#### Insulation

Insulation shall be XLPE and shall be applied by extrusion and cross-linked to form a compact and homogeneous layer in accordance with the standards specified. Nominal thickness of the cables shall be as per BS 6622:2007 or IEC 60502-2:2014 as applicable.

#### Insulation Screen

Insulation screen shall be non-metallic semi-conducting layer having a resistivity not exceeding 500 Ω.m at 90 °C, in combination with metallic layer. The extruded layer shall be continuous and shall cover the surface of the insulation completely. The insulation screen shall be cold strippable. Thickness shall be in accordance with BS 6622:2007 or IEC 60502-2:2014 standards.

The conductor screen, the insulation and the non-metallic insulation screen shall be extruded simultaneously in a single-head triple extrusion process, ensuring cold strippable feature for insulation screen.

#### Metallic Screen

Metallic screen shall be Copper Wire or Tape Screen. If Copper Wire screen is offered, such wires shall be in contact with each other. The cross-sectional area of the metallic screen shall be able to withstand maximum earth fault current over the full duration specified. Manufacturer shall prove the fault current withstand capability with calculations.

#### Separation Sheath

Metallic screen and the armour shall be separated by an extruded sheath. Extruded separation sheath shall be comprising material conforming to BS 6622:2007 or IEC 60502-2:2014 standards.

## **Metallic Armour**

Metallic armour shall be Aluminum alloy and shall consist of round wires. Metallic armour shall have a non-hygroscopic inner covering conforming to BS 6622:2007 or IEC 60502-2:2014 standards as applicable. The nominal diameter of the armour wires shall be in accordance with BS 6622:2007 or IEC 60502-2:2014 standards as applicable.

## **Longitudinal Water Barrier**

Water barrier swelling tape over conductor, over insulation screen, over metallic screen and over armour shall be provided to protect against longitudinal water penetration.

## **Oversheath**

Oversheath shall be PVC-ST2 as per IEC 60502-2 or PVC Type 9 as per BS 6622 and shall be suitable for the maximum operating temperature of 90°C. Colour of the oversheath shall be black. Mean value of the thickness shall not be less than the specified values in BS 6622:2007 or IEC 60502-2:2014 as applicable and compliance shall be checked by carrying out tests given in the relevant standards.

## **Coatings**

A coating of Graphite shall be applied over the oversheath to carry out D.C. Voltage Test.

## **Identification and Labeling/Marking**

The word "ELECTRIC CABLES", voltage rating as U<sub>0</sub>/U (Um), size of the cable, standard adopted, conductor size, year of manufacture, manufacturer's name or trade mark and travel length shall be embossed at intervals as stipulated in BS 6622-2007 or IEC 60502-2-2014 as applicable, on the outside of the oversheath. The embossing shall be weatherproof and abrasion proof.

Cables shall be supplied in maximum drum lengths, bearing in mind any transportation that may be involved. No drum shall contain more than one length of cable.

Immediately after cable laying and testing, both ends of every cable length shall be sealed by a heat-shrinkable end-cap. The ends of the factory lengths shall be marked "A" and "Z" in accordance with BS 6480.

The cable and projecting from the drum shall be adequately protected to prevent damage during handling and in transit.

### **8.6.1.2 Cable terminations**

Terminations and joints shall be either of a heat shrinkable polymeric or pre-moulded type. They shall be factory assembled kits of the cable manufacture containing all the necessary components to reinstate the cable insulation, metallic shielding of each core, together with the reinstatement of the outer sheath, equivalent for size of cable.

Each terminating or jointing kit shall be in a separate package and a list of materials indicating quantities and weights in the kit, and an instruction sheet shall be included in the package.

Kits shall contain sufficient cleaning solvents and cleaning clothes for the proper making of the joint or termination.

Voltage stress relief shall be provided and this may be inherent in the heat recoverable polymeric material or alternatively incorporated in the pre-moulded termination.

The termination or joint shall be capable of tolerating any variances in the manufacture dimensions of the cable such as oval, out of round, sectored or oversize cable cores. The termination shall be capable of immediate energisation once all components have been installed. The terminating or jointing materials shall not be subject to storage limitations such as controlled temperature or humidity restrictions, nor have shelf life limitations.

The termination kits shall have the following features (one or more of which may be included in one item):

- bimetallic compression lugs
- weatherproof seal between lugs and termination
- non-tracking weather resistant exterior complete with weather skirts for outdoor terminations
- built-in stress control equipment
- copper braid for earthing onto screen
- all other items necessary to complete the kit

Heat shrinkable polymeric materials and terminations shall comply with requirements of IEC 60502, IEC 60466 appendix C, IEC 60060 sub clause 3.3, IEC 60071, IEC 60507 Chapter 3.

The materials, completed terminations and joints shall be for the appropriate type of service, size and voltage. They shall include ferrules, lugs and other materials necessary for the terminating and jointing of the conductor and clamps, braid, etc. necessary for the terminating, jointing of screen and sheath for earth continuity.

All heat shrinkable polymeric tubing and premoulded materials shall be ultra violet stable, non-tracking (per ASTM D2302) and suitable for operation in the presence of severe external contamination and environmental pollution.

The entire termination or joint shall be environmentally sealed and capable of preventing the ingress of external moisture and contamination.

Terminations for station service transformers shall be withdrawable plug and socket type (elastomeric or similar), which shall provide a fully insulated assembly of the cable and transformer bushing.

The Contractor shall submit for the approval of the Engineer, before jointing commences copies of all the jointing instructions to be issued to the cable jointers for each type of jointing accessories included in this Chapter. Further copies shall be supplied at the completion of the Contract in the operation & maintenance manual.

## **8.7 OIL AND COMPOUND (AS APPLICABLE)**

The Contractor shall supply the first filling of all oil and compound required for the operation of the Plant. It shall comply with BS.148 or BS.1858, as appropriate and be of the appropriate grade for operating conditions at Site.

## **8.8 245KV AND 145KV XLPE INSULATED CABLES.**

### **8.8.1 General**

XLPE cables to be offered shall be designed in accordance with the IEC 60840 and IEC 62067 standards and shall withstand any voltage surges that may occur due to

switching operations, sudden load variations, or faults, etc. They shall also withstand all the tests described. 245kV and 145kV XLPE cables from manufacturers with a minimum of fifteen years successful experience in manufacturing 245kV and 145kV cables will only be accepted. Offered 245kV and 145kV XLPE cables will only be accepted if cables identical in design have a minimum five years field experience.

### 8.8.2 Conductors

The conductor shall comprise stranded, soft annealed, electrolytic copper wires, round and compacted with standardised conductivity, and shall be proof against water penetration in longitudinal axis. Conductors shall comply with IEC 60228.

### 8.8.3 Conductor Screen

The conductor shall be covered with three layers (screen, insulation, screen) of high-density polyethylene, chemically cross-linked with mixed organic peroxides, anti-oxidants and voltage stabilisers, extruded under high pressure and heat treatment.

### 8.8.4 Insulation

The XLPE insulation of the cable conductors shall meet the requirements of IEC 60840 and IEC 62067.

The conductor screen, the insulation and the insulation screen shall be mutually compatible and shall, in the same manufacturing process, be continuously extruded and completely dry cured by a common head (simultaneously). For cooling after vulcanisation, preference is given to dry cooling. To reduce the methane content of XLPE a heat treatment after curing shall be carried out.

The lagging will not be considered as satisfactory if an examination during the lagging process or of the finished cable shows, in the option of the Engineer, wrinkles of undue severity or number, or undue departure from correct lagging.

The cable construction shall include a layer of water swellable tape or compound to ensure that any ingress of moisture can not spread internally.

### 8.8.5 Core Screen

The screen applied over each individual core shall consist of a layer of semiconductive XLPE. In order to give protection to the screen against mechanical damage, a copper woven fabric tape may be applied over the screen where considered necessary by the manufacturer.

### 8.8.6 Manufacturer's Identification

The identification of the manufacturer shall be provided in accordance with the requirements of BS 6480 or equivalent IEC Publication.

A distinctive marking, including the following details, shall be embossed continually along with the whole outer covering:

- Manufacturer's name and/or trade mark
- Year of manufacture
- Nominal voltage
- Symbol mark "CV" (Continuous Vulcanisation)
- Conductor size.

### 8.8.7 Laying Up

The three single cores shall be laid -up in a right hand direction as required by BS 6480 or equivalent IEC Publication. A copper woven fabric tape binder shall be applied overall. If it is impossible to achieve the required current carrying capability with a single cable, parallel cables shall be installed at no additional cost to the Employer.

### 8.8.8 Metal Sheath

The cable shall then be drawn into a extruded lead alloy or aluminium. The thickness and composition of the sheath shall be stated in the Technical Particulars and Guarantees. The outer covering shall be preferably high-density polyethylene (HDPE), termite-resistant, vermin-proof, resin-bonded graphite coated, and suitably prepared against decomposition under the prevailing service conditions at site.

### 8.8.9 Sealing Ends

The cable terminations shall be suitable for application to single-cores of the XLPE underground cable as described. They shall be designed to withstand the short circuit current as specified.

The Contractor shall supply all necessary material (whether specifically mentioned or not), including cable clamps, labels, cable markers, compounds, tools, etc. for the proper termination of the cables.

Bidders shall attach drawings to their Proposals showing in detail the method of termination of the cable and of earthing the sheaths.

The outdoor type cable sealing end bases shall be insulated from the structural steel work.

The arrangement to meet these requirements shall be subject to the approval of the Engineer.

For outdoor sealing ends, porcelain insulators shall be provided, designed with a creepage distance as specified in Chapter 1 to cater for the pollution at the site area. The shape of the sheds of the insulator shall cater for the marine pollution. The insulators shall be of self-cleaning, open profile type, they shall have smooth surface with no under-rips. No drip edge is permitted.

Arcing horns with reduced gap for insulation coordination shall be provided.

All terminations shall be made by using stress control cones. They shall consist of prefabricated epoxy, silicone rubber, ethylene-propylene rubber or ethylene-propylene-terpolymer rubber and joined to the cable afterwards, or of stress control cones moulded in one piece together with the cable insulation, or made of crepe paper (elastic paper method), or of self-vulcanising insulation tapes.

The stress control cone material shall have the same thermal expansion coefficient as the cable. The sealing ends shall be filled with high viscosity polyisobutylene, silicone oil, or equivalent and suitable expansion device shall be provided.

Supply and installation of the necessary hot-dip galvanized steel structures and non-magnetic clamps to support and fasten the cables at the gantries shall be included in the Contract Price.

These structures shall be designed to allow simple installation of down-droppers to the terminations.



The arrangement of the terminations, the supporting structures, including the cable fastening, shall be subject to the approval of the Engineer. A complete and detailed list of tools and equipment required for terminating the cables shall be submitted with the Bid.

For proposal of alternative methods, which shall be equivalent in performance to the method specified, the Bidder shall submit information necessary to demonstrate the performance and experience of the method.

#### **8.8.10 Outer Covering**

The outer protective covering shall be with a minimum thickness of 5 mm of extruded anti-termite black PE or alternatively polyethylene if cables are not exposed to direct sunrays and shall have complied with the tape approval tests specified.

The outer surface of plastic coverings shall preferably have a baked-on graphite coating to provide an electrode for high voltage DC sheath integrity testing.

All cable installed in buildings or in cable tunnels shall have an extruded outer covering of flame retardant PE in accordance with IEC. Publication 60331 and 60332.

#### **8.8.11 Voltage Identification**

The plastic oversheath shall be embossed with the name of the manufacturer followed by:

ELECTRIC CABLES - 245,000 VOLTS OR ELECTRIC CABLES - 145,000  
VOLTS

The letters and numbers shall comply with the requirements of BS 6480 or equivalent IEC publication.

#### **8.8.12 Sealing & Drumming**

Immediately after the cable laying & testing, both ends of every cable shall be sealed by means of a heat-shrinkable or slip-on end-cap. The ends of each factory length of the drum shall be marked "A" and "Z". Only one cable length shall be allowed per one drum.

#### **8.8.13 Jointing Accessories**

Jointing accessories for stranded copper conductors may be designed for compression type ferrules or indentation type ferrules. Three core cables may be jointed with soldered type ferrules.

Stranded aluminium conductors shall be jointed with indentation type ferrules or by welding process. Accessories for 3-core cables with aluminium conductors may be designed for soldered ferrules. Annular compression type ferrules are not approved for stranded aluminium conductors.

Conductor temperature during plumbing and welding shall be monitored by means of a thermocouple. The temperature shall not exceed the value stated in the Technical Particulars and Guarantees.

The cable installation shall be an insulated system and the accessory designs shall include provision for periodic electric testing to check the integrity of the cable anticorrosion or oversheath protection.

All outdoor type cable sealing end bases shall be installed from the surrounding structural steelwork by means of post insulators interposed between the bases and the supporting structure. A brass link device shall be provided at the base of each sealing end to enable the post insulators to be open-circuited when required for testing purposes.

The cable glands of SF<sub>6</sub> type sealing ends or transformers shall be insulated from the metallic structures and the arrangement to meet this requirement shall be subject to the approval of the Engineer.

#### **8.8.14 Pulling Eyes**

Unless otherwise confirmed in writing by the Engineer, cables shall be pulled during installation by bond pulling where the whole mechanical tension is concentrated in a steel wire.

If nose pulling is approved then pulling eyes shall be fitted to the cable at the factory to the approval of the Engineer. A sufficient number of rollers over which the cable can ride shall be provided to ensure that the cable does not rotate or twist on its longitudinal axis during the pulling operation. The cost of fitting pulling eyes deemed to be included in the Bid price. Nose pulling by means of a cable stocking is only permitted for short length within the Sub Station.

### **8.9 CABLE END BOXES AND GLANDS**

#### **8.9.1 Cable End Boxes:**

Electrical equipment supplied under this Contract is to be fitted where specified with approved cable end boxes or glands, which are to be completed with all necessary fittings.

Cable boxes are to be adequate proportions and designed in such a manner that they can be opened for inspection without disturbing the gland plate or incoming cable. Filling and venting plugs, where required, are to be positioned so as to avoid the possibility of air being trapped internally and adequate arrangements are to be made for expansion of compound etc. Where applicable, there must be no possibility of oil entering the connection chambers. Drain plugs of suitable size are to be provided to facilitate rapid removal of the filling medium when this is required.

Air filled cable boxes are not acceptable except where the terminations of solid dielectric or oil impregnated non draining cables and the connections to the Plant or cable disconnecting chamber are entirely sealed in heat shrinking plastic or elastomeric sheaths.

Glands insulated from the body of the cable box are to be supplied where detailed in the appropriate Chapter of this Specification.

Provision shall be made for earthing the metal body of each cable box.

Where cable boxes are provided for three-core cables the seating sockets on the outer phases shall be inclined towards the centre to minimise bending of the cable cores.

#### **8.9.2 Compression Glands:**

Compression type glands with armour and bonding clamps for the termination of all solid dielectric multicore cables shall be designed to secure the armour wires to provide electrical continuity between the armour and the threaded. Fixing component of the gland and to provide watertight seals between the cable outer sheath and gland

and between the inner sheath and threaded fixing component. The glands shall preferably project above the gland plate to avoid entry of moisture.

### **8.9.3 Earthing/Bonding of the Metallic Sheath**

The metallic sheath of the power cables shall be earthed in single point for safety.

The sheath bonding system shall be earthed at one location, interrupting the currents path. Sheath voltage limiters (arresters: SVL) shall be provided at the open end for 132kV cable. These bonding or bonding with the SVL shall be accommodated in a link box to be located near the cable end.

## **8.10 LAYING DIRECT IN GROUND**

### **8.10.1 Excavation of Trenches**

The exact location of each trench shall be agreed at the site with the Engineer before the installation work begins. Permits for excavation shall be obtained from the Engineer. Trenches shall be kept as straight as possible and shall be excavated to approved formations and dimensions. Trenches shall have vertical sides and shall be close timbered and strutted where necessary to prevent subsidence.

Unless otherwise agreed with the Engineer, the depth of excavated trenches for the installation of HV cables shall be 1meter. The contractor shall use no power excavation tools for excavation with in outdoor switchgear. The contractor shall take all precautions to avoid damaging any other power cables along the cable route. All excavation, cable laying and back filling shall be carried out only under the direct supervision of a responsible officer and only in the presence of a representative of the Engineer.

### **8.10.2 Cable Laying and Protection**

Before the cables are laid, the bottom of the trench shall be lined with approved soften sand well tamped down to a minimum depth of 50 mm to form a bed. After the cable are laid, the first cover of backfill shall consist of approved soften sand, well tamped down. A minimum depth of 80 mm of backfill shall be provided over the cables, over which the cable protective covers shall be placed. Cable protective covers shall be of reinforced concrete, hydraulically pressed and otherwise approved shall be 300 mm wide 50mm thick and 1000mm long, each cover shall have cable route mark embossed in the concrete. They shall be design interlocking one with the other, both vertically and laterally. Special covers shall be provided where required for short radius bends. All cable protective covers shall meet the requirements of BS 2484 or equivalent IEC or ISO standard.

When the power cables are buried, the route of the cable shall be mark with concrete markers on the surface where direction of the cable route is changing.

### **8.10.3 Backfilling**

The back filling of the trench shall be carried out in 150 mm thick layers, which shall be well rammed and consolidated. The Contractor shall supply any backfill material necessary to achieve the specified thermal resistivity in replacement of any unsuitable excavated material and the cost of removing and supplying the required material shall be included in the contract price.

## 8.11 TESTS AT MANUFACTURER'S WORK

### 8.11.1 Low Voltage and Medium Voltage Cable:

#### 8.11.1.1 General

Type Tests, Routine Tests and Sample Tests shall be carried out in accordance with BS 6622. Type tests to be carried out at Accredited independent testing laboratory.

#### 8.11.1.2 Inspection for Factory Acceptance Test

During manufacturing the products by the Contractor, the inspection for the factory acceptance tests shall be carried out by the Employer and/or by the Engineer.

The Contractor shall submit the method statement of factory acceptance tests for the inspections by the Employer and/or the Engineer. The method statement shall be checked and approved by the Engineer. If the factory acceptance test is carried out without the Engineer's approval, the result of the test is invalid and the Contractor shall carry out the retest according to the approved method statement. The cost of the retest shall be borne by the Contractor.

#### 8.11.2 145kV and 245kV XLPE Cable:

Components of equipment shall subject to appropriate inspections during manufacturing. Equipment shall wherever be subject to inspections on completion in the manufacturer's works. The Contractor shall submit the method statement of the inspection for approval. The method statement shall include type and layout of the test facility, location of instrumentation, formula for calculation of tested results and correction to the site conditions etc.

All measuring instruments used in the inspections shall be calibrated and the calibration records shall be submitted to the Engineer and/or the Employer.

All tests shall be made at an ambient temperature of 20°C ( $\pm 15$  K) unless otherwise specified. The frequency of the ac test voltages shall be in the range 49Hz to 51Hz. The wave form shall be substantially sinusoidal. The testing procedures shall consider and model the future service conditions as far as possible.

Test Categories:

- a) Type tests to be carried out at recognized Accredited independent testing authorities,
- b) Routine tests to be carried out at the manufacturer's factory
- c) Sample tests to be carried out at the manufacturer's factory
- d) Site tests during cable installation to be carried out at the site
- e) Site tests after cable installation to be carried out at the site

All above mentioned tests shall be carried out in accordance with;

IEC 62067 for 220kV XLPE cable and accessories

IEC 60840 for 132kV XLPE cable and accessories

Incase CCV extrusion method is used for manufacturing of HV cables, it is required to submit following additional Tests Certificates carried out for HV cables as per ICEA S-108-720-2018 Standard. It has to be submitted with type test reports.

- I. Amber, Agglomerate ,Gel ,Contaminant ,Protrusion, irregularity and Void Test
- II. Wafer Boil Test for conductor and Insulation shield.

In addition to that "Amber, Agglomerate ,Gel ,Contaminant ,Protrusion, irregularity and Void Test" need to be carried out at the Factory Acceptance Test as well.

The type test shall be submitted from an accredited independent testing laboratory. The testing laboratory shall be accredited by a local or international ILAC(International Laboratory Accreditation Cooperation) member accreditation organization for the relevant testing scope. Proof of accreditation and accredited scope by a national/international authority shall be forwarded with the offer. The type test certificate shall be complete including all the pages as issued by testing authority. Type test certificates shall be in English language with following information:

- 1) General
  - a) Applicable standards
  - b) Cable construction
- 2) Cable manufacturing
  - a) Type of extrusion line
  - b) Method of curing and cooling
  - c) Details of cable degassing
- 3) Cable materials
  - a) Material of inner semi-conducting screen over the conductor.
  - b) Type and grade of material for the main insulation of the XLPE cable
  - c) Material of semi-conducting screen over the insulation
- 4) Cable and accessories construction
  - a) Description and drawing of the cable type offered in the Bid
  - b) Drawing of each tested accessories

The Bid shall include all information requested above.

All components and the complete facilities shall be subject to the inspection by the Engineer and/ or Employer during all project phases such as manufacturing, installation and commissioning. The Contractor shall carry out all tests which are necessary to ensure the specified quality of materials and products as well as to demonstrate the compliance with the required performance and guarantees.

### **8.11.3 Test Requirements of 220kV and 132kV XLPE Cables and accessories**

Type Tests, Routine Tests and Sample Tests shall be carried out in accordance with IEC 62067 for 220kV XLPE cable and accessory and IEC 60840 for 132kV XLPE cables and accessory.

## **8.12 SITE INSPECTIONS AND TEST AFTER INSTALLATION**

### **8.12.1 Tests of 220kV and 132kV XLPE Cables**

After the installation is completed, the inspection shall be carried out by the Employer and/or by the Engineer.

The Contractor shall submit the method statement of site tests after the installation for the inspections by the Employer and/or the Engineer. The method statement shall be checked and approved by the Engineer. If the site test after the installation is carried

out without the Engineer's approval, the result of the test is invalid and the Contractor shall carry out the retest according to the approved method statement. The cost of the retest shall also be borne by the Contractor.

#### **8.12.1.1 Check of Cross-bonding Scheme**

The sequence of phases of the cables, conformation of cable transposition and the cross-bonding scheme shall be checked and tested in order to ensure the correct installation according to the designed configuration.

#### **8.12.1.2 Tests of Link Boxes and Surge Voltage Limiters**

The link boxes and surge voltage limiters shall be tested according to relevant standards.

#### **8.12.1.3 Tests of Earthing Installation and Earth Resistance**

All tests necessary shall be executed on the earthing system and its earthing points along the cable route.

#### **8.12.1.4 Tests after Installation of 220kV and 132kV Cable Systems**

After the installation of the 220kV and 132kV XLPE cable systems has been completed, the following electrical tests shall be carried out in accordance with IEC 62067 and IEC 60840.

- a) DC voltage test of oversheath
- b) AC voltage test (HV soak tests) of the insulation.

In addition to the above test, insulation resistance test of the cable insulation shall be measured and recorded immediately before and after impose of AC test voltage.

#### **8.12.1.5 Site Tests of 220kV & 132kV XLPE Cable Systems**

The following test but not limited to shall be conducted to verify that the cable system has been constructed to meet fully the every requirement of the specification.

- i. Phase verification
- ii. Conductor DC resistance
- iii. Capacitance of the cable system
- iv. Verification of transposition and cross-bonding
- v. Positive, negative and zero sequence impedance

In case of the following tests have already been carried out, the such data shall be added and filled in the Site Test Report.

- vi. Insulation resistance
- vii. Earthing resistance at joint bays
- viii. Contact resistance of the link boxes
- ix. High voltage test on SVL
- x. Verification of the optical-continuity of the optical fiber unit for DTS
- xi. Integrity connection with the 24 fiber optical fiber cable between telecommunication and SCADA systems

### **8.12.1.6 HV Soak Tests**

HV Soak Tests on 220kV and 132kV cable systems shall be carried out in order to demonstrate the overall system functionality.

### **8.12.2 Tests of 33kV and 11kV XLPE Cables**

#### **8.12.2.1 Site Inspection during Installation**

During the installation, the site inspection shall be carried out by the Employer and/or by the Engineer.

The Contractor shall submit the method statement of site tests for the inspections by the Employer and/or the Engineer. The method statement shall be checked and approved by the Engineer. If the site test is carried out without the Engineer's approval, the result of the test is invalid and the Contractor shall carry out the retest according to the approved method statement. The cost of the retest shall be borne by the Contractor.

#### **8.12.2.2 Tests of 11kV and 33kV cables after installation**

After installation of cables the following electrical tests shall be carried out in accordance with BS 6622

- i. DC voltage test of oversheath
- ii. AC voltage test of the insulation

In addition to the above test, insulation resistance test of the cable insulation shall be measured and recorded immediately before and after impose of AC test voltage.

#### **8.12.2.3 Commissioning Tests of 11kV and 33kV XLPE cable system**

The following test but not limited to shall be conducted to verify that the cable system has been constructed to meet fully the every requirement of the specification.

- i. Phase verification
- ii. Conductor DC resistance
- iii. Insulation resistance

In case of the insulation resistance test have already been carried out, such data shall be added and filled in the Commissioning Test Report.

**CHAPTER 9 – ENERGY METERING**  
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## **CHAPTER 9 – ENERGY METERING**

### **9.1 SCOPE**

This Specification covers the general requirements of the design, engineering, manufacturing, assembly and inspection & testing of CT/ VT connected, Programmable Static Poly Phase Energy Meter (herein after referred to as “The Meter” in this specification) of Accuracy Class 0.2S with Time of Day Reading Facility and option for remote reading. The meters shall be used for commercial/ tariff metering for inter License power flows/ bulk consumers application and suitable for operation on either MV or HV application as specified.

The meter shall have wide secondary current range support i.e. same meter shall be put up for 1A or 5A rating as per field availability of CT’s. Meter required to be commissioned at each substation shall be of 3 phase 4 wire or 3 phase 3 wire.

The Meter shall have the facility to programme and read from a PC connected to the meter using USB and Optical port. Meter shall also have the communication facility to take the meter reading and any other data remotely via a data communication network. The communication modules including accessories required at both local and remote ends and software for remote meter reading shall be supplied with the meter. It shall be possible to replace the communication unit at site without breaking the meter calibration seals.

Following items shall be supplied for the offer

- 1) The meter as specified
- 2) Communication module for the meter including accessories
- 3) Communication module for the PC including accessories
- 4) PC software and accessories including optical cable for local configuration (One optical cable for each 50 Nos. meters shall be provided)

### **9.2 APPLICABLE STANDARDS**

The equipment and components supplied shall be designed manufactured and tested in accordance with the latest editions/amendments of the Standards specified below. However, the CEB Specification shall supersede these standards in the event there is a discrepancy.

S.N.	Standard No.	Title
a.	IEC 62052-11	Electricity metering equipment (AC) – General requirements, tests, and test conditions- Part 11: Metering equipment
b.	IEC 62053-22	Electricity metering equipment (AC) Particular requirements - Part 22: Static meters for active energy (classes 0.2S and 0.5)
c.	IEC 62053-23	Electricity metering equipment (AC) Particular requirements - Part 23: Static meters for reactive energy (classes 2 and 3)
d.	IEC 62058-11	Electricity metering equipment (A.C) – Acceptance inspection- Part 11: General acceptance inspection methods
e.	IEC 62058-31	Electricity metering equipment (A.C) – Acceptance inspection- Part 31: Particular requirements for static meters for active energy (Class 0.2S, 0.5S, 1 and 2)
f.	IEC 62056-21	Electricity metering - Data exchange for meter reading, tariff and load control

		Part 21: Direct local data exchange
g.	IEC 62056-42	Electricity metering - Data exchange for meter reading, tariff and load control Part 42: Physical layer services and procedures for connection-oriented asynchronous data exchange
h.	IEC 62056-4-7	Electricity metering data exchange –The DLMS/COSEM suite – Part 4-7: DLMS/COSEM transport layer for IP networks
i.	IEC 62056-52	Electricity metering - Data exchange for meter reading, tariff and load control Part 52: Communication protocols management distribution line message specification (DLMS) server
j.	IEC 62056-5-3	Electricity metering data exchange –The DLMS/COSEM suite – Part 5-3: DLMS/COSEM application layer
k.	IEC 62056-6-1	Electricity metering data exchange –The DLMS/COSEM suite – Part 6-1: Object Identification System (OBIS)
l.	IEC 62056-6-2	Electricity metering data exchange –The DLMS/COSEM suite – Part 6-2: COSEM interface classes
m.		
n.	IEC 60529	Degrees of protection provided by enclosures (IP code)
o.	ISO 75	Plastics — Determination of temperature of deflection under load
p.	ISO 9001	Quality management systems - Requirements
q.	ISO/IEC: 17025	General requirements for the competence of testing and calibration laboratories

### 9.3 METER REQUIREMENT

#### 9.3.1 PRINCIPAL PARAMETERS

i)	Reference Voltage	110 V AC
ii)	Standard Rated Current	1 Amp
iii)	Maximum Current	1.2 x standard rated current
iv)	Auxiliary Supply	60-240 V AC/ DC
v)	Wiring Configuration	3P4W

#### 9.3.2 BASIC FEATURES OF THE METER

##### 9.3.2.1 Measurement

The Meter shall be suitable for full power factor range from zero (lagging) through unity to zero (leading). The Meter shall work as an active energy import and export meter along with reactive (lag and lead) meter. The energy measurement should be true four quadrant type.

The Meter shall be of programmable type suitable for recording active energy consumption in kWh/MWh, reactive energy consumption in kvarh/Mvarh, average demand in kVA/MVA and

kW/MW. The accuracy class of the Meter shall be Class 0.2S for Active Energy and Class 2 or less for reactive Energy.

The Meter shall be suitable for Time-of Day (minimum of 6 intervals), Import-Export Energy Metering. The Meter shall have provisions to change the time of day tariff in the field and shall have facility to programme for a minimum of six (06) times of day tariffs.

Export Energy shall be measured as positive and shall be able to re-programme depending upon the necessity.

The Meter shall record the monthly cumulative consumption of active energy and reactive energy separately. It also shall record the maximum of average apparent and active power demand over a demand integration period of fifteen (15) minutes every month.

#### **9.3.2.2 Operation**

The Meters shall detect and record CT polarity reversal as an event with date and time of such occurrence and restoration with phase identification. The Meter shall record the consumption in a separate register with TOD which shall be displayed when required in case polarities are reversed or shall record the consumption correctly even under polarity reversed.

The Meter shall be capable of detecting and recording occurrence of missing voltages and shall display the details of Power disconnections, tampering attempts, power restorations and other details such as time and date of such occurrences.

The Meter shall record the consumption accurately irrespective of the phase sequence of supply.

#### **9.3.2.3 Mounting**

The Meter shall be of the indoor type surface mounting, having terminals at the bottom connected with the secondary side of outdoor current and voltage transformers and mounted in suitable panel/ cubicles.

#### **9.3.2.4 Maximum Demand**

Facilities shall be provided to reset the maximum demand automatically at a preset date and time as well as manually. It shall be possible to disable the MD reset button and to seal it, if required. It shall also be possible to programme, download data and reset the maximum demand remotely through software running on a PC compatible on latest version of Windows.

#### **9.3.2.5 Security**

The Meter shall have necessary security facilities to prevent unauthorized meter parameter changes (password protected). It shall include minimum two levels of authorizations in order to read and programme meters. Facilities shall be provided to modify the password at the meter programming level. A list of set passwords shall be provided with the samples.

#### **9.3.2.6 Flashing Light Indication**

Minimum two flashing light indications shall be available on the front face of the Meter which acts as an activity indicator, one LED which blinks analogous to the active energy and another to the reactive energy metered, for testing and calibration purposes. Facilities shall be provided to change the pulse/kWh and pulse/ kvarh to an appropriate value according to the energy flow.

#### **9.3.2.7 Calendar Clock**

The Meter shall have a Calendar clock to provide time and date information and be equipped with built in battery backup. Battery life shall be not less than 10 years.

### 9.3.2.8 Display Sequence

The Meter shall directly display the sequence of data given below. However, it shall be possible to alter the display sequences using the programme software. The Meter display shall have OBIS code or clearly readable meaningful text.

#### Auto Display Mode

1. Lamp Test
2. Actual Time
3. Actual Date
4. Cumulative Total Active Export Energy
5. Cumulative Active Export Energy (Rate 1)
6. Cumulative Active Export Energy (Rate 2)
7. Cumulative Active Export Energy (Rate 3)
8. Cumulative Total Active Import Energy
9. Cumulative Active Import Energy (Rate 1)
10. Cumulative Active Import Energy (Rate 2)
11. Cumulative Active Import Energy (Rate 3)
12. Maximum Demand (active power)
13. Maximum Demand (apparent power)
14. History 1: Cumulative Total Active Export Energy up to last month reset
15. History 1: Cumulative Active Export Energy (Rate 1) up to last month reset
16. History 1: Cumulative Active Export Energy (Rate 2) up to last month reset
17. History 1: Cumulative Active Export Energy (Rate 3) up to last month reset
18. History 1: Cumulative Total Active Import Energy up to last month reset
19. History 1: Cumulative Active Import Energy (Rate 1) up to last month reset
20. History 1: Cumulative Active Import Energy (Rate 2) up to last month reset
21. History 1: Cumulative Active Import Energy (Rate 3) up to last month reset

#### Push Button Mode

1. Meter Serial No.
2. History 1: Cumulative Total Active Export Energy
3. History 1: Cumulative Active Export Energy (Rate 1)
4. History 1: Cumulative Active Export Energy (Rate 2)
5. History 1: Cumulative Active Export Energy (Rate 3)
6. History 1: Cumulative Total Active Import Energy
7. History 1: Cumulative Active Import Energy (Rate 1)
8. History 1: Cumulative Active Import Energy (Rate 2)
9. History 1: Cumulative Active Import Energy (Rate 3)
10. History 1: Maximum Demand Export Active Power (MD)
11. Date and Time: History 1: Maximum Demand Export Active Power (MD)
12. History 1: Maximum Demand import Active Power (MD)
13. Date and Time: History 1: Maximum Demand Import Active Power (MD)
14. History 1: Maximum Demand Export Apparent Power (MD)
15. Date and Time: History 1: Maximum Demand Export Apparent Power (MD)
16. History 1: Maximum Demand import Apparent Power (MD)
17. Date and Time: History 1: Maximum Demand Import Apparent Power (MD)
18. MD Reset Date
19. History 1: Cumulative Total Reactive Import Energy

20. History 1: Cumulative Reactive Import Energy (Rate 1)
21. History 1: Cumulative Reactive Import Energy (Rate 2)
22. History 1: Cumulative Reactive Import Energy (Rate 3)
23. History 1: Cumulative Total Reactive Energy Export
24. History 1: Cumulative Reactive Energy Export (Rate 1)
25. History 1: Cumulative Reactive Energy Export (Rate 2)
26. History 1: Cumulative Reactive Energy Export (Rate 3)
27. Maximum Demand Active Power
28. Date and Time : Maximum Demand Active Power
29. Maximum Demand Apparent Power
30. Date and Time : Maximum Demand Apparent Power
31. Phase to Neutral voltage ( R )
32. Phase to Neutral voltage ( Y )
33. Phase to Neutral voltage ( B )
34. R Phase Line current.
35. Y Phase Line current.
36. B Phase Line current.
37. Instantaneous Average power factor.
38. Instantaneous Load Active
39. Instantaneous Load Apparent
40. Phase Sequence ABC ( FOR – Correct / REV – Incorrect )
41. Present PT Status
42. Present CT Status
43. LED Pulse Output/ Meter Constant
44. Primary current /CT Ratio
45. Connection Check

Measured energy and maximum demand shall be displayed either in prefix 'kilo' or 'Mega'.

#### 9.3.2.9 Memory

The Meter shall have facilities to store a minimum of twelve months of billing history data, Load Profile data for at least forty five (45) days (Load profile data shall contain parameters, active power, reactive power and apparent power in both directions, power factor, voltage of each phase and current of each phase at 15 minute interval), Event Log Data (minimum 100 records). Each event log or tamper log shall have the date and time of occurrence and restoration. However, these log channels and parameters shall be user configurable. Sampling period for load profile shall be 30s or less. There shall be a facility in the Meter to select average/ maximum/ minimum of the values to be recorded in Load Profile.

It shall have sufficient channels in Load Profile to capture power quality data such as THD in current and voltage

For the display, the Meter shall have non-volatile memory type electronic display. The non-volatile memory shall have a minimum retention time of twelve months. The principle unit for the measured value shall be kilowatt-hour (kWh) and kVA and kW.

#### 9.3.2.10 Meter Programming Facility

It shall be possible to fully program display settings, time of day tariff settings, CT/VT ratios, load profile parameters, automatic billing/resetting date and time, historical registers and other programmable parameters, reset the maximum demand, and download data both locally and remotely through suitable software running on PC without any assistance of the manufacturer.

### 9.3.3 LOCAL/REMOTE COMMUNICATION

The Meter shall be accessible from the communication software installed and running on Windows based PC supplied by CEB.

The manufacturer shall disclose and provide all necessary protocol information or API(Application Programming Interface) to CEB at any time throughout the guaranteed life span of the Meter, so that independently developed HES(Head End System) and MDMS(Meter Database Management System) can freely communicate with the Meter and manage its data as required.

#### 9.3.3.1 Communication Ports

The Meter shall have following communication ports for local/remote reading:

- i) Optical port (Locally programming and downloading data)
- ii) RS232 port (for remote communication using GSM/GPRS Modem)
- iii) TCP/IP Ethernet (should be configurable on DLMS TCP/MODBUS TCP)

#### 9.3.3.2 Local/Remote Accessibility

Facilities shall be available to carry out following tasks for each of the meter locally/remotely.

- i. To program each meter
- ii. To take the relevant meter readings for each meter separately
- iii. To reset the maximum demand value of each meter.
- iv. To get error messages when the meter is faulty, tampering of meter etc and the date and time of occurrence of such event.
- v. To download stored data from meter (Present values, Historical values, Load Profiles).

#### 9.3.3.3 Methods of Remote Communication

Method for remote communication shall be

- 1. GSM/ GPRS based wireless communication
- 2. CEB communication network based wired communication (Applicable only if the scope of supplier includes supply delivery installation and commissioning)

#### 9.3.3.4 GSM/ GPRS Based Wireless Communication

##### a) At the Meter end

The Communication Module shall be supplied with the meter and shall be powered from the meter. The module and accessories shall be;

- i. A modem which can operate in 900/1800 MHz (GSM) range and 800/900 MHz (2G) range or 2100 MHz (3G) range or 1800/2300 MHz (4G LTE) range.
- ii. Tamper proof SIM Card Holder
- iii. A built-in connector for an external antenna and antenna cable with 3m wire length
- iv. Minimum speed of 9.600 kbps for GSM, 40 kbps for GPRS, 2 Mbps for 3G and 6 Mbps for 4G
- v. Data cables to connect to meter

##### b) At the PC end

One GSM/GPRS Communication Module for each lot of 50 meters or part there of shall be supplied with the meter, as specified in the price schedule.

The module shall have;

- ii. A modem which can operate in 900/1800 MHz (GSM) range and 800/900 MHz (2G) range or 2100 MHz (3G) range or 1800/2300 MHz (4G LTE) range.
- iii. Tamper proof SIM Card Holder
- iv. A built-in connector for an external antenna and antenna cable with 3m wire length
- v. Minimum speed of 9.600 kbps for GSM, 40 kbps for GPRS, 2 Mbps for 3G and 6 Mbps for 4G
- vi. Data cables to connect to meter

#### 9.3.3.5 CEB Communication Network Based Wired Communication (Not applicable in case the Scope of supplier is limited to Supply and Delivery of Goods)

There shall be two separate network switches installed at Transco and Disco meter panels. Meters in each panel shall be connected to the respective switch installed at the relevant panel and both these switches shall be linked to two dedicated Ethernet ports in the fiber optic multiplexer in the substation providing remote access to energy meters via CEB communication network.

The network switch shall be of unmanaged industrial type with minimum 24 ethernet ports having speed of 10/100 Mbps. It shall be of rack mountable with fan-less air-cooled cooling system and have LED activity for power and link/activity.

#### 9.3.3.6 Communication Software

A user-friendly windows based Graphical User Interface (GUI) basic software with free license to install in any number of PCs shall be supplied on a CD with the meters in order to programme the meters (locally and remotely) and to download the data from the remote data communication facilitated meters. The software shall have the facility to communicate via a communication modem connected to the PC. Relevant manuals in English language shall be provided.

The downloaded data shall be stored in a suitable fool proof database. This data shall be able to be extracted as a delimited MS Excel format.

Software shall be valid or provided with necessary keys and upgrades for at least the full life span of the Meter. The manufacturer/ supplier shall provide necessary support throughout this period. The software should facilitate remote data downloading individually from each meter as well as batch wise data downloading of particular set of meters through automated function.

#### 9.3.4 MECHANICAL REQUIREMENTS

The Meter shall be designed and constructed in such a way as to avoid introducing any danger in normal use and under normal working conditions, so as to ensure especially;

- a) Personal safety against electric shock
- b) Personal safety against effects of excessive temperature
- c) Safety against spread of fire
- d) Protection against penetration of solid objects, dust and water.

All parts which are subject to corrosion shall be suitably protected and any protective coating shall not be liable to damage by normal handling.

#### 9.3.4.1 Case and Window

The Meter shall have an insulated case which shall be sealed in such a way that the internal parts of the meter are not accessible to unauthorized persons such that double insulation for the meter is ensured.

Any non-permanent deformation of the case shall not affect the satisfactory performance of the meter.

The window shall be of transparent material which cannot be removed without damaging the window or breaking seals.

#### 9.3.4.2 Terminal Block

The terminal block shall be made of insulating material and it shall be capable of passing the test stipulated in ISO 75-2:2013 for a temperature of 135°C and a pressure of 1.8 MPa.

Each terminal shall have two screws for effectively clamping two numbers 2.5mm<sup>2</sup> copper cables and the bore of the terminals shall be adequate enough to accommodate two numbers 2.5mm<sup>2</sup> copper cables. It shall be made of tin/nickle plated brass/copper.

#### 9.3.4.3 Terminal Cover

The wiring terminals shall be protected by a sealable terminal cover and the terminal cover shall be made of an insulating material.

The terminal covers shall be of extended type with easily breakable knockouts. Provision shall be made to seal the meter cover and terminal cover separately.

#### 9.3.4.4 Resistance to Heat and Fire

The terminal block, the terminal cover and the meter case shall not ignite by thermic overload of live parts in contact with them and they shall meet the tests stipulated in Clause 5.8 of IEC 62052-11

#### 9.3.4.5 Protection Against Penetration of Dust and Water

The Metering equipment shall be suitable for indoor use and conform to the degree of protection of IP51 as per IEC 60529.

#### 9.3.4.6 Display of Measured Values

The Meter shall be provided with a LED Display under a viewing panel conforming to the degree of protection of IP 65 and the dimensions of figures shall not be less than 4 mm (Height) and 4mm (Width). Minimum number of digits shall be 10 including the decimal point and shall be capable of showing three decimal points in a particular reading.

#### 9.3.4.7 Output Device

The Meter shall have a test output device (outlet port) accessible from the front and capable of being tested with the help of the universal reference standard meter.



### 9.3.5 CLIMATE CONDITION

#### 9.3.5.1 Temperature Range

The operating Temperature range of the Meters shall conform to the table 5 of IEC 62052-11 for indoor meters.

#### 9.3.5.2 Relative Humidity

The meters shall be suitable for indoor operation in a humid tropical climatic condition with the maximum relative humidity of 90%

### 9.3.6 INFLUENCE OF HEATING

The temperature rise at any point of the external surface of the meter shall not exceed 25K with the ambient temperature at 40°C. Under normal operating condition the electrical circuits and insulation shall not reach a temperature which might affect the operation of the meter

### 9.3.7 ELECTROMAGNETIC COMPATIBILITY

#### a) Immunity to Electromagnetic Disturbance

The Meters shall be designed in such a way that conducted or radiated electromagnetic disturbance as well as electrostatic discharge do not damage or influence the meter.

#### b) Radio Interference Suppression

The Meters shall not generate, conduct or radiate noise which could interfere with other equipment.

### 9.3.8 ACCURACY REQUIREMENTS

#### a) Starting and Running with No-Load

The Meter shall be fully functional within 5 seconds after the voltage is applied to the meter terminals.

When the voltage is applied with no current flowing in the current circuit the test output of the meter shall not produce more than one pulse. The meter shall start and continue to register at 0.001 of basic current.

#### b) Meter Constant

Sufficient pulse rate (meter constant) shall be generated at low load condition (1/10 of CT ratio). The relation between the test output and the indication in the display shall comply with the marking on the name plate.

### 9.3.9 MARKING OF METERS

a) Every meter shall be indelibly marked with a diagram of connections and this diagram shall also show the sequence for which the meter is intended, preferably inside the meter terminal cover.

b) The Name Plate of Meters shall bear all the information stipulated in clause 5.12 of IEC 62052-11. The marking shall be indelible, distinct and readable from outside the meter.

- c) The words “Property of the Ceylon Electricity Board (CEB) with a mark “Warranty 5Y “shall be engraved on the nameplate.
- d) Serial number (which will be indicated at the time of placing an order) shall also be engraved on the nameplate.

#### 9.4 QUALITY ASSURANCE

The manufacturer shall possess ISO 9001 Quality Assurance Certification for the design, manufacture and testing of Programmable Static Poly phase Energy Meters. In the event the meters are manufactured in a plant under the licensed of the manufacturer, the manufacturing plant shall possess ISO 9001 Quality Assurance Certificate for manufacturing and testing of Three Phase Energy Meters. The Bidder shall furnish a copy of the ISO Certificate certified as true copy of the original from the manufacturers, along with the offer.

Each Meter to be tested and calibrated at a meter testing laboratory having ISO/IEC: 17025:2015 and properly sealed with security synthetic seal with identification numbers. Test report shall be dispatched to the purchaser before inspection.

The proof documents with regard to the accreditation for the above facility in accordance with ISO/IEC: 17025:2005 shall be submitted along with the bid.

#### 9.5 TESTING, INSTALLATION AND COMMISSIONING

##### 9.5.1 TYPE TEST

The following Type Test Certificates conforming to IEC 62052-11 shall be furnished with the offer.

- i) Test of insulating properties
  - a) Impulse test voltage
  - b) A.C. Voltage Test
- ii) Test of Accuracy requirements
  - a) Test of meter constant
  - b) Test of starting condition
  - c) Test of no-load condition
  - d) Test of influence quantities
- iii) Test of electrical requirements
  - a) Test of power consumption
  - b) Test of influence of supply voltage
  - c) Test of influence of short-time current
  - d) Test of influence of self-heating
  - e) Test of influence of heating
  - f) Test of immunity to earth fault
- iv) Test of electromagnetic compatibility
  - a) Radio interference suppression
  - b) Fast transient burst test
  - c) Damped oscillatory waves immunity test
  - d) Test of immunity to electromagnetic RF fields
  - e) Test of immunity to conducted disturbances, induced by radio-frequency fields
  - f) Test of immunity to electrostatic discharges.
  - g) Surge immunity test

- v) Tests of the effect of the climatic environments
  - a) Dry heat test
  - b) Cold test
  - c) Damp heat cyclic test
  - d) Solar radiation test
  
- vi) Mechanical Tests
  - a) Vibration Test
  - b) Shock test
  - c) Spring Hammer Test
  - d) Tests of protection against penetration of dust and water
  - e) Test of resistance to heat and fire

The Type Test Certificates shall clearly indicate the following;

- a) Name, Address and Country of the Testing Authority
- a) Date of Testing
- b) Name of Equipment Type Tested
- c) Number of pages of the Type Test certificates
- d) Manufacturers identity/Catalogue Reference Number etc.
- e) Basic Parameters
- f) The Standard to which the equipment Type tested.
- g) Comments and Observations of the Testing Authority

The Type Test shall be performed at a reference voltage of 110V/400V at a reference frequency of 50Hz.

Type Test Certificates shall be from an accredited independent testing laboratory acceptable to the CEB complying to ISO/IEC 17025. Proof of accreditation by a national/international authority shall be forwarded with the offer. Test reports shall be complete including all the pages as issued by the testing authority. Type test reports shall be in English language. Parts of test reports shall not be acceptable.

### 9.5.2 ACCEPTANCE/SAMPLE TEST

Following tests shall be carried out conforming to IEC 62052 – 11, IEC 62053-22, IEC 62053-23 and IEC 62058-31 under the witness of;

- An independent testing authority acceptable to CEB : If the scope covers supply delivery and installation of meters or
- An Engineer is appointed by CEB : If the scope is limited to supply and delivery of meters (Refer clause 8.2 of this specification)

- a) Preliminary tests and pre-conditioning

Meters shall be visually examined for none shown signs of damage and their specified marking are correct. The meter shall be energized at reference voltage and 0.1I<sub>b</sub> at unity power factor for at least 30 min to verify that the rotors turn and to pre-condition the meters.

- b) Test of insulation properties
  - i) A.C. Voltage Test
  
- c) Tests of Accuracy requirements
  - i) Test of Meter Constant
  - ii) Test of Starting condition

- iii) Test of No-load condition
- iv) Limits of error due to variation of current
- v) Limits of error due to influence qualities (voltage variation, voltage unbalance, harmonics in voltage and current, external magnetic fields).

Extra copies of the acceptance test report shall also be supplied with the meters.

### **9.5.3 INSTALLATION AND COMMISSIONING (Not applicable in case the Scope of supplier is limited to Supply and Delivery of Goods)**

Two separate sets of meter panels shall be installed as Transco and Disco where each set includes Energy meters for Transformer Incomers, Generator feeders and Distribution feeders. Each set shall include an ethernet switch as specified in clause 9.3.3.5 of this specification.

For energy metering, measuring signal shall be taken from dedicated class 0.2 cores/windings of CTs and VTs installed in each Transformer Incomer, Generator feeder and Distribution feeders.

#### **9.5.3.1 Meter Panel**

All panels shall be constructed or braced rolled steel section, with recessed panels and substantial mounting sheets for power and control cable work. All steelwork shall be constructed of steel sheets with a minimum thickness of 2mm. The minimum width, depth and height of all cubicles shall be 800 mm, 800mm and 2200 mm respectively.

The interior of each cubicle shall be finished with a mat light coloured surface and an interior lamp suitable for local LVAC supply and controlled by a door-operating switch and fitted at the top of each cubicle. Anti-condensation heaters shall also be fitted in each cubicle and each cubicle shall be well ventilated top and bottom through vermin proof louvers fitted with brass gauze screens. Each protection cubicle shall also be equipped with a built in AC supply socket outlet of single phase. Three wire rated 13 A at 230 V, 50 Hz.

The cubicle shall be of the self-standing, floor-mounted type and shall be provided with ways and means for floor fixing and anchoring devices. They shall be supplied completely with their fixing and lifting racks and eyebolts. Equipment and terminals shall be readily accessible and shall require a minimum of disturbance of associated adjacent equipment for access. The arrangement of panel wiring and multicore cable terminal boards shall be in accordance with the relevant clauses of Chapter 3 of this Specification.

Enclosures shall be provided for bottom entry of power and multi core cables via gland plates. Removable gland plates shall be located within the cubicles so as to provide adequate working clearance for terminating the cables.

Where any sensitive equipment are mounted on hinged front panels, these shall be designed to minimize shock and wiring shall be so arranged as to impose no strain on terminations. No equipment whatsoever shall be mounted on rear access doors.

All sections of a composite cubicle shall be suitably labelled in accordance with the specification and labels at the rear shall also readily identify each section or panel with the access doors either opens or close.

Each panel shall be of the swing rack type including 19" swing frame and a front cover door equipped with a glass window and each control panel shall be of the enclosed type.

The indoor meter panel shall be of at least IP 41 protection class. Each door shall be fitted with suitable earth straps of at least 16 mm<sup>2</sup> highly flexible stranded copper wire with an insulation in green-yellow colour.

Doors are to be arranged so that every individual door or frame can be opened without moving doors of adjacent cubicles. Doors shall be of 2mm thick sheet steel, equipped with 120° concealed hinges, with foamed-in seal and shall be provided with a stable, bolted, rectangular tube frame, with pre-punched holes at 25 mm pitch for fixing channels, covers, cable harnesses, wiring plan pockets and etc. The door stopper at the end of the throw shall be provided. Doors shall be handled by smooth action locking bars with rollers and security lock system, prepared for insert lengths of 40 or 50 mm. The insert shall be provided in accordance with the master key system of Employer, for which details shall be forwarded to the contractor on request.

The contractor shall perform a calculation for the heat dissipation for enclosures with the maximum installed heat-losses and shall propose a suitable temperature control method. However the method has to be approved by the Engineer.

Panels and cabinets are to be installed in totally air-conditioned control rooms. Cubicles provided as extensions or for erection in the same room with existing cubicles shall be of similar appearance. All enclosures and accessories such as swing frames shall be corrosion protected by electrophoresis-dip-coat primers and final coats by an approved procedure as to suit the surrounding conditions at site.

The arrangement and mounting of meters and all other devices shall be to the approval of the Engineer. The exterior and interior finish and colour of all cubicles shall be to the approval of the Engineer.

#### 9.5.3.2 Cabling and Wiring

In selecting cable and wire sizes, due regard shall be paid to the appropriate de-rating factors in relation to the climate conditions at site. All cables and wires shall continuously carry their rated currents under the worst temperature conditions and shall also withstand maximum fault currents without damage or deterioration.

All secondary copper wiring within panels, racks, boards, etc. shall be in accordance with the pertaining IEC, it shall be carried out for the fully rated distribution voltage (2 kV AC/ 1 min. test voltage) and shall consist of copper wires. The bare ends of stranded wires shall be provided with squeezed sleeves.

The minimum Cross-section of each copper wire shall be at least as specified in the chapter 3 of this specification. Wiring shall be neatly run in PVC rigid plastic wire-ways, clear of any metal panels and filled not more than 70% or bundles with no bunch containing more than 12 wires. All power and control cables used for less than 60 V DC shall be laid and terminated separately. Where power and control cables cannot be laid separately, suitable metallic barriers shall be provided.

Both ends of every wire core and all secondary panel wiring above 60 V (at the screwed terminal side for external connection as well as at the screwed device sides in the panel) shall be fitted with numbered slip-on ferrules of moisture and oil-resisting insulation material having a glossy finish, and with their identification numbers clearly engraved, each being the same as for the relevant terminal.

Ferrules of white colour with black letters, shall be fitted in such a way that they cannot become detached when the wire is removed from the terminal. (i.e. end crimps shall be provided).

All secondary wiring to be performed at site shall enter the terminal block at one side only. The panel wiring shall terminate in one or more terminal blocks accommodated at the side or bottom of each panel. Internal wiring between meters shall be permitted within the same cubicle only.

Cables with spiral wrap designed shield shall be used for the current transformer circuits and voltage transformer circuits. The shield shall be grounded at both ends of the cable. Generally, for wiring, the cable tails shall be so bound that each wire may be tracked back to its associated cable without difficulty. Cores in pairs or groups shall be terminated together.

All incoming control cables shall contain minimum 20% spare cores and be connected to terminal blocks, with 20% spare terminals of each type. Any further spare cores shall be numbered included in the list of cable table and shall be sealed in further spare terminals.

### 9.5.3.3 Terminal blocks

Terminal block shall be numbered consecutively in both sides, preferably beginning with 1, from left to right or top to bottom. Terminal blocks shall consist of single "insertion" type terminals of non-tracking, non-inflammable synthetic plastic, or ceramic of an approved type, lined up in one row. Polyamide terminal blocks are not acceptable. All terminals shall have two separate pressure clamping plates suitable for connection of incoming or outgoing stranded or solid conductors, respectively. However, only one wire per terminal will be accepted. Terminals with clamping screws in direct contact with the conductor are not acceptable.

The following minimum categories of terminals shall be used:

- Terminals for power circuits of 6 mm<sup>2</sup> and 2.5 mm<sup>2</sup> size
- Current transformer secondary terminal shall be 4 mm<sup>2</sup> size and shall have :
  - Facility to short circuit the current transformer side
  - Facility to isolate the current transformer secondary side and relay side by opening link in each terminal
  - Facility to directly plug in probes from test kit without removing wires from the terminal block
- Voltage Transformer Secondary terminals shall be 4 mm<sup>2</sup> size and shall have
  - Facility to isolate the voltage transformer secondary side by opening link in each terminal
  - Facility to directly plug in probes from test kit without removing wires from the terminal block
- DC circuit: It shall be possible to isolate the internal and external wiring using "knife disconnection" mechanism
- Terminals for wiring of 1.5 mm<sup>2</sup> and 0.6 mm<sup>2</sup> size with bridging facilities to the neighbouring terminals.

Insulating barriers shall be provided between each group of power circuit terminal categories, the height and the spacing begin such as to give adequate protection to terminals. Current and voltage transformer secondary circuits, battery and auxiliary power supply wiring, supervisory, alarm and communication circuits shall be protected against conductive, electrostatic and electromagnetic influences.

### 9.5.3.4 Meter Installation

- a) Contractor shall perform visual inspection to ensure that there is no damage resulting from shipment. Contractor shall install meters in accordance with the drawings and manufacturer's instructions. Any damaged paintwork shall be touched up.
- b) Meters should be programmed by the contractor for the settings specified in this specification and for any other variations requested at the time of installation.

- c) Terminals and connecting cables from voltage transformers, and current transformers up to and including the meter (including any and all terminations between voltage/current transformers and the meter) shall be made inaccessible by a sealed cover, complete with an approved seal. Furthermore, meters shall be sealed with an approved seal.
- d) Energy meters shall be supplied from dedicated VT windings and CT cores. No other loads shall be connected to these windings/cores.
- e) Energy meters shall be installed on a dedicated panel in the existing station relay room.
- f) Contractor should perform an accuracy measurement test and check the CT and VT ratios using secondary injection methodology or any other means to the satisfaction of the Engineer.
- g) Technical literature in English language on the installation, calibration and maintenance shall be supplied with each set of meters and they shall be descriptive and self-explanatory, complete with necessary connection diagrams and drawings
- h) The Contractor shall prove to the satisfaction of the Engineer and the Owner, that the metering system and remote access to the meter system is functional, in all regards.

#### 9.5.3.5 Establishing Remote Communication

Remote communication with meters shall be successfully implemented under following two methods.

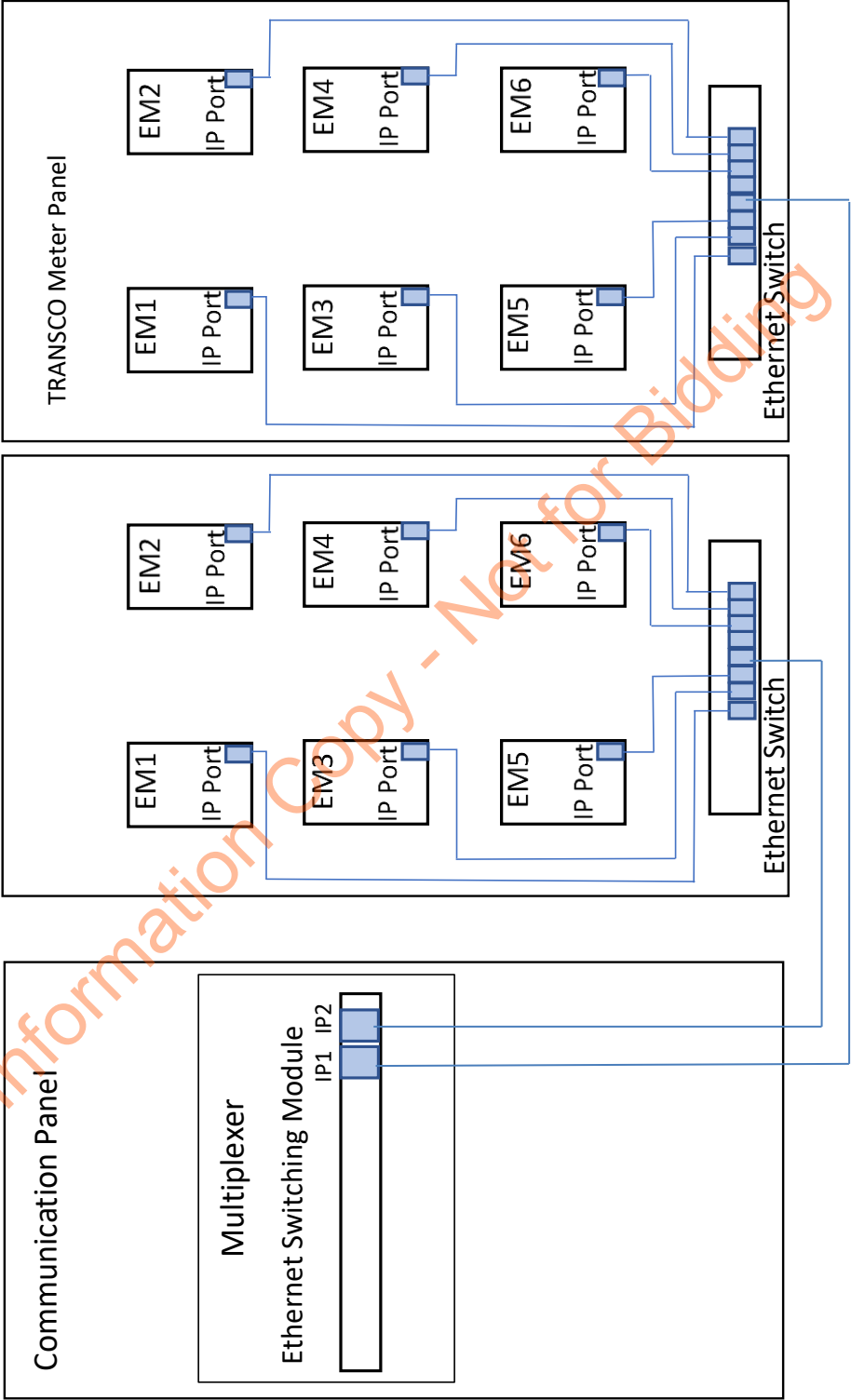
##### a) GSM/ GPRS based wireless communication

Install GSM/GPRS modem and all accessories at the meter end and establishing GSM/GPRS based remote communication between meters and modem connected to the PC on which the meter Software is installed at Energy Marketing branch Meter Data Downloading Centre.

##### b) CEB communication network based wired communication

Energy meters in DISCO panel shall be linked to the network switch install at the same panel while energy meters in TRANSCO panel shall be connected to the network switch in that panel. Two switches shall be connected to two separate Ethernet ports in the fiber optic multiplexer using Ethernet cable (of type UTP, CAT 6) laid through a PVC insulated GI spiral conduit. The necessary surge protectors for the Ethernet cable shall also be installed at the multiplexer end. The required configurations on the CEB communication network shall be carried out by CEB and remote connection between energy meters and the Energy Marketing branch Meter Data Downloading Centre shall be tested by the contractor.

Figure: Proposed Panel Layout & Connection Diagram for the CEB Communication Network Based Wired Communication





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## 10. CHAPTER 10 – TRANSFORMERS

### 10.1. APPLICABLE STANDARDS

Standard	Description
IEC 60060	High-voltage test techniques
IEC 60076-1	Power Transformers - General
IEC 60076-2	Power Transformers - Temperature rise for liquid-immersed transformers
IEC 60076-3	Power Transformers - Insulation levels, dielectric tests and external clearances in air
IEC 60076-4	Power transformers - Guide to the lightning impulse and switching impulse testing - Power transformers and reactors
IEC 60076-5	Power Transformers - Ability to withstand short circuit
IEC 60076-6	Power Transformers – Reactors
IEC 60076-7	Power Transformers - Loading guide for oil-immersed power transformers
IEC 60076-8	Power Transformers - Application Guide
IEC 60076-10	Power Transformers - Determination of sound levels
IEC 60076-18	Power Transformers - Measurement of frequency response
IEC 60137	Insulated bushings for alternating voltages above 1000 V
IEC 60214-1	Tap-changers - Performance requirements and test methods
IEC 60214-2	Tap-changers - Application Guide
IEC 60270	High-voltage test techniques - Partial discharge measurements
IEC 60296	Fluids for electro-technical applications - Unused mineral insulating oils for transformers and switchgear
IEC 60422	Mineral Insulating Oil in Electrical Equipment - Supervision and Maintenance Guide
IEC 60567	Oil-filled electrical equipment - Sampling of gases and analysis of free and dissolved gases – Guidance
IEC 60529	Degrees of protection provided by enclosures
IEC 60815	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions
IEC 61869-1	Instrument transformers - General requirements
IEC 61869-2	Instrument Transformers - Additional requirements for current transformers
IEC 61869-3	Instrument Transformers - Inductive Voltage Transformers
IEC 61869 -5	Instrument Transformers - Capacitive Voltage Transformers
IEC 62155	Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V
IEC 60071-1	Insulation co-ordination - Definitions, principles and rules
IEC 60071-2	Insulation co-ordination - Application guide

ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles
ISO 8501-1	Preparation of steel substrates before application of paints and related products - visual assessment of surface cleanliness
ISO 12944	Paints and varnishes - Corrosion protection of steel structures by protective paint systems
BS 61	Specification for threads for light gauge copper tubes and fittings
IEEE C57.93	IEEE Guide for Installation of Liquid Immersed Power Transformers
BS EN 10025	weldable structural steels

## **10.2. TYPE OF TRANSFORMER AND OPERATING CONDITIONS**

### **10.2.1. GENERAL**

All transformers shall be oil immersed and suitable for outdoor installation and shall comply with standards mentioned in clause 10.1. Each item or function which is obviously necessary for the proper completion of the work, its full functionality and safety as well as complete interfacing with other work, whether especially specified in the Bidding documents or not, shall be included in the Bid price.

### **10.2.2. COOLING**

The types of cooling shall be as stated in the Employer's Requirements and the letters relating to the method of oil circulating and cooling used in this Specification and Employer's Requirements shall be in accordance with IEC 60076.

Where a combination of two methods of cooling is applied to one transformer as for ONAN/ONAF units, the transformer shall be capable of operating under the ONAN condition as stated in the Employer's Requirements, after which the cooling equipment is to come into operation and the Transformer will operate as an ONAF unit.

Transformers shall be fitted with tank mounted radiators. They shall be capable of remaining at the operation of full load for 20 minutes in the event of failure of blowers associated with both coolers without the calculated winding hot spot temperature exceeding 130°C.

Failure of one fan in each group of blowers shall not reduce the continuous maximum rating of the transformer.

### **10.2.3. PARALLEL OPERATION**

Transformers supplied against each item shall be designed to operate satisfactorily one with the others when operating on the same tap position.

### **10.3. CONTINUES MAXIMUM RATING**

Transformers shall have the continuous maximum rating as stated in the Employer's Requirements and shall comply with the requirements as regards temperature rise and overloads on all tappings irrespective of the direction of power flow and with the voltage of the lower voltage winding at the normal voltage stated in the Employer's Requirements. To allow for high atmospheric temperatures, the allowable temperature rise shall be reduced as stated in this Specification.

The overload capability shall be in accordance with IEC 60076-7.

#### **10.3.1. ELECTRICAL CONNECTIONS**

Transformer windings shall be connected in accordance with the IEC 60076-1 group symbol specified in the Employer's Requirements. The neutral point shall be brought out of the tank and earthed outside of the tank.

All electrical connections within windings shall be brazed but subject to approval, mechanically crimped joints may be used for round stranded conductors on tapping, bushing or earthing connections and on bundle conductors when design has been proved by the type test and application is subject to rigorous quality control.

### **10.4. ABILITY TO WITHSTAND SHORT CIRCUIT**

#### **10.4.1. GENERAL**

All transformers shall be capable of withstanding on any tapping and without damage the thermal and dynamic effects of external short circuits under the conditions stated in IEC 60076-5 Clause 4.

Manufacturer shall demonstrate the ability to withstand the thermal effect of short circuit by calculation, and the ability to withstand the dynamic effect of short circuit either by test (as per IEC60076-5 Clause 4.2) or calculation, design and manufacture considerations (as per 10.4.2 below). The method of demonstration of the ability to withstand the dynamic effects of short circuit shall be stated in the bid

#### **10.4.2. CALCULATIONS, DESIGN AND MANUFACTURE CONSIDERATIONS**

Following shall be submitted with the bid.

a) Thermal ability to withstand short circuit

Calculations shall be done according IEC 60076-5:2006 Clause 4.1 to prove the thermal ability to withstand the short circuit, for at least 3 seconds at rated conditions and after all loading conditions as specified in IEC 60076-7 Clause 7.3.3, and shall be submitted with the offer.

b) Ability to withstand dynamic forces

During the bidding stage manufacturer shall prove his ability of designing and manufacturing transformers which can withstand dynamic effects of short circuit as per IEC 60076-5 by means of complete test reports of short circuit tests. These tests shall be conducted in a test laboratory which is a member of Short circuit Testing Liaison ( STL) and the laboratory shall also possess ISO/IEC17025:2015 certification.

## 10.5. LOSSES AND EVALUATION OF LOSSES

The Bidder shall state in the Technical Particulars and Guarantees, guaranteed values for component losses of the total loss which shall be as low as is consistent with transport restrictions, reliability and economic use of materials.

Bids will be assessed on the basis of the least 'Present Worth' of capital cost plus guaranteed losses, being the sum of the installed Bid Price of the transformers plus:

Sri Lanka Rupees per kW of guaranteed loss			
Power Transformer	No load loss	Load loss at CMR	Auxiliary loss at (CMR)
Rupees/kW	2,156,377	1,154,493	600,599

The acceptance of transformers yielding component losses higher than the guaranteed values shall be governed by either of the following: -

- (A) Component losses in excess of guaranteed values but within the tolerance permitted under IEC 60076 Part 1. Transformers shall be accepted subject to full compliance with all technical particulars including temperature rises at CMR and subject to the Bidder accepting deduction from the Contract Price of charges for each kW on part thereof of component losses in excess of the guaranteed values, at the above evaluation rates.
- (B) Component losses in excess of guaranteed values and exceeding the tolerance permitted under IEC 60076 Part 1.

The acceptance of transformers shall be entirely at the discretion of the Engineer/Employer and subject to the Bidder accepting the deduction from the Contract Price of charges for each kW on part thereof of component losses in excess of the guaranteed values, at the above loss evaluation rates.

In the event of transformers, which are, either equal to or below the guaranteed losses values, the Bidder will not be entitled to any premium in respect of reduction in losses below the guaranteed values.

## 10.6. IMPEDANCE

The value of impedance measured on principal and extreme tapplings shall be as stated in the Schedule and minimum and maximum values where stated in the Employer's Requirements shall not be subject to tolerance.

Where transformers are required to operate in parallel with existing units the appropriate data will be stated in the Employer's Requirements.

## 10.7. NOISE

The transformer noise levels shall be measured as a type test and in accordance with IEC 60076-10. The noise level of the transformers shall be as stated in the Employer's Requirements.

When the bottom plate of the transformer tank will be in direct contact with the surface of the foundation anti-vibration pads shall be provided for insertion between the transformer and its foundation.

## **10.8. HARMONIC SUPPRESSION**

Transformers shall be designed with particular attention to the suppression of harmonic voltages, especially the third, fifth and seventh harmonics and to minimize the detrimental effects resulting therefrom.

## **10.9. MAGNETIC CIRCUIT AND WINDINGS**

### **10.9.1. MAGNETIC CIRCUIT**

The design of the magnetic circuit shall be such as to avoid static discharges development of short circuit paths internally or to the earthed clamping structure, and the production of flux components normal to the plane of the laminations. Each lamination shall be insulated with a material stable under the action of pressure and hot oil.

The winding structure and major insulation shall be designed to permit an unobstructed flow of cooling oil through core cooling ducts to ensure efficient core cooling.

The magnetic circuit shall be insulated from all structural parts, and shall be capable of withstanding a test voltage to core bolts and to the frame of 2,500 volts RMS for one minute. In order to allow testing, the magnetic core shall be earthed to the tank cover at one point only through removable links in an appropriate terminal box, placed in an accessible position on the tank cover.

### **10.9.2. FLUX DENSITY**

Core shall be constructed from cold rolled grain oriented electrical steel sheets. Design shall be such that there will be no adverse effects due to core or stray flux heating with the quality of steel employed, and that when operating under the most onerous conditions envisaged in IEC 60076 - 7, flux density in any part of the magnetic circuit does not exceed 19,000 lines per square centimeter (i.e. 1.9 Tesla).

Core shall be constructed from cold rolled grain oriented (CRGO) electrical steel sheets, and the flux density at magnetizing force of 800 A/m shall not be less than 1.9 T (Data sheet of the CRGO electrical steel shall be provided with the bid including DC magnetizing curve). Design shall be such that there will be no adverse effects due to core or stray flux heating with the quality of steel employed, and that when operating under the most onerous conditions envisaged in IEC 60076 - 7.

The maximum flux density in the legs and yokes of the core shall not exceed 1.6 Tesla at nominal ratio at rated voltage and rated frequency. The maximum flux density in any part of the core shall not exceed 1.9 Tesla at highest operating voltage and lowest frequency at any tap position to achieve rated secondary voltage, considering voltage regulation and AVR operation under full load condition at lowest possible power factor.

The no-load current of the transformer at nominal voltage and frequency and at nominal ratio shall not exceed 0.15% of its rated current. Further, no-load current at 1.1 times the nominal voltage shall not exceed 2.5 times the no-load current at nominal voltage.



### 10.9.3. WINDINGS

All windings shall have copper conductors. Transformer 220kV and 132kV star connected windings may have graded insulation as defined in IEC 60076 and 33 kV and 11 kV winding shall have uniform insulation as defined in IEC 60076. All neutral points shall be insulated to withstand an applied voltage test specified in the Employer's Requirements.

The windings shall also be thoroughly seasoned during manufacture by the application of axial pressure at a high temperature for such length of time as will ensure that further shrinkage is unlikely to occur in service.

The windings and leads of all transformers shall be braced to withstand the shocks, which may occur through rough handling and vibration during transport, switching and other transient service conditions including external short circuit.

If the winding is built up of sections or of disc coils splitted by spacers, the clamping arrangements shall ensure that equal pressures are applied to all columns of spacers.

### 10.9.4. INTERNAL EARTHING

- (i) General - All metal parts of the transformer with the exception of the individual core laminations, core bolts and associated individual clamping plates shall be maintained at some fixed potential.
- (ii) Earthing of Core Clamping Structure - The top main core clamping structure shall be connected to the tank body by a copper strap. The bottom main core clamping structure shall be earthed by one or more of the following methods.
  - (a) by connection through vertically tie rods to the top structure;
  - (b) by direct metal to metal contact with the tank base maintained by the weight of the core and windings;
  - (c) by connection to the top structure of the same side of the core as the main earth connection to the Tank.
- (iii) Earthing of Magnetic Circuits - The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link placed in an accessible position just beneath an inspection opening in the tank cover and which, by disconnection, will enable the insulation between the core and clamping plates, etc., to be tested at voltages up to 2.5 kV as specified in IEC 60076-1. The link shall have no detachable components and the connection to the link shall be on the same side of the core and the main earth connection. These requirements are compulsory.

Magnetic circuits having insulated sectional construction shall be provided with a separate link for each individual section. The arrangement of the connections shall be subjected to the plane of the laminations divide the magnetic circuit into two or more electrically separate parts, the ducts and insulating barriers which have a thickness greater than 0.25 mm are to be bridged with tinned copper strips so inserted as to maintain electrical continuity.
- (iv) Earthing of Coil Clamping Rings - Where coil clamping rings are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure on the same side of the Transformer as the main earth connection.

- (v) Size of Earthing Connections - Main earthing connections shall have a cross-sectional area of not less than 80 sq. mm. but connections inserted between laminations may have cross-sectional areas reduced to 20 Sq. mm. when in close thermal contact with the core.

## 10.10. TANKS AND ANCILLARY EQUIPMENT

### 10.10.1. TRANSFORMER TANKS

Each transformer shall be enclosed in a suitable stiffened welded steel tanks such that the transformer can be lifted and transported without permanent deformation or oil leakage. The construction shall employ weldable mild steel and shall be of sufficient strength and rigidity to withstand moving, shipping and handling without deformation.

Lifting lugs shall be provided, suitable for the weight of the transformer, including core and windings, fittings, and with the tank filled with oil. Each tank shall be provided with jacking lugs suitably positioned for transport.

The design and positioning of lifting points, stiffeners and under-bases on the tank should prevent distortion of the core during lifting and transport.

The transformer tank shall be capable of withstanding full vacuum without deflection as per IEC 60076-1.

Where the design of the tank is such that the bottom plate will be in direct contact with the surface of the foundations, the plates shall have the following minimum thickness: -

Length of Transformer	Minimum Thickness	
	Side Plates	Bottom Plates
Less than 2500 mm	6 mm	19 mm
Greater than 2500 mm	9 mm	25 mm
Greater than 7500 mm	32 mm	40 mm

Where skid type bases are provided, the plates shall have the following minimum thickness: -

Length of Transformer	Minimum Thickness	
	Side Plates	Bottom Plates
Less than 2500 mm	6 mm	9 mm
Greater than 2500 mm	9 mm	12 mm

In case of a self-supporting tank bottom of the power transformer without steel crossbeams, the bottom plate shall have a minimum thickness of 40 mm.

The base of each tank shall be so designed that it is possible to move the complete transformer unit in any direction without injury when using rollers, plates, or rails.

Transformers may have flat, skid or wheel bases subject to the approval of Engineer, but, detachable under bases must not be used unless specifically approved by the Engineer.

All joints other than those, which may have to be opened, shall be welded. Caulking of defective welded joints may be re-welded subject to the written approval of the Engineer.

The tank and cover shall be designed in such a manner as to leave no external pockets in which water can lodge no internal pockets in which oil can remain when draining the tank or in which air can be trapped when filling the tank, and to provide easy access to all external surfaces for painting.

When built-on radiators are used, each radiator bank shall be connected to the main tank through flanged valves mounted on the tank at top and bottom and each bank shall be fitted with drain valve and air release plug.

Each tank cover shall be of adequate strength, must not distort when lifted and shall be provided with suitable flanges having sufficient and properly spaced bolts. Inspection openings shall be provided to give access to the internal connections of bushings, winding connections and earthing links. Each opening shall be correctly located and must be of ample size for the purpose of which it is intended. All inspection covers shall be provided with lifting handles.

All the openings on the cover should have a raised flange to prevent water from entering the openings when individual covers are removed.

Tank covers with low level welded flanged joints are preferred, but contractors may offer alternative designs with high level covers.

If transformer cover is welded, a magnetic particle test shall be carried-out after first (root) welding run. Photographs and test results of MPT test shall be submitted to CEB and shall be discussed with CEB if any abnormalities are found. Then only manufacturer should continue next welding runs.

It is also mandatory to preheat all the welding surfaces before starting weldings.

It must be possible to remove any bushing without removing the tank cover.

Pockets shall be provided for a stem type thermometer and for the bulbs of temperature indicators where specified. These pockets shall be located in the position of maximum oil temperature and it must be possible to remove any bulb without lowering the oil level in the tank. Captive screwed caps shall be provided to prevent the ingress of water to the thermometer pockets when they are not in use.

### **10.10.2. CONSERVATOR TANKS, BREATHERS AND AIR DRYERS**

Each transformer shall be provided with an overhead conservator tank formed of substantial steel plates and arranged above the highest point of the oil circulating system (see also Clause 10.12.1). Connections into the main tank shall be at the highest point to prevent the trapping of air or gas under the main tank cover. Main tank conservator vessels shall be equipped with elastic diaphragms of the air-bag type.

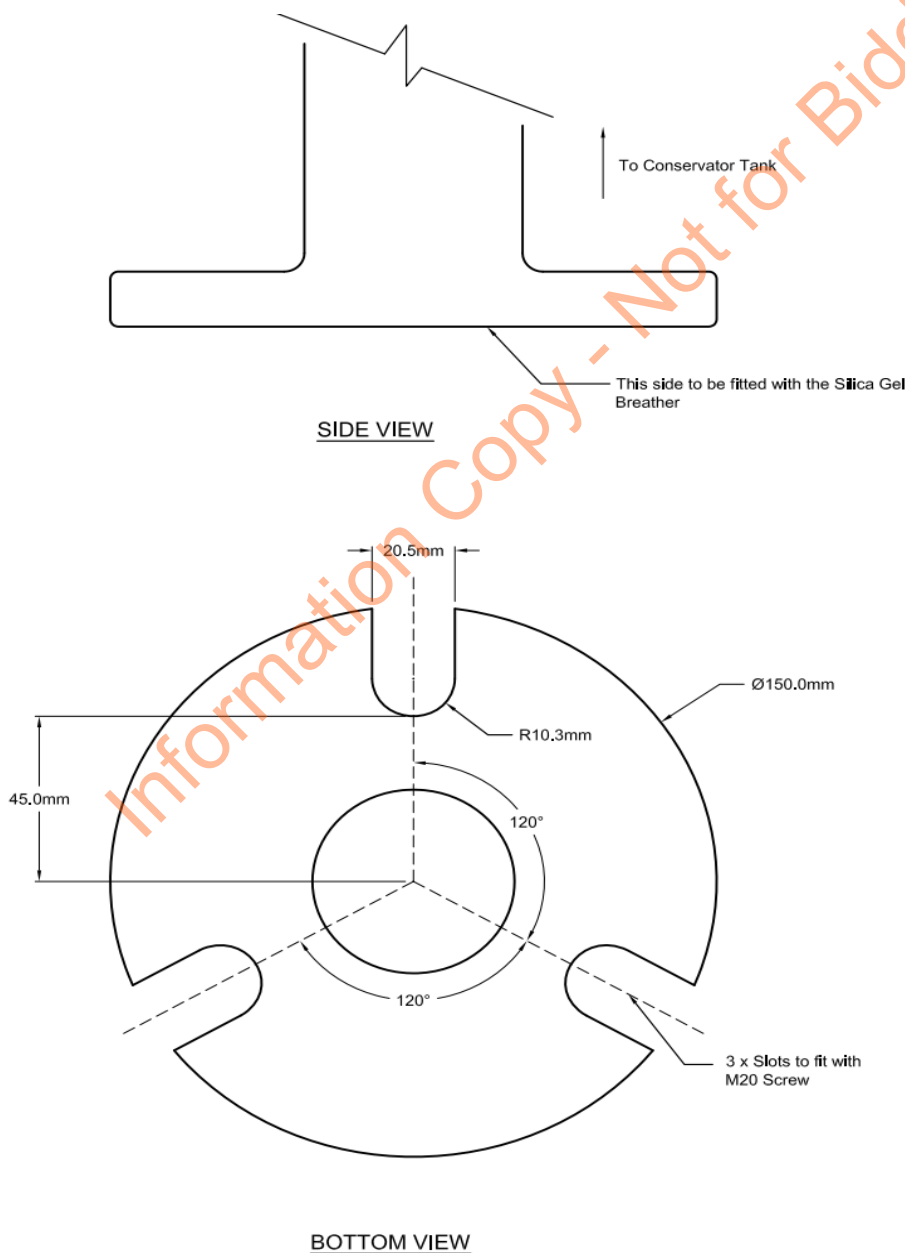
The capacity of each conservator tank shall be adequate for the expansion and contraction of oil in the whole system under the specified operating conditions. Conservator tanks shall also be provided with a cleaning door, filling cap, drain valve with captive cap and a prismatic type oil level indicator with minimum and maximum levels indicated.

The location of the conservator tank shall be so arranged that it does comply with the requirements and a valve shall be provided at the conservator to cut off the oil supply to the tank.

Each conservator shall be fitted with silica gel breather and a magnetic type oil level indicator. The breather shall be a type, which permits the silica gel content to be removed for drying. Due to the climatic conditions at site, this breather shall be larger than would be fitted for use in a temperate climate. All breathers shall be mounted at a height of approximately 1400 mm above ground level. Breathers for the power transformer main tank conservator shall have a minimum filling capacity of 3 kg.

The pipe work between the conservator and the transformer tank shall comply with the requirements of clause 10.12.5 and a valve shall be provided at the conservator to cut off the oil supply to the tank.

Breather mounting flange shall comply following drawing.



### 10.10.3. VALVES AND LOCATION

All valves up to and including 75 mm bore shall be made of gunmetal.

Each Transformer shall be fitted with the following valves as a minimum requirement:-

#### Main Tank

- (a) One 50 mm bore filter valve located near to the top of the tank.
- (b) One 50 mm bore filter valve located near to the bottom of the tank and diagonally opposite to the filter valve required against (a). Where design permits, this valve may be combined with item (c).
- (c) One 50 mm drain valve with such arrangements as may be necessary inside the tank to ensure that the tank can be completely drained of oil as far as practicable. This valve shall also be provided with an approved oil sampling device.

All the valves fitted on main tank specified in item (a), (b) and (c) shall be of the type of 'Gate Valve' or 'Ball Valve' with a flange having PCD of 125mm. Any valve without straight opening shall not be accepted.

#### Conservator

- (d) One valve between the conservator and gas actuated relay for the main tank and, where appropriate, for the tap change diverter switch tank.
- (e) One drain valve for oil conservator tank so arranged that the tank could be completely drained of all oil.

#### Tap Changer Selector Switch

- (f) 50 mm filter and 50 mm drain valve where selector switches are contained in a separate tank.

#### Diverter Switch

- (g) One 50 mm drain valve to be fitted to each tank. An approved oil sampling device shall also be provided.

#### Forced Air Oil Coolers

- (h) One ball valve at the top and one ball drain valve at the bottom of each radiator unit.

Blank flanges, plate or captive screw caps shall be fitted to all valves and pipe ends not normally connected in service.

The omission of any, or the provision of alternative arrangements to the above requirements, will not be accepted unless approved in writing by the Engineer before manufacture.

#### **10.10.4. JOINTS AND GASKETS**

All joint faces shall be arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of oil or air.

Oil resisting synthetic rubber is not permissible except where metal inserts are provided to limit compression.

Gaskets shall be as thin as is possible consistent with the provision of a good seal and full details of all gasket sealing arrangements shall be shown on the Plant drawings.

Material of gaskets should be "UV-resistant Nitrile Rubber" (NBR). List of gaskets with dimensions and dimensional drawings should be provided with the transformer manual.

#### **10.10.5. PRESSURE RELIEF DEVICE**

An approved type pressure relief device of sufficient size for the rapid release of any pressure that may be generated in the tank and designed to operate at a static pressure lower than the hydraulic test pressure called for in Schedule of Works Tests, shall be provided. In the event that the device is a spring operated valve type, it shall be provided with one set of normally open signaling contacts to trip the transformer.

The relief device is to be mounted on the tank cover and is to be provided with a skirt to project at least 25 mm into the tank to prevent gas accumulation.

#### **10.10.6. EARTHING TERMINALS**

Two bare steel contact surfaces having two 14 mm diameter holes on 45 mm centers shall be located one on either side and near to the bottom of the Transformer to facilitate connection to the local earthing system.

#### **10.11. RATING, DIAGRAM AND VALVE PLATES**

The following plates, or an approved combined plate, shall be fixed to each transformer tank at an average height of 1500 mm above the ground level:-

- (a) A rating plate with the data specified in IEC 60076 Part 1. This plate shall also include a space for the Purchaser's serial number and in addition include the short-circuit current rating and time-factor for each winding.
- (b) A diagram plate showing in an approved manner, the internal connections and the voltage relationship of the several windings, in accordance with IEC 60076 Part 1 with the Transformer voltage ratio for each tap and, in addition, a plan view of the Transformer giving the correct physical relationship of the terminals.
- (c) A plate showing the location and function of all valves and air release cocks or plugs. This plate shall also if necessary warn operators to refer to the Maintenance instructions before applying vacuum.

Plates are to be of high-quality (Grade 316 or higher) stainless steel with sand blast finish capable for continuous outdoor service and withstanding the climatic conditions of at site.

In addition, the Manufacturer's Serial Number and transformer model shall be engraved on the main tank, such that it is visible without obstructed by any other part/accessory fixed on the tank. The size of the letters/numbers shall not be less than 25 mm height. The preferable place of engraving the serial number and the transformer model would be, below the panel in which

temperature indication devices are installed. This engraving shall be available for inspection during the Factory Acceptance Testing.

## **10.12. COOLING PLANT**

### **10.12.1. COOLING PLANT - GENERAL**

Radiators and cooling fans shall be hot dip galvanized accordance with ISO 1461. The design shall also avoid pockets in which water can collect and shall be capable of withstanding the pressure tests specified in Schedule of Works Tests for the transformer main tank.

The clearance between any oil or other pipe work and live parts shall be not less than the minimum clearances as specified in the specification.

### **10.12.2. RADIATORS CONNECTED DIRECTLY TO TANK**

Radiators connected directly to the tank shall be detachable and shall be provided with flanged inlet and outlet branches. Plugs shall be fitted at the top of each radiator for air release and at the bottom for draining.

A valve shall be provided on the tank at each point of connection to the tank.

### **10.12.3. COOLER BANKS**

Each cooler bank shall be provided with:-

- (a) A valve at each point of connection to the tank.
- (b) A valve at each point of connection of radiators.
- (c) Loose blanking plates to permit the blanking off of the main oil connection to the top.
- (d) A 50 mm filter valve at the top of each cooler bank.
- (e) A 50 mm drain valve at lowest point of interconnecting oil pipes.
- (f) A thermometer pocket, fitted with captive screw cap, in the inlet and in the outlet oil pipes.
- (g) Air release and drain plugs on each radiator.
- (h) Visual oil flow indicators, on transformers having forced oil circulation fitted with electrical contacts to close when oil did not flowing. Contacts to be connected in the cooler fail alarm circuit.

The omission of any, or the provision of alternative arrangements to the above requirements, will not be accepted unless approved in writing by the Engineer before manufacture.

An approved expansion piece shall be provided in each oil pipe connection between the transformer and each oil cooler bank.

### **10.12.4. FORCED COOLING**

The type of forced cooling shall be as stated in the Employer's Requirements. Forced cooling equipment for transformers of similar rating and design shall be completely interchangeable one with the other without modification on Site.

### **10.12.5. OIL PIPES AND FLANGES**

All oil piping shall be of approved material with machined flanged joints.

Copper pipe work is to comply with BS.61.

Dimensions of steel pipes shall be in accordance with BS.10220 and the drilling of all pipe flanges shall comply with BS.4504.

It shall be possible to drain any section of pipe work independently of the rest and drain valves or plugs shall be provided as necessary to meet this requirement.

### **10.12.6. AIR BLOWERS**

Air blowers for forced air cooling shall be of approved make and design and be suitable for continuous operation out-of-doors. They shall also be capable of withstanding the stresses imposed when brought up to speed by the direct application of full line voltage to the motor.

To reduce noise to the practical minimum, motors shall be mounted independently from the coolers or, alternatively, an approved form of anti-vibration mounting shall be provided.

It shall be possible to remove the blower complete with motor without disturbing or dismantling the cooler structure framework.

Blades shall be of galvanized steel unless otherwise approved.

Blower casings shall be made of galvanized steel of thickness not less than 2.6 mm (14 S.W.G.) and shall be suitably stiffened by angles or tees.

Galvanized wire mesh guards shall be provided to prevent accidental contact with the blades and to prevent access of birds and their nests. Guards shall also be provided over all moving parts. Guards shall be designed such that blades and other moving parts cannot be touched by test fingers to IEC.60529.

### **10.12.7. COOLER CONTROL**

Where multiple fan cooling using small single-phase motors is employed, the motors in each cooling bank shall be grouped so as to form a balance three-phase load.

Each motor or group of motors shall be provided with a three-pole electrically operated contactor and with control gear of approved design for starting and stopping manually. The electrical supply for the control of the cooling units shall be provided by means of two independent feeders.

Where forced cooling is used on transformers provision shall be included under this Contract for automatic starting and stopping from the contacts on the oil / winding temperature indicating device as specified.

Where small motors are operated in group, the group protection shall be arranged so that it will operate satisfactorily in the event of a fault occurring in a single motor. The control arrangements are to be designed to prevent the starting of motors totaling more than 1.5 kW simultaneously either manually or automatically.

All contacts and other parts, which may require periodic renewal, adjustment or inspection, shall be readily accessible.



Outdoor mounted fan control equipment should be housed in a weatherproof cabinet with protection grade IP 55.

All wiring for the control gear accommodated in the marshalling kiosk together with all necessary cable boxes and terminations and all wiring between the marshalling kiosk and the motors shall be included in the Contract.

The first group of fans shall come into operation at lower temperature (i.e. at 75° C hot spot temperature) and the second group at a higher temperature. (i.e. at 85° C hot spot temperature). The winding temperature shall give the starting signal for the fans and the oil temperature shall give the stopping signals.

### **10.13. VOLTAGE CONTROL**

#### **10.13.1. GENERAL**

Transformers shall be provided with voltage control equipment of the on-load tap changing type for varying the effective transformation ratio. Attention is drawn to Clause 10.13.3.

Winding taps as called for in the Employer's Requirements shall be provided on the high voltage winding. But, where stated in the Employer's Requirements, in the case of on-load tap selectors, the Bidder is at liberty to submit transformers with tap selectors on the lower voltage winding if by so doing a more economical and robust design can be offered and provided the transformer complies in all respects with Clause 10.13.2. In this event, details of the tappings shall be given in the Employer's Requirements.

All terminals shall be clearly and permanently marked with numbers corresponding to the cables connected thereto.

#### **10.13.2. ON LOAD TAP CHANGERS**

##### **10.13.2.1 GENERAL**

On-load tap changers shall comply with IEC.60214 and shall be suitable for power flow in both directions. Only designs, which have been type tested in accordance with these standards, will be accepted.

On-load tap changers of Maschinenfabrik Reinhausen manufacture are in wide use on the CEB's transformers for standardization purposes. Tap changers shall be Vacuum Type and shall be mounted from the cover into the transformer tank.

Vacuum interrupter shall be contained in a tank designed in a manner to make it impossible for the oil therein to mix with oil in the main tank of the transformer. The head of oil in this tank may be maintained by a separate compartment of the main conservator or by a separately mounted tank.

An oil surge detector relay and an oil level indicator shall be provided. The same requirements shall apply also in respect of designs in which tap selection and vacuum interrupters are accomplished by the same contacts within a tank separate from the transformer.

##### **10.13.2.2 MECHANISMS**

The tap change mechanism shall be designed such that when a tap change has been initiated, it will be completed independently of the operation of the control relays and switches. If a failure of the auxiliary supply during tap change or any other contingency would result in that movement not

being completed an approved means shall be provided to safeguard the Transformer and its auxiliary equipment.

Limit switches shall be provided to prevent over-running of the tap changing mechanism. These shall be directly connected in the operating motor circuit. In addition, mechanical stops shall be fitted to prevent over-running of the mechanism under any conditions. For on-load tap change equipment these stops shall withstand the full torque of the driving mechanism without damage to the tap change equipment. Thermal devices or other approved means shall be provided to protect the motor and control circuit.

A permanently legible lubrication chart shall be provided and fitted inside the tap change mechanism chamber.

### **10.13.2.3 LOCAL AND REMOTE CONTROL**

Equipment for local manual and electrical operation shall be provided in an outdoor cubicle mounted on the transformer. Electrical remote control equipment shall also be supplied where specified in the Employer's Requirements.

The following operating conditions are to apply to the on-load tap selector controls: -

- (a) It must not be possible to operate the electric drive when the manual operating gear is in use.
- (b) It must not be possible for two electric control points to be in operation at the same time. Operation from the local or remote control switch shall cause one tap movement only unless the control switch is returned to the off position between successive operations.
- (c) It must not be possible for any transformer operating in parallel with one or more Transformers in a group to be more than one tap out of step, with the other Transformers. In such case "Transformer out of step" alarm shall be indicated. In the case of Transformers are more than one step out of step all the tap changers shall be blocked.
- (d) All electrical control switches and local manual operating gear shall be clearly labeled in an approved manner to indicate the direction of tap changing.

### **10.13.2.4 INDICATIONS**

Apparatus of an approved type shall be provided on each Transformer: -

- (a) To give indication mechanically at the transformer and electrically at the remote control point of the number of the tapping in use.
- (b) To give electrical indication, separate from that specified above, of tap position at the remote supervisory point.
- (c) To give indication at the remote control point and at the supervisory control point that a tap change is in progress, this indication to continue until the tap change is completed.
- (d) To give indication at the remote control point and at the supervisory control point when the transformers operating in parallel are operating at more than 1 tap apart.
- (e) To indicate at the tap change mechanism the number of operations completed by the equipment.

### **10.13.3. AUTOMATIC VOLTAGE CONTROL**

Automatic Control shall be suitable for control of all transformers in parallel.

In addition to the methods of control covered by Clause 10.13.2, the following alternative methods shall be provided.

- a. Automatic independent Remote - It shall be possible to select non-automatic remote or local electrical control, or automatic remote control for each transformer irrespective of the method of independent control selected for any other of the associated transformers.
- b. Automatic parallel control in one group or independent groups. - It shall be possible to select any transformer for either group and also select any transformer in a group for master control.

It must not be possible to operate any tap changer by remote or local electrical hand control while the equipment is switched for automatic operation.

In the event of reverse power flow occurring through the transformer, the automatic voltage control function shall be automatically switched out.

### **10.13.4. VOLTAGE REGULATING RELAYS**

Automatic voltage control shall be initiated by a microprocessor based voltage regulating relay of an approved type and suitable for flush mounting. The relay shall operate from the nominal reference voltage stated in the Employer's Requirements derived from a circuit mounted LV voltage transformer having Class 3P accuracy to IEC 61869-3 and the relay voltage reference balance point shall be adjustable.

The relay bandwidth shall preferably be adjustable to any value between 1.5 times and 2.5 times the transformer tap step percentage, the nominal setting being twice the transformer tap step percentage.

The relay shall be insensitive to frequency variation between the limits as specified in chapter 1. The relay shall be complete with a time delay element adjustable between 10 and 120 seconds. The relay shall also incorporate an under voltage blocking facility which renders the control inoperative if the reference voltage falls below 80 percent of the nominal value with automatic restoration of control when the reference voltage rises to 85 percent of nominal value.

On each transformer the voltage transformer supply to the voltage regulating relay shall be monitored for partial or complete failure. The specified indicating lamp and alarm will be inoperative when the circuit-breaker automatic control controlling the lower voltage side of the Transformer is open and also that it is disconnected when the tap changer is on control other than automatic control.

### **10.13.5. SUPERVISORY CONTROL**

#### **10.13.5.1 REQUIREMENTS**

Transformer tap change control will be effected from the Sub-station Automation System in the control room. All necessary connections, indicating auxiliary switches, relays and changeover switches to meet supervisory control requirements shall be provided and connected under this Contract to terminal blocks at the transformer marshalling kiosk or cubicle or at the Transformer control cubicle, as appropriate.

The following supervisory facilities are required:

Control Selection: A multi-pole changeover selector, i.e., switch labelled "remote" and "Automation".

Controls: Tap change raise/lower by direct operation of tap changer. AVR voltage reference adjustment.

Indications and Alarms:

Refer alarm scheme specified in Chapter 5.

## **10.14. BUSHING INSULATORS AND TERMINALS**

### **10.14.1. GENERAL**

Transformers are to be provided bushing and terminals for phase and neutral terminals as required in the Technical Particulars & Guarantees.

All bushings shall comply with IEC.60137 and the minimum creepage distance for outdoor bushings shall be as specified in the Employer's Requirements and IEC 60815.

Bushings shall be provided with adjustable arcing horns.

Bushings shall be of sealed construction suitable for service under the very humid conditions at Site and, in addition, to the very rapid cooling of equipment exposed to direct sunlight when this is followed by sudden heavy rainstorms.

Typical sections of bushing insulators showing the internal construction, method of securing the top cap and methods of sealing shall be included in the Bid.

The 220/132kV bushing insulators shall be oil impregnated paper type and have no communication with the oil in the transformer. An oil gauge shall preferably be provided to indicate that the correct level is maintained. The 33/11 kV bushing insulators shall be of the oil filled or solid type.

On all condenser bushings a tapping shall be brought out to a separate terminal for testing purposes on Site.

Special precautions shall be taken to exclude moisture from paper insulation during manufacture, assembly, transport and erection. The surfaces of all paper insulators shall be finished with approved non-hygroscopic varnish, which cannot easily be damaged.

### **10.14.2. PORCELAIN**

Hollow porcelain shall meet the test requirements of IEC 62155 and IEC 60672. Hollow porcelain shall be sound, free from defects thoroughly vitrified. The glaze must not be depended upon for insulation. The glaze shall be smooth, hard, of a uniform shade of brown and shall cover completely all exposed parts of the insulator. Outdoor insulators and fittings shall be unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

The porcelain must not engage directly with hard metal and, where necessary, gaskets shall be interposed between the porcelain and the fittings. All porcelain clamping surfaces in contact with gaskets shall be accurately ground and free from glaze.

All fixing material used shall be of suitable quality and properly applied and must not enter into chemical action with the metal parts or cause fracture by expansion in service. Cement thicknesses are to be as small and even as possible and proper care is to be taken to centaur and locate the individual parts correctly during cementing. All porcelain insulators shall be designed to facilitate cleaning.

#### **10.14.3. MARKING**

Each porcelain insulator shall have marked upon in the manufacturer's name or identification mark and year of manufacture. These marks shall be clearly legible and visible after assembly of fittings and not impressed but shall be imprinted before firing.

When a batch of insulators bearing a certain identification mark has been rejected, no further insulators bearing this mark shall be submitted and the Contractor shall satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there can be no possibility of the insulators being re-submitted for the test or supplied for the use of the Purchaser.

Each bushing shall be marked with the manufacturer's name or identification mark, year of manufacture, serial number, electrical and mechanical characteristics in accordance with IEC 60137.

#### **10.14.4. MOUNTING OF BUSHINGS**

Bushing insulators shall be mounted on the tank in a manner such that the external connections can be taken away clear of all obstacles. Neutral bushings shall be mounted in a position from which a connection can be taken to a neutral current transformer mounted on a bracket secured to the transformer tank. The current transformer will be supplied by the switchgear manufacturer provision shall be made on the tank for mounting to the Engineer's requirements.

The clearances from phase to earth and phase to phase must not be less than those stated in the specification.

The line current transformers, where required, will be provided under this contract, the bushing is to be so arranged that it can be removed without disturbing the current transformers, secondary terminals and connections or pipe work.

When bushing with an under-oil end of a re-entrant type is used the associated flexible pull-through lead is to be fitted with a suitably designed gas bubble deflector.

The bushing flanges must not be of re-entrant shape, which may trap air.

Clamps and fittings made of steel or malleable iron shall be galvanized in accordance with the specification and all bolt threads are to be greased before erection.

#### **10.14.5. PHASE LOCATIONS OF 220 KV, 132KV AND 33KV BUSHINGS**

During the designing stage, the required locations for L1, L2, L3 phases in 220 kV, 132kV and 33kV side shall be obtained from the purchaser.

## **10.15. CABLES AND TERMINATIONS (FOR 31.5MVA, 45 MVA AND 63 MVA TWO WINDING TRANSFORMERS)**

### **10.15.1. CABLE BOXES AND SEALING END CHAMBERS**

All cable boxes shall have oil-tight joints and are to be tested for leaks with oil as per clause 11.8 of IEC 60076-1 and pressure deflection test as per clause 11.10 of IEC60076-1. During which time no oil leakage shall occur and no permanent deformation shall place in the structure.

### **10.15.2. DISCONNECTING CHAMBERS**

Where specified, oil-filled cable disconnecting chamber with removable links shall be provided for testing purposes. Barriers shall be provided on both sides of the disconnecting chamber to prevent ingress of the oil used for filling the chamber into the cable box or the transformer. It must only be necessary to remove part of the oil in the chamber itself when making the necessary testing connections.

The oil level in the disconnecting chamber shall be maintained from the main conservator tank by means of a connection to the highest point of the main conservator tank. Suitable valves shall control this connection. The connection to the conservator shall be made so that any gas leaving the chamber must pass through the gas and oil-actuated relay.

An earthing terminal shall be provided in each disconnecting or sealing-end chamber to which the connections from the transformer winding can be earthed during cable testing.

### **10.15.3. TESTING**

The cable boxes and disconnecting or sealing-end chambers shall be capable of withstanding those test voltages for which the transformer is designed as per this specification.

### **10.15.4. CABLES**

The HV/MV Cables will be 245 kV or 145kV (if any) and 36kV/12 kV single core XLPE insulation type. Auxiliary power and multicore control cables between the integral parts of the transformer, its marshalling kiosk or tank mounted cubicle and ancillary equipment shall be installed, glanded and have individual cores identified and terminated under this contract.

Cable from each transformer to its associated remote control and protective equipment to auxiliary supply switchboards and interconnections with other transformers will be supplied, glanded and have individual cores identified and terminated.

## **10.16. TEMPERATURE AND ALARM DEVICES**

### **10.16.1. TEMPERATURE INDICATING DEVICES AND ALARMS**

The transformer shall be provided with two approved devices of direct hot spot temperature measuring and dial type temperature monitoring equipment for indicating the hottest spot HV and LV winding temperatures.

#### **10.16.1.1 DIRECT HOT SPOT MEASUREMENT:**

The manufacturer shall use the direct hot spot measuring technique using sensors made of photo-luminescent material attached to the end of optical fiber material and in contact with the winding.

The sensor shall be sufficiently small and signal transmission system shall not degrade dielectric strength of transformer and the components used shall withstand thermal, mechanical and chemical shocks and changes of the transformer. Sensors shall be proven zero-drift, GaAs technology based on the wavelength of light. The sensors shall be directly installed in each phase of transformer to measure the winding hotspot and top oil temperatures. There shall be a total of eight (8) sensors inside the transformer, in places specified in table E.1, Annex E of IEC 60076 - 2: 2011. The locations of the probes shall be proposed by the transformer manufacturer and locations shall be finalized by agreement of CEB. The sensors shall be able to be completely immersed in hot transformer oil and they shall withstand exposure to hot kerosene vapor during the transformer insulation drying process. Sensors shall be certified by an independent high voltage testing laboratory for the ASTM test, D-2413 and D-149 for lightning impulse withstand, switching impulse withstand, AC voltage withstand and partial discharge measurement.

Temperature range of the system shall be  $-80^{\circ}\text{C}$  to  $+250^{\circ}\text{C}$  with an accuracy of  $\pm 1^{\circ}\text{C}$ .

All the measured temperatures shall be displayed simultaneously in a display mounted in local control cubical. The display should be bright enough and digits shall be large enough to see 1m away from the cubical in day light. The display unit shall withstand higher temperature and durable.

Signal conditioner shall meet IEEE C37.90.1-2002, IEC 60255-5 and IEC 6100-4-2 emissivity and EMI immunity tests on all inputs and outputs and it shall have a fail safe mode. It shall have optically isolated RS-485 serial port for local communication to the transformer monitoring system or remote communication. It shall be possible to install inside the Local Control cabinet of the Transformer. Minimum and maximum temperatures shall be retained by the signal conditioner until they are reset.

The fiber optic cable shall be brought out of the tank up to the instrument through a hole made in the tank with proper oil sealing arrangement. It is preferable that the feed through of the optical fiber cable to have independent connectors inside and outside of the transformer wall plate to prevent oil leakages during the long-term use of the transformer. Literature of the method used shall be furnished with the bid.

The signal conditioner and the sensors shall not require recalibration throughout the life time of the transformer.

The temperature device shall have separate contacts fitted with it for the following purposes:

- (1). Control of the cooling plant motors.
- (2). Winding temperature high alarm.
- (3). Oil temperature high alarm

The continuous measured oil and winding temperature trend curve shall be plotted and to be integrated with DFR to monitor past temperature trend curve of the transformer along with the loading current. All historical trend curves and data should be saved inside and kept for reference at any time without wipe out with time.

Calculation of locations of winding hotspots shall be provided using finite element thermo-fluid analysis. Photographs of fiber optic sensor installed locations for each winding shall be submitted to CEB within one week from the installation for approval.

### **10.16.1.2 DIAL TYPE TEMPERATURE INDICATORS**

In addition to clause 10.16.1.1, winding temperature indication, trip and alarm devices and oil temperature indication, trip and alarm device with dial type indicator and a pointer to register the highest temperature reached shall be provided as backup indication, trip and alarm devices. The instrument shall have three sets of contacts, one for alarm and one for trip, and one for stopping the fan motors shall be operated from a sensing bulb installed in the top of the transformer tank. The oil temperature indicator shall be installed in the transformer marshalling kiosk. The tripping contacts are to be adjustable to close between 60°C and 120 °C and re-open when the temperature has fallen by not more than 10°C. The alarm contacts shall be adjustable to close between 50°C and 100°C and to re-open when the temperature has fallen by not more than 10°C.

The alarm contacts and the contacts used to control the cooling plant motors and initiate automatic start-up of the reserve cooler on the above devices shall be adjustable to close between 50°C and 100°C and to re-open when the temperature has fallen by a desired amount between 10°C and 15°C.

All contacts shall be adjustable to a scale and must be accessible on removal of the cover. Alarm and trip circuit contacts shall be suitable for making or breaking 150 VA for 250 volts AC and 245 V DC and for making 500 VA for 250 V AC and 245 V DC. Cooler motor control contacts shall be suitable for operating the cooler contactors direct, or if necessary, through an auxiliary relay.

The temperature indicators in the marshalling kiosk shall be so designed that it is possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment.

The working parts of the instrument shall be made visible by the provision of cut-away dials and glass-fronted covers and all setting and error adjustment devices shall be easily accessible.

Connections shall be brought from the device to terminal boards placed inside the marshalling cubicle.

Terminals, links and a 63 mm moving iron ammeter shall be provided in the marshalling kiosk for each Winding Temperature Indicator for: -

- a. Checking the output of the current transformer.
- b. Disconnecting the bulb heaters from the current transformer secondary circuit to enable the instrument to be used as an oil temperature indicator.

### **10.16.2. GAS AND OIL ACTUATED RELAYS**

Each transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts, which close on collection of gas or low oil level, and tripping contacts which close following oil surge conditions.

Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

Each relay shall be fitted with a calibrated glass window for indication of gas volume.

To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point approximately 1400



mm above ground level, where it shall be terminated by a cock which shall have provision for locking to prevent unauthorized operation.

The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal operation of the relays will not take place under normal service conditions, including starting or stopping of oil circulating pumps whether by manual or automatic control under all operating temperatures.

The pipe work shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, or is to be teed into or connected through the pressure relief vent. Sharp bends in the pipe work shall be avoided. When a transformer is provided with two conservators the gas and oil-actuated relays shall be arranged as follows: -

- (a) If the two conservators are connected to the transformer by a common oil pipe one relay shall be installed in the common pipe.
- (b) If the two conservators are piped separately to the transformer two relays shall be installed, one in each pipe connection.

The clearance between oil pipe work and live metal is to comply with the specifications as specified.

### **10.16.3. FACILITIES FOR FUTURE FITTING OF CONDITION MONITORING SYSTEMS TO TRANSFORMERS**

When specified in the scope of works, manufacturer shall provide the necessary facilities for the future fitting of monitoring systems to the offered transformer recommended in table F.1 in Annex F of IEC 60076-1.

### **10.17. ALARMS**

One electrically independent N.O./N.C. (C-form) contact shall be furnished for each alarm condition. Each form contact shall be wired to isolated terminal points in the control cabinet for use by the Owner for SCADA system and/or substation annunciator alarms.

Contacts shall be furnished for the following:

#### Trip Alarms:

Buchholz trip

Winding Temperature trip

Oil Temperature trip

Buchholz Gas

Tap Change Oil Surge trip

Tap change oil level trip

Tap change Buchholz trip

Oil level low trip

Pressure relief valve trip

Tap change pressure relief trip

Non Trip Alarms:

Heater AC supply fail  
Winding temperature alarm  
Oil temperature alarm  
Transformer – pressure alarm  
Low oil level  
Oil level high  
Marshalling kiosk supply fail  
Tap changer AVR internal fail  
Cooling fan fail ( Group A / Group B)  
Air Forced cooling over current  
VT fail  
Tap Changer in progress. (Only indication)  
Air forced cooling equip group running (Only Indication)  
Oil Temperature (Only Indication)  
Supply Voltage to OLTC failure. (Only Indication)  
Tap position Indications to Control  
Tap Change Control “On Local” (Only (Indication))

**10.18. CONDITION REPORT DURING THE MANUFACTURING OF THE TRANSFORMER**

The detailed condition report about its manufacturing stage shall be submitted along with invitation letter of FAT and which should include followings in minimum;

- a. Design review completion certificate issued by CEB
- b. CEB approved protective coating system
- c. Photographs of tank top plate before painting
- d. Hot spot sensor location photograph
- e. Any NCR raised during the manufacturing process
- f. Permissible shock values

g. Material test certificate

- Cu
- Lamination material
- Ball and Gate Valves
- Pipe Lines
- Flanges
- Metal Plates
- Insulation materials
- T/F Oil

CEB shall be immediately notified of any unusual damage occurring during construction of the transformer and of all tests which do not meet specified or standard values. The CEB shall be permitted, at his option, to personally inspect such damages and/or test failures

## **10.19. SHIPMENT AND DRYING OUT**

### **10.19.1. SHIPMENT**

Before shipping, transformer shall be completely assembled and filled with oil and Pressure tested to determine that all parts fit properly and no leaks are present. Parts removed for shipment shall be marked so as to permit easy identification for assembly in the field.

Each transformer when prepared for shipment shall be fitted with impact recorder which shall remain in situ until the transformer is delivered to Site.

The impact recorder shall be switched off in the presence of the Engineer if the transformer is kept in a place for a long time and shall switch on when it is carried back to the site.

The impact recorder shall be jointly inspected with the employer at the site and recorded data shall be forwarded to the Employer for approval before the installation, including the analysis software which shall be compatible for Windows 7/8/10, 32/64 bit operating systems with graphic signal analysis & export functions and frequency analysis of shock as per EN13011. The recorder data download shall be possible via USB (or wireless IR/Bluetooth). Procedure for turning off of the impact recorder shall be provided to the employer before dispatching the transformer from the factory.

#### Impact Recorder

Impact recorder battery life shall be adequate until the transformer is delivered to site and recorder memory shall be non-volatile at least up to 3 months.

Impact recorder shall be 3D - accelerometer impact recorder with measurements in X, Y and Z axis (both plus and minus directions). The impact recorder(s) should have the possibility to measure acceleration events with 3D curve in the range of 1024ms or more. The number of such stored events must be sufficient for the transport. Acceleration range should be adjustable up to 10g with a frequency range of 1-100Hz. In addition the impact recorder should also be able to register both dynamic inclination curves and time-synchronous inclination events.

In case of transportation without oil one impact recorder should also be fixed to the active part during the transportation and one outside the tank. A master-slave connected system could be of value as events inside and outside the tank will be time synchronized.

Impact recorder mounting

- the impact recorders should be bolted rigidly to the transformer tank (or active part).
- Impact recorders on the transformer tank should be mounted at or near the location where the transformer is supported by the transport vehicle.
- The mounting location inside the tank is dictated by accessibility, i.e. Near a manhole or cover of bushing turret. Fixing to the core and coil clamping system is a good option.
- The mounting orientation is irrelevant as long as the axis of the impact recorder align with the axis of the transformer.
- The mounting location should be rigid, preferably near the corner of three intersecting surfaces, i.e. bottom plate near a stiffener and the tank wall.

Impact records

Manufacturer shall provide maximum allowable readings for the safe transportation filled in following table in advance.

Axis	Outside tank	Inside tank	Duration (cont. or msec)	Comments
	Max g-forces used for the design			
longitudinal				
Vertical				
Lateral				

In the event that the transformer is found to have been subjected to excessive shock/impact or the impact recorder has been damaged in transit, the transformer shall be brought back to the factory for necessary inspection. Such examination as is necessary shall be made in the presence of the Engineer.

The purchaser's inspector shall witness inside abnormalities of the transformer and Factory Acceptance Tests shall be repeated after the necessary repairs. All the expenses including travelling and accommodation incurred for sending the purchaser's inspector to the factory shall be borne by the Manufacturer.

Shipping Documents

Manufacturer shall furnish packing list for each crate or container. Each crate or container shall be numbered or lettered to correspond with the packing list furnished. Packing list shall specify quantity of various items with their serial number, catalog number, purchase order number, or other specific identifying information to facilitate check-off of material when received.

Manufacturer shall furnish receipt, handling, and storage instructions that affect warranties and/or guarantees and that may be used to preserve integrity of equipment placed in outdoor storage. A preliminary set of instructions shall be furnished with the bid.

#### Transportation without oil

If the transformer is transported without oil, provision should be made to prevent the ingress of moisture and to maintain the internal insulation in first-class condition. In addition the transformer should be filled with breathable dry gas and maintained at a continuous positive pressure. The air pressure and dew-point should be monitored continuously throughout the period immediately after the oil is removed until the transformer is refilled with oil at site. At all times alternative standby means should be provided to restore any loss of air pressure immediately.

The dew point of the dry air should be measured and recorded to ensure it is below  $-40^{\circ}$  C. The dew point should be checked again within 24 hours of the oil having been removed and the transformer dry air filled, the measurements being recorded in the test report and on the shipping tag. If the dew point readings indicate an average moisture level at the surface of the transformer cellulose insulation is higher than 0.5%, the manufacturer must dry the transformer. The estimation of average moisture level shall be done as per IEEE Std. C57.93 and forward for approval before dispatching. The air pressure and dew-point should be monitored immediately before the transformer is refilled with oil at site. **The estimation of average moisture level shall be again done as per IEEE Std. C57.93. If it exceeds 0.5% average moisture level, drying out at site shall be done to the satisfaction of CEB.**

#### **10.19.2. DRYING OUT**

The transformer shall be dried to less than 0.5% moisture content in cellulose insulation (by dry weight of cellulose). The entire active part of the transformer shall preferably be using by vacuum vapour pressure drying at the manufacturer's works and so arranged that the transformer shall be put into service without further extended drying out at Site. Literature of the vapour pressure drying plant facility available at the manufacturer's work and description of complete drying process of windings and active part shall be furnished with the bid.

Clear instructions shall be included in the Maintenance Instructions regarding any special precautionary measures which must be taken before the specified vacuum is applied to the transformer.

The employer considers seriously the moisture content in cellulose insulation and, hence vapour pressure drying (or approved type) and workmanship thereafter shall be maintained at a extremely high level of standard. Further, employer adopts estimation of moisture in cellulose insulation by using Ommen's Equilibrium curves and Dielectric Frequency Response Analysis Techniques during commissioning at site, in addition to the estimation of average moisture level as per IEEE Std. C57.93 using dew point. If any serious deviation exists from 0.5% moisture content in cellulose insulation, the transformer may be liable for rejection.

### **10.19.3. OIL STORAGE**

The Contractor shall supply the first filling of transformer oil, which in accordance with IEC 60296. It is envisaged that the oil will be supplied to site in 200 L drums and filtered by use of the plant described in the preceding paragraph into the Employer's mobile storage tank prior to transfer again via filter plant into the transformer.

### **10.19.4. OIL TREATMENT PLANT (IF SPECIFIED IN SCOPE OF WORKS)**

Plant for the treatment of transformer oil at site shall be mounted on steerable trailer equipped with pneumatic tyres, over-run and parking breakers and weatherproof canopy. The plant shall be capable of treatment of oil to IEC 60296 and IEC 60422, shall be of the replaceable paper filter type and shall have the following facilities: -

- a) Oil treatment rate not less than 400lit/hour.
- b) Water extraction capability down to 5ppm.
- c) Reduction of dissolved gas content to 1% by volume or less.
- d) Oil transfer, vacuum pumps and heaters suitable for 415V 3 phase 50Hz, 4 wire supply.
- e) Vacuum capability approximately 1 Torr.
- f) Facility to apply vacuum to transformer tank during oil filling.
- g) Two 15m lengths of wire reinforced housed coloured differently for clean and dirty oil.
- h) One 20m length of power supply cable with plug and socket at the filter end only.

### **10.19.5. TRANSFORMER OIL**

Transformer and switchgear oil shall be compatible with that available in Sri Lanka. Transformer oil available in Sri Lanka has the following characteristics:

Type of Oil - uninhibited class 1

Required Standard - IEC 60296/ BS 148

Offered transformer oil shall meet general specifications specified in table 2 of IEC 60296.

### **10.19.6. DESIGN REVIEW**

#### **10.19.6.1. GENERAL**

The selected bidder with the **consultation of manufacturer's design engineers and experts** shall conduct an in-depth review of the offered power transformer at site to allow CEB to have a clear understanding of the transformers design, manufacture and test including the likelihood of operating in service as intended. The electrical, thermal and mechanical draft design, documents, the dimensional drawings, the rating plate drawings shall be completed by the manufacturer at the time of design review.

The following the subjects of shall be clearly presented to the CEB representatives during the design review.

- Core
  - A general description of the core design & material

- Geometry and cross section data
  - Special issues of the core design
- Windings
  - Winding arrangement & material
  - Cross section and number of turns
  - Insulation design
- Thermal design
  - Losses
  - Cooling
  - Temperature
- Short circuit withstand capability as per IEC 60076-5
  - Thermal ability to withstand short circuit
  - Ability to withstand the dynamic effects of short circuit
- Core, Winding Assembly and Drying
- Leads and Cleats
- Insulation Design & material
- Leakage Flux Control
- Drying and Processing
- Sound Level
- Seismic
- Tank, Radiators, Turret & Conservator
  - Design & Drawings
  - Fabrication
  - Testing
  - Surface Preparation and Painting
- Ancillary Equipment
  - HV, LV & Neutral Bushings
  - Bushing/Internal Current Transformers

- Buchholz Relay
- Pressure Relief Device
- Valves
- Breather
- Offline Tap Changer
- Control Cabinet and External Cabling
- Cooling fans/oil pumps
- On-line Monitoring Equipment
- Testing at factory
- Transportation
  - Design for Transport
  - Transportation Route and Preparedness
  - Transportation Shipping Impact Withstand
  - Marking of Center of Gravity
  - Transportation monitoring management of transformer
    - Type/Location of Impact Recorder
  - Transportation of transformer accessories, components removed from the transformer
  - Acceptance criteria for receiving transformer
  - Transformer Unloading at site
- Commissioning Testing at Site

The bidder shall bear all the costs incurred for this design review.

#### **10.19.6.2. EVALUATION OF ABILITY TO WITHSTAND THERMAL AND DYNAMIC EFFECTS OF SHORT CIRCUIT**

At detailed design stage, manufacturer shall submit evaluation of ability of withstanding thermal and dynamic of short circuit within 4 weeks from contract award.

Following documents, drawings and calculations shall be submitted with this evaluation as per IEC 60076-5 Annex A.

##### **Documents required under Clause A.3.2**

- Electromagnetic design data sheets as needed for calculation



- Drawings or sketches of the complete winding and insulation arrangement within the core window with indication of the types of material
- Calculation of the short-circuit current values (both peak and symmetrical r.m.s. values) affecting each single winding as a result of the service duty requirements specified and types of fault taken into consideration, with also due regard to the tapping positions in case of winding(s) provided with taps.
- Calculation of the main short-circuit forces (peak values occurring at the highest peak of the respective current), with reference to the fault cases, tapping positions and geometrical and relative positions of windings considered for design purposes. Full information has to be given if any simplified geometrical configurations have been adopted for the windings, core and tank for the purpose of magnetic leakage field and electromagnetic force calculations.
- Calculation of basic mechanical stresses on winding conductors and adjacent mechanically coupled structures originated by the short-circuit forces.
- Drawings, sketches, or computer outputs, concerning the winding support structure and core-and-coil clamping arrangement
- Instructions for quality assurance and quality control concerning both materials and manufacturing practices, with specific reference to manufacturing activities
- Checks concerning main transformer external components, in particular high-voltage bushings, especially in the case where they are slope-mounted on turrets, etc.

#### **Calculation of EM Forces (Clause :A.3.2 (d))**

- radial inward or outward force on each physical winding
- maximum axial compression force on each physical winding ( $F_c$ )
- maximum axial end thrust force (up/down) on each physical winding
- maximum axial force-per-limb on common press ring (or plate), if used, and core clamps
- thrust force acting on the lead exits of each main low-voltage winding ( $T^*f$ )

#### **Calculation of Stresses (Clause: A.3.2 (e))**

- mean hoop tensile stress on outer windings ( $\sigma^*t$ )
- mean hoop compressive stress on disc-, helical-, single-layer-type inner windings ( $\sigma^*c$ )<sup>12</sup>
- equivalent mean hoop compressive stress on layer-type inner windings
- stress due to radial bending on conductors in the span between axial sticks and between spacers used to build any axial cooling ducts within the winding radial width

- stress due to axial bending on conductors in the span between radial spacers with disc- and helical-type windings
- compressive stress on radial spacers with disc- and helical-type windings
- compressive stress on conductor paper insulation with layer-type windings
- compressive stresses on end stack insulation structures and end rings
- compressive stress on common press rings (or plates)
- tensile stress on tie rods (flitch plates) of the clamping structure

**Drawings (Clause: A.3.2 (f))**

- arrangement of the radial supports against the core limb
- configuration of the end stack insulation structures
- Arrangement of common press rings
- overall core-and-coil clamping arrangement
- means for securely fastening the winding lead exits and LV connection leads or bars to the bushings and lead runs to tap-changers
- means for the application of any axial pre-load

**Instructions for Quality Assurance and Control (Clause: A.3.2 (g))**

- winding of the conductors on the mandrel and control of the pulling force
- sizing and elastic stabilizing of windings and coils
- assembling within specified tolerances
- drying and impregnation with oil
- application of pre-load
- fastening/securing of winding supports
- leads and clamping devices

**Acknowledgement of the manufacturer's design information for short-circuit strength (Clause A.3.3.3.1 )**

- The list of transformers built by the manufacturer which have been subject to the short-circuit test, including main transformer data, such as rated power, rated voltage, tapping range, and short-circuit impedance

- The results of the tests performed on models, if any, and their impact on the design rules
- The contents of the technical standards for short-circuit strength of power transformers used by the manufacturer in regular design and production activities
- Service records and in-field failure rates as regards short-circuit performance
- The number of units produced and the number of service years of successfully operated transformers

**Checking procedure (Clause A.3.3.3.2)**

- Preliminary examination of the winding and main insulation structures and clamping arrangement of the transformer
- Comparing any force and stress values calculated on the transformer with the corresponding allowable or critical values that the manufacturer has adopted in his design practice

If any of document or documents could not be provided due to proprietary nature of information, manufacturer shall show the those documents to engineer at employers' premises or manufacturers' premises.

Information Copy - Not for Bidding

## **10.20. 220/33 KV, 132/33 KV AND 132/11 KV TRANSFORMERS**

### **10.20.1. GENERAL**

The 220/33 kV, 132/33 kV and 132/11 kV transformer shall comply with the general requirements of the specification and the particular requirements of this chapter.

### **10.20.2. CONTINUOUS MAXIMUM RATING**

The transformer shall have the continuous maximum rating (CMR) stated in Employer's Requirements when operating as ONAF.

### **10.20.3. IMPEDANCE**

The transformer shall have impedance between the 220 kV (or 132 kV) and 33 kV (or 11 kV respectively) windings as stated in Employer's Requirements. The impedance on other tapplings shall be stated in Technical Particulars and Guarantees.

It is preferred that the equivalent zero sequence impedance of the transformer, when viewed from the 220 kV (or 132 kV) terminals is not less than the positive sequence impedance between 220 kV (or 132 kV) and 33 kV (or 11 kV respectively) terminals at normal ratio normal rating. The value shall be stated in Technical Particulars and Guarantees on the basis of system short circuit levels stated in Employer's Requirements.

### **10.20.4. WINDING TERMINATIONS**

Terminations of delta connected windings and neutral ends of windings shall be as follows: -

- (i) Neutral ends of the three phase windings shall be connected at points accessible from hand holes in the cover and brought out via one bushing insulator.
- (ii) Delta windings shall be closed within the tank and the termination shall be brought into cable termination boxes.

### **10.20.5. VOLTAGE CONTROL**

Winding taps for the transformer shall be provided on the 132 kV neutral end.

### **10.20.6. TEMPERATURE INDICATING DEVICES AND ALARMS**

The transformer shall be provided with separate winding temperature indicators associated with the main and delta connected windings.

## **10.21. 220/132/33 KV AUTO CONNECTED TRANSFORMERS**

### **10.21.1. GENERAL**

Auto connected transformers when required for interconnection between the 220 kV and 132 kV system shall comply with the general requirements of the specification and the particular requirements of this Chapter.

The auto-transformers will be star connected and the system will be solidly earthed at each auto transformer neutral.

A 33 kV delta connected tertiary winding shall be provided to supply the future capacitor banks.

The tank shall be designed without pockets in which gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipes.

Drains valves and valves for oil sampling (top and bottom) shall be provided at convenient floor height.

### **10.21.2. CONTINUOUS MAXIMUM RATING**

The auto-transformers shall have the continuous maximum rating stated in Scope of Works in Employer's Requirements and be provided with a delta connected winding capable of supplying the load stated in the Employer's Requirements. No compensation shall be made to the rating of the series or common windings of the auto-transformer for any limitation in output consequent on the tertiary load, but Technical Particulars & Guarantees shall be completed showing any restriction in 132kV output, for conditions of input from the 220 kV system, with the tertiary winding fully loaded and with varying 132kV and tertiary power factors of their respective loads down to 0.8 lagging.

The transformers shall be capable of operating continuously at their rated power within the specified temperature rise limit at 10% over or under excited operation. This is applicable for all tap changer settings and all forced cooling in operation.

### **10.21.3. IMPEDANCE**

Auto transformers shall have an impedance between 220kV & 132kV windings as stated in Employer's Requirements. The impedance on other tappings and between other windings shall be stated in Technical particulars and Guarantees.

It is preferred that the equivalent zero sequence impedance of the auto-transformer, when viewed from the 220kV terminals and feeding a fault at the 132kV terminals is not less than the positive sequence impedance between 220kV and 132kV terminals at normal ratio and normal rating. The value shall be stated in Technical particulars and Guarantees on the basis of system short circuit levels stated in Scope of Works. Built in short circuit limiting reactors, if any, shall only be installed in the main tank. A separate tank, appended to the main tank is not acceptable.

### **10.21.4. WINDING TERMINALS**

Terminations of delta connected windings and neutral ends of windings shall be as follows:

- (i) Neutral ends of the phase windings shall be connected at a point outside the transformers.
- (ii) Delta windings shall be closed outside the transformers.

Where delta windings are initially loaded, the delta windings shall be terminated as stated above. The system supplied by the delta winding will be separately earthed.

### **10.21.5. TAP CHANGING**

Single-phase Tap-changers are required on 132kV winding and 33 kV winding or as per employers requirement. The 132 kV tap changer shall be provided on the line end. Tap-changers shall comply with Clauses 10.13.2. The tap changers of Auto-transformer winding shall be insulated for the higher of the two voltage levels.

### **10.21.6. TEMPERATURE INDICATING DEVICES AND ALARMS**

Auto transformers shall be provided with separate winding temperature indicators associated with the series, common and delta connected windings.

### **10.21.7. CURRENT TRANSFORMERS**

Where required built-in current transformers for protection shall be provided for 132kV and 33 kV differential REF and over-current protection plus neutral terminal CT's for REF & SBEF protection. The technical data shall be coordinated with the protection requirements and the related switchgear CT's. Where built-in CT's are provided, the related bushing, connection boxes and cable terminal boxes shall be arranged to be removable without interfering with the CT.

## **10.22. EARTHING & AUXILIARY TRANSFORMERS**

### **10.22.1. EARTHING TRANSFORMER**

#### **10.22.1.1 GENERAL**

Earthing transformers shall comply with IEC 60076-6 and shall be of the oil immersed ONAN type suitable for outdoor installation and are to have a main zigzag winding which will be directly connected to the 11 kV/33 kV terminals of the associated main transformer.

The neutral point of the zigzag winding shall be brought out of the tank through a bushing insulator. This point will be connected to earth directly in order to provide an earthing point for the neutral of the system.

#### **10.22.1.2 ELECTRICAL AND SHORT CIRCUIT CHARACTERISTICS**

The maximum fault current for a solid earth fault on the earthing transformer terminals shall not exceed the value given in the Employer's Requirements. To achieve this earthing transformer minimum zero sequence impedance per phase shall not be less than the value given in the Employer's Requirements.

Under the condition of a solid earth fault in the transformer terminals, limited only by the earthing transformer zero sequence impedance, the earthing transformer shall be capable of withstanding this condition, both thermally and dynamically without damage.

Additionally, earthing transformers shall, when operating continuously at any load up to CMR, be capable of withstanding for three seconds the current obtained when a short circuit is applied between any or all of the lower voltage terminals with full line voltage maintained at the higher voltage terminals.

The foregoing conditions shall assume an initial winding temperature which is the sum of the maximum ambient temperature stated in Employer's Requirements and the temperature rise obtained by continuous operation at CMR.

### **10.22.2. AUXILIARY TRANSFORMER**

#### **10.22.2.1 GENERAL**

Auxiliary transformers shall comply with IEC 60076 and shall be of the hermetically sealed oil immersed ONAN type suitable for outdoor installation. Auxiliary transformers shall also be provided with off load tap change from -10% to +5%, arranged to give a 400/230 V, three phase, four wire

supply. The auxiliary transformer winding shall have the continuous rating stated in the Employer's Requirements and shall conform to IEC.60076.

#### **10.22.2.2 TERMINALS AND CONNECTIONS**

The three-phase, four-wire connections from the transformer windings shall be terminated at a three-pole combined switch-fuse unit with bolted neutral link and gland entry for a four-core solid dielectric cable. This shall be accommodated in a lockable, fully weatherproof compartment together with a neutral earthing link. The purpose of the neutral earthing link is to connect the 400V system neutral to earth. It shall be connected between the transformer winding end of the neutral link and a suitably located earthing terminal to which the system earth can be connected. Three L.T. surge arresters shall be provided.

An earthing terminal shall be provided on the transformer core frame with a cross bonding connection to the main earthing terminal which shall be provided at the base of the cubicle.

Three spare fuses shall be supplied with each transformer.

#### **10.22.3. TANKS AND FITTINGS**

Earthing transformer & Auxiliary transformer shall be provided with the following necessary fittings:-

- A) Conservator vessel with removable end cover and prismatic oil gauge.
- B) Buchholz Protector.
- C) One thermometer pocket with captive screw cap.
- D) Silica gel breather of the oil seal type with a minimum capacity of 2 kg.
- E) Pressure relief device.
- F) Filter valve and combined filter and drain valves.
- G) Oil sampling device.
- H) Oil and winding temperature gauges
- I) HV cable box
- J) LV cable box

#### **10.23. QUALITY ASSURANCE**

A Quality Inspection and Test Plan (QITP) should be submitted with each tender and agreed with the purchaser before contract.

Any subsequent alteration to and deviation from the agreed QITP should be submitted to the purchaser in advance for approval in writing. No changes to the QITP ought to be permitted without the prior written approval of the purchaser.

#### **10.24. UNLOADING EQUIPMENT**

Special attention has to be given for unloading the transformers as the harbour in Colombo as today has limited facilities (Maximum lifting capacity under spreader – 65000 Kg, Maximum lifting capacity under hook beam – 75000 Kg) to handle such heavy equipment. Also the transport to site by trailers etc. has to be thoroughly planned by the Contractor, with regard to max. Permissible

loads for roads and bridges or other obstacles and detailed information has to be included in the Bid.

Inside the boundaries of the substations under this project, it is the Contractors responsibility to construct any means required for an easy moving of the transformers onto their foundations, as for example access roads, temporary crossings of culverts or drains, temporary dismantling of existing facilities etc.

For movement and alignment of the main transformers on site, 8(eight) hydraulic jacks of 100t and 50t respectively, each with common hand operated oil pump and housing system and all accessories and spare parts as necessary are to be included in the scope of supply. Individual hand operation shall also be possible. The final capacity shall be matched to the heaviest transformers.

Furthermore, twelve heavy duty tank type steel rollers, and ten numbers 1 cm high, 2m by 1m steel sheets for offloading of the transformers together with 10m<sup>3</sup> heavy wood oil impregnated, rectangular sectioned timber logs of assorted length between 0.5m and 3m and assorted thickness between 5cm and 20cm shall be supplied.

## **10.25. TEST AT MANUFACTURE'S WORK**

### **10.25.1. MAIN TRANSFORMERS**

Each of the transformers shall be subject to acceptance tests to be performed at the Contractor's premises (and at site) in order to verify their conformity with the guaranteed and other design data. The methods of testing shall be submitted for approval at least three months before testing. The transformers shall be completely assembled in every respect. All of the tests shall be performed with all original bushings installed. Deviations from this requirement should be by agreement between the purchaser and manufacturer.

The tests shall be performed in accordance with the latest issues of the recommendations of the (International Electro-technical Commission) IEC, in particular IEC 60076 and IEC 60060.

The Contractor is obliged to submit a detailed test program (including detailed test connections for all dielectric tests) for approval in due time, prior to the tests (at least three months before testing). Detailed test schedules separately for each unit showing exactly when each of the tests will be carried out shall be submitted for approval at least six weeks prior to the tests.

Test equipment must have a valid calibration certificate, which should be available for inspection at the test location before starting any tests.

The following test shall be performed in the presence of the Employer/Engineer:

#### Routine Tests

Routine test shall be according to the IEC 60076, part 1, clause 11.1.2.

- a) Measurement of winding resistance (11.2).
- b) Measurement of voltage ratio and check of phase displacement (11.3).
- c) Measurement of short-circuit impedance and load loss (11.4).



- d) Measurement of no-load loss and current (11.5).
- e) Dielectric routine tests (IEC60076-3). (For non-uniformly insulated transformers of category 72,5 kV <  $U_m \leq 170$  kV as per Table 1 of IEC 60076-3-2013, LTAC shall be performed on all units.)
- f) Tests on on-load tap-changers (11.7).
- g) Leak testing with pressure for liquid-immersed transformers (tightness test) (11.8).
- h) Check of the ratio and polarity of built-in current transformers.
- i) Check of core and frame insulation for liquid immersed transformers with core or frame insulation (11.12).
- j) Insulation of Auxiliary wiring (IEC 60076 , part 3)
- k) Partial discharge measurement (IEC 60076 , part 3)
- l) Determination of capacitances windings-to-earth and between windings (test shall be conducted on multiple voltages)
- m) Measurement of d.c. insulation resistance and polarity index between each winding to earth and between windings.
- n) Measurement of dissipation factor ( $\tan \delta$ ) of the insulation system capacitances. (test shall be conducted on multiple voltages)
- o) Measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment.
- p) Measurement of no-load loss and current at 90 % and 110 % of rated voltage (11.5).

**Note:** Tests e, g, i, k, l, m, n and o shall be performed after temperature rise test.

Type Tests (apply only for one transformer.)

Type test shall be according to the IEC 60076, part 1, clause 11.1.3.

Special test (apply only for one transformer.)

Special test shall be according to the IEC 60076, part 1, clause 11.1.4 -

- a) Dielectric special tests (IEC60076-3).
- b) Winding hot-spot temperature-rise measurements.
- c) Determination of capacitances windings-to-earth, and between windings.
- d) Measurement of dissipation factor ( $\tan \delta$ ) of the insulation system capacitances.

- e) Determination of transient voltage transfer characteristics (Annex B of IEC60076-3:2000).
- f) Measurement of zero-sequence impedance(s) on three-phase transformers (11.6).
- g) Short-circuit withstand test (IEC60076-5). (Bidder shall understand that, short circuit withstand test as per IEC 60076-5 will have to be performed at the manufacturer's work or the nearest accredited High Voltage Laboratory if the manufacturer fails to provide successful theoretical evaluation of the ability to withstand the dynamic effects of short circuit as per IEC 60076-5, version 2006. Total cost of short circuit test and witnessing of test shall be borne by the manufacturer. Therefore manufacturers are advised to evaluate their own ability of submitting successful short circuit theoretical evaluation before bidding.)
- h) Measurement of d.c. insulation resistance each winding to earth and between windings.
- i) Vacuum deflection test on liquid immersed transformers (11.9).
- j) Pressure deflection test on liquid immersed transformers (11.10).
- k) Vacuum tightness test on site on liquid immersed transformers (11.11).
- l) Measurement of frequency response (Frequency Response Analysis or FRA). The test procedure shall be agreed between manufacturer and purchaser. Tests shall be performed on following minimum test configurations. This test shall be performed on all the units.
  - 1. End to end open circuit measurements
  - 2. End to end short circuited measurements
  - 3. Capacitive inter winding
  - 4. Inductive inter winding
- m) Check of external coating (ISO 2178 and ISO 2409 or as specified).
- n) Measurement of dissolved gasses in dielectric liquid.
- o) Mechanical test or assessment of tank for suitability for transport (to customer specification).
- p) Determination of weight with transformer arranged for transport. For transformers up to 1,6 MVA by measurement. For larger transformers by measurement or calculation as agreed between manufacturer and purchaser.
- q) Measurement of the harmonics of the no-load current
  - r) Level of the TF top plate
  - s) Markings in bushings and phase locations
  - t) Dielectric Frequency Response Analysis and estimation of moisture in cellulose insulation.
  - u) Oil Tests before and after temperature rise tests (Breakdown voltage, Interfacial tension & Moisture in Oil)

**Note:** Tests a, c, d, e, h, i, j, k, l, n and Measurement of sound level test shall be performed after temperature rise test.

## **10.25.2. EARTHING AND AUXILIARY TRANSFORMERS**

### Routine Tests

- a) Measurement of winding resistance (11.2).
- b) Measurement of voltage ratio and check of phase displacement (11.3).
- c) Measurement of short-circuit impedance and load loss (11.4).
- d) Measurement of no-load loss and current (11.5).
- e) Dielectric routine tests (IEC60076-3).
- f) Leak testing with pressure for liquid-immersed transformers (tightness test) (11.8).
- g) Check of the ratio and polarity of built-in current transformers.
- h) Check of core and frame insulation for liquid immersed transformers with core or frame insulation (11.12).
- i) Insulation of Auxiliary wiring (IEC 60076 , part 3)
- j) Measurement of zero-sequence impedance
- k) Insulation resistance of each winding
- l) Measurement of capacitance and power factor

### Type tests

- (1) Temperature rise test:

Unless acceptable type test certificates can be submitted in respect of a transformer similar in design to that specified a temperature rise test shall be carried out and the costs shall be included in the contract price.

This test shall take into account temperature rise due to both the specified earth fault current and continuous operation at CMR of the auxiliary winding.

- (2) Impulse-voltage withstand (full wave) test

### Special Tests

- (1) Short-circuit current withstand test included in IEC 60076.

### **10.25.3. ACCEPTANCE CRITERIA FOR FACTORY ACCEPTANCE TESTS**

If the results of the inspection are not within the offered values, CEB shall have the right to reject the transformer as defective.

If any defect arises during the testing of the transformer and CEB representative for the inspection considers the defect as a major defect then the transformer will be rejected as defective will not be accepted after the repairs by the manufacturer. In which case the manufacturer shall agreed to replace the transformer with a new design without any additional cost.

However If the CEB representative considers the defect as a minor defect and manufacturer request for repair and re-inspection, this may be considered subjected to the following,

1. Dismantling and inspection of the transformer for repairs shall be done in the presence of an Engineer nominated by Ceylon Electricity Board. The manufacturer shall agree to bear the cost of travelling and accommodation of the representative nominated by CEB for the period of dismantling & inspection of the defective transformer.
2. All the Routine Tests specified in Clause 10.25 must be repeated. Manufacturer shall agree to bear the cost of travelling and accommodation of the representative nominated by CEB for the period of testing of the repaired defective transformer

If CEB decides that the repair to be executed at the manufacturer's work, the cost of transporting the transformer back to the manufacturer's works and rectifying the defects shall be at the manufacturer's expense. In this case the factory acceptance test shall be repeated according to the above conditions 1 and 2. Total cost for transportation back to the site, installation and commission shall be at manufacture's expense.

### **10.26. SITE ACCEPTANCE TESTS**

Prior to removal from the transporter at site, following tests shall be carried out to ascertain if any damage has occurred in transportation.

- insulation resistance measurement of core and frame insulation, winding insulation to earth and between windings
- frequency response analysis
- interrogation of shock recorders fitted for transport

After the assembly of the transformer at site, following tests should be performed as a minimum to verify that the unit has not been damaged during transport and that it has been erected correctly.

- Voltage ratio
- Vector group
- Insulation resistance measurement

- all windings to earth
- between windings
- current transformer windings to earth
- between current transformer windings
- control cabling
- auxiliary power cabling
- between core and tank
- between core and core clamping
- Check of protective earthing connections
  - bushing turrets
  - on load tap changer and motor drive
  - cubicles
  - control cabling
  - auxiliary power cabling
  - coolers, pipes and bridging of flanges
- Current transformer polarity check
- Control equipment circuit check
- Oil tests
  - oil level check
  - dielectric withstand test
  - oil samples for gas-in-oil analysis
- Operation test of supervisory equipment
- Operation test of cooling equipment
- Operation test of on load tap changer

After erection, following tests and inspections shall be performed before commissioning the transformer.

- visual inspection

- verify and adjust if required:
  - conservator oil level
  - dehydrating breather
  - valves
  - cubicles
  - touch up painting
  - cubicle heaters
  - de-aeration of the gas and oil actuated relay
  - oil leaks
  - tank protective earthing
  - neutral earthing
  - line and bus connections
  - air clearances
- fingerprint tests ( $U_m > 72$  kV)
  - Determination of capacitances windings-to-earth and between windings ( $U_m > 72.5$  kV)
  - Measurement of dissipation factor ( $\tan \delta$ ) of the insulation system
  - capacitances ( $U_m > 72.5$  kV)
  - frequency response analysis (FRA)
  - Insulation dielectric response (PDC, RVM or FDS etc.)
  - low voltage no-load magnetisation current measurement
  - low voltage impedance measurement

## 10.27. TRIAL OPERATION

14 days trial operation is required to prove the functional capability of the transformer and to show that it will meet its performance target. The warranty period shall be started after the successful trial operation.

## **10.28. DRAWINGS**

All approval drawings shall be sent to the Employer.

### **10.28.1. REQUIRED DRAWINGS PART I**

Four (4) paper copies and soft copy of each of the drawings specified below shall be provided.

- i. Outline drawings including the following information:
  - a. Untanking dimensions.
  - b. Center of gravity, shipping and completely assembled, in three dimensions.
  - c. Exact bushing terminal locations named with L1,L2,L3 phases, accessory equipment locations, weights and dimensions.
  - d. Identification of all components or accessories which will be shipped separately or disassembled due to shipping restrictions.
  - e. Base detail required for foundation designing.
- ii. Schematics and wiring diagram, which shall include auxiliary power requirements and fuse and breaker sizes.
- iii. Instruction nameplate for oil preservation equipment.
- iv. Bushing and Surge Arrester detail drawings.
- v. OLTC and On Line Transformer Diagnostic Device equipment detail drawings
- vi. Excitation and ratio correction curves for all current transformers including hot spot CT.

### **10.28.2. REQUIRED DRAWINGS PART II**

Four (4) paper copies and CADD files in AutoCad Ver 2010 of each of the drawings specified below shall be provided.

Certified test data for all testing

Instruction books shall include exact information for all auxiliary equipment, such as thermometers, gauges, relays and alarm set-points, and manual and automatic load tap changing equipment actually supplied on the transformer. It will not be considered sufficient to include only "typical" device instruction books. Instruction books shall include copies of all final drawings.

Four (4) color photographs of the core and coil assemblies shall be taken immediately prior to tanking at such angles as to provide a maximum of design and construction information for record.

One photograph of the completely assembled transformer with cooling equipment in place shall be taken. One print of each of the above photographs shall be incorporated in each copy of the instruction books.

## 10.29. WATER SPRAY SYSTEM

All 220/132kV transformers, transformers having capacity 45MVA and above in the 132kV category and for transformers located in highly populated areas where, transformer fire could disturb their lives, fire suppression systems shall be provided.

The power transformers are to be equipped with the water spray system arrangements specified below:

The water spray system shall be provided with a valve station including the necessary control and monitoring cabinet to be capable of extension to serve no. of future transformer units as specified in the scope of works.

The water spray system is to be designed for manual, automatic and electrical remote operation and must be provided in free-standing and self-supporting design, with the following basic equipment:

- The required number of triggering and fire extinguishing nozzles, with galvanized pipes and mountings,
- The necessary galvanized connecting lines from the appropriate valve station to the nozzle pipe network,
- the necessary drainage valves, struts, diaphragm sleeve valves, single chamber valve stations with all fittings and connections, pressure-sensitive switches for signaling and air pressure drop, with the possibility of extension by no. of transformers as specified in the scope of works.
- The necessary tank feed pump,
- pressurizing air vessel for maintaining a reserve of fire-fighting water

The required water discharge rate shall be 10 litter /m<sup>2</sup>/min.

The minimum spraying time shall be 5 minutes.

Design wind velocity shall be 10 m/sec.

The required water volume shall be considered for splaying for any one unit of the power transformers.

The pressurizing air vessel is to be designed for a minimum spraying time of 5 minutes and is to be fully equipped with all necessary fittings and connecting pipes, pressure controllers, low water level alarm, reducing valves and all other equipment essential for trouble-free operation.

The pressurizing air vessel is to be installed above ground.

Two air pressure units, rated pressure 10 bar, each provided with the following main equipment:



- 1 air compressor
- 1 400/230 V three-phase motor
- 1 flexible coupling
- 1 oil and water separator
- 1 non-return valve
- 1 vent and drain valve
- 1 pressure gauge

installed complete on a sturdy base frame with all necessary anti vibration mounts and fixing material.

One compressed air container, vertical type, welded with manhole, rated pressure matched to the water spray system, including the following main fittings:

- 1 contact type pressure gauge
- 1 relief valve
- 1 pressure switch
- 1 drain valve

assembled completely and ready for operation, the volume of air being matched to the time sequence of the transformer extinguishing operation.

The necessary control cabinet, enclosure type IP 55, completely equipped with the following main items:

- 2 motor protection switches, 400/230 V, 50 Hz, coil voltage 230 V 50 Hz/110 Vdc, auxiliary contactors and relays for optional operation of compressors 1 and 2 with switch controlling operation

with terminal board and cable entry glands as well as the necessary local fault and indicator lamps and spare contacts for remote monitoring and the necessary interlock criteria.

One complete compressed air distribution system with the necessary signaling pressure gauges, contact pressure gauges, pressure relief valves, pressure gauge valves, drain valves, pressure reducing valves, hand-operated shut-off valves and copper piping in the diameters required for the compressed air distribution.

**CHAPTER 11 - INSPECTION AND TESTING**

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## CHAPTER 11 - INSPECTION AND TESTING

### 11.1 GENERAL REQUIREMENTS

The plant covered by this Contract will be subjected to inspection and test witnessed by the Employer/Engineer during manufacture and on completion. The approval of the Employer/Engineer or the passing of any such inspection or test will not, however, prejudice the right of the Purchaser to reject the Plant if it does not comply with the Specification when erected to give complete satisfaction in service. The costs of all tests and inspection shall be born by the Contractor and shall be deemed to be included in the Contract Price.

Before any plant is packed or dispatched from the Main or Sub-Contractor's works, all tests called shall have been successfully carried out to the satisfaction of the Employer/Engineer.

Adequate notice shall be given when the plant is ready for inspection or test and every facility shall be provided by the Contractor and his Sub-Contractors to enable the Employer/Engineer to participate at the necessary inspection and tests.

### 11.2 TESTS AT MANUFACTURER'S WORKS

Works tests shall include all routine electrical, mechanical and hydraulic tests in accordance with the relevant IEC Standard except where departures therefrom and modifications thereto embodied in this Specification. For plant not covered by any ISO or IEC or specially mentioned in this Specification, such tests as are relevant shall be agreed with the Employer/Engineer.

Should the Plant or any portion thereof fail under test to give the required performance, further tests, which are considered necessary by the Employer/Engineer, shall be carried out by the Contractor and the whole costs of the repeated tests will be borne by the Contractor. This applies also to tests carried out at the Sub-Contractor's works.

No item of Plant is to be dispatched to Site until the Engineer has given his approval in writing.

#### 11.2.1 Sub-Contractors

Within two months of acceptance of the Bid, the Contractor shall forward to the Engineer, a list of all sub-orders placed or intended. The contractor shall submit three copies of all sub-orders as selected by the Engineer for progress or inspection. One copy of all drawings referred to in the sub-orders is to be submitted, unless otherwise agreed by the Engineer.

The drawings and sub-orders submitted to the Engineer shall cover all components, which are subjected to electrical & mechanical pressure or stress when the plant is in operation and also those items, which will be dispatched to Site direct from the sub-Contractor's works.

For the purpose of this clause, inter works orders shall be treated as sub-orders.

Sub-ordered shall include a statement advising the Sub-Contractor that the items being ordered will be subject to inspection and test by the Employer/Engineer.

It is important that all copies of sub-orders are clearly marked with the name of the contractor and the following references.

Employer's Name:

Contract Number:

Sub-Contractors shall comply with all the applicable requirements of this Specification and, in particular, with this Chapter. Orders issued by the Sub-Contractor shall also include the Main Contractor's name and reference on their sub-order in addition to the above-mentioned heading.

### **11.2.2 Material Tests**

The contractor shall provide test pieces as required by the Engineer to enable him to determine the quality of the material supplied under this contract. Such test pieces shall be prepared and supplied free of charge and any cost of the tests shall be borne by the contractor. If any test piece fails to comply with the requirements of the appropriate specifications for the material in question, the Engineer may reject the whole of the material represented by that test piece: the Contractor's designers and metallurgists will be consulted before any material is so rejected.

In the event of the Engineer being furnished with certified particulars of tests, which have been carried out for the Contractor by the suppliers of materials, they may, at their own discretion, dispense with the previously mentioned test entirely.

### **11.2.3 Test Certificates**

Triplicate sets of all principal test records, test certificates and performance curves shall be supplied for all tests carried out in accordance with the provision of this Contract. These test records, certificates and performance curves shall be supplied for all tests, whether or not they have been witnessed by the Employer/Engineer. The information given in such test certificates and curves shall be sufficient to identify the material or equipment to which the certificate is issued.

### **11.2.4 Switchgear, Protective Relay Equipment, D.C. Batteries, Chargers and Distribution Switchboards, Power Cables**

Refer relevant Chapters.

## **11.3 SITE TESTS AND COMMISSIONING TESTS**

Tests on completion of erection shall be carried out by the Contractor in accordance with Clause 28 of the General conditions of Contract (FIDIC). Test equipment shall be provided by the Contractor. The contractor shall state in the Schedule of "Special Tools and Appliances", any special testing equipment he thinks necessary.

The Contract Price shall include the hire of the equipment but the Schedule of Prices shall include the cost of the equipment so that the Engineer may have option to buy the equipment on completion of the Contract.

Written programmes for all kind of dry and wet tests and checks shall be agreed in advance between the Employer and the Contractor.

### **11.3.1 General Test Requirements**

#### **11.3.1.1 Procedure**

A program of tests shall be agreed between the Contractor and the Engineer, and a test program for all Sites agreed in conjunction with the erection and commissioning program approved by the Engineer. Test protocols and procedures shall be submitted

for approval by the Contractor in advance keeping a sufficient time before the commencement of the tests

Testing shall be carried out during normal working hours as far as is practicable. Tests, which involve existing apparatus and outages, may be carried out outside normal working hours. The Contractor shall give sufficient notice to allow for the necessary outage arrangements to be made in conformity with the testing program.

The Contractor shall advise the Employer/Engineer in writing already at the time of commencement of site erection of the supplies which will be required for the operation of the test equipment this should be necessary, to enable the Employer/Engineer to arrange accordingly or to agree alternative arrangements.

The Contractor shall provide the requisite experienced test personnel and all relevant test equipment, unless otherwise agreed by the Engineer or stated in the Employers Requirements. The Engineer shall approve the data of the test equipment provided.

The commissioning engineers shall have the sufficient experiences of commissioning of same type equipment, relays, Bay controllers, Protection schemes, Substation Automation System, SCADA etc. to be provided.

#### **11.3.1.2 Standards and Methods**

The method of testing, unless otherwise specified in the Employer's Requirements, shall be agreed with the Engineer.

Before commencement of each commissioning test, the test methodology referring to the relevant standard along with expected results shall be explained to the Engineer/ witness personal from the CEB. The relevant IEC and other standards shall be available with commissioning engineers so that witness personnel can refer them whenever necessary.

If any result get deviated from the expected limits, the Contractor shall clearly state the reasons and remedial measures are to be recommended for the Engineer's approval.

No tests as agreed under the test program shall be waived except upon the agreement of the Engineer in writing.

#### **11.3.1.3 Test Equipment**

Details of the test equipment and instruments used shall be noted in the test sheets in cases where the instrument or equipment characteristics can have influence on the test results

The Contractor's test equipment shall be of satisfactory quality and condition and, shall be appropriately calibrated by an approved authority or standard at the Contractor's expense.

The test instrument calibration expire dates are to be clearly indicated and such evidences shall be available at sites for engineer's reference.

The testing requirements detailed under this Specification may be verified only by instruction of the constructional techniques.

#### **11.3.1.4 Documentation and Format of Test results**

The Contractor shall submit the necessary sets of test schedules and copies prior to the commencement of the tests. One legible copy of the test results as taken on site immediately after the tests are completed and shall be handed over to the Engineer.

The Contractor shall record the results of the tests clearly, in an approved form and with clear reference to the equipment and items to which they refer and get the certification of employer's representative who witnessed the test so that the record can be used as the basis for the maintenance tests during the working life of the equipment. The required number of site test reports shall be provided by the Contractor to the Engineer as soon as possible after completion of the tests.

The test results shall be forwarded in both in hard copy and electronic format (MS-Word or PDF)

The test templates, custom made parameter files used in test instruments ( such as RIO files and Test Docs for OMICRON or any other electronic files which are used by the Contractor for testing) shall also be forwarded in electronic format.

### **11.3.2 Protection, Control, Alarms, Measurements and Indication Equipment**

#### **11.3.2.1 Wiring**

Insulation resistance Tests at 2kV AC for one minute are to be carried out on all protection, control, alarm and indication circuits to ensure that wiring is in satisfactory condition. Visual inspection shall be made on cable glands, cable jointing, fuse or circuit-breaker ratings and small panel items, such as indicating lamps.

Static equipment, which may be damaged by the application of test voltages, shall have the appropriate terminals short-circuited.

Inter-relay, inter-unit and cubical wiring carried out at site is to be checked to the appropriate circuit and/or wiring diagram. This may be done by using bells or buzzers. DC supplied from the station battery may also be used. Where it is found necessary during pre commissioning work to make modifications to the secondary wiring, then the diagrams shall be suitably marked as agreed with the Engineer before the circuit is commissioned.

Loop resistance measurements are to be made on all current transformer circuits. Separate values are required for current transformer and lead resistance and all measurements are to be recorded on lead resistance diagrams.

When pilot wire cable is used to transmit protection measured values, its impedance and phase angle shall be compensated for properly in the protection settings.

#### **11.3.2.2 Mechanical Inspection**

All relays are to be examined to ensure that they are in proper working condition and correctly adjusted, correctly labelled and that the relay case, cover, glass and gaskets are in good order and properly fitting.

#### **11.3.2.3 Secondary Injection**

Secondary injection shall be carried out on all AC relays, using voltage and current of sinusoidal waveform and rated power frequency.

For circulating current protection employing high impedance voltage operated relays, the points of injection for relay voltage setting tests shall be across the relay and stabilizing resistance. The fault setting for the type of protection is to be established by secondary injection, where it is impracticable to ascertain this value by primary injection. Injection is to be made across the appropriate relay bus wires with all associated relays, setting resistors, and CT's connected.

#### 11.3.2.4 Current Transformer Magnetizing Tests

The magnetization characteristic of all current transformers shall be checked at the minimum of two points and up to a maximum of five points as necessary to identify the current transformers with reference to the manufacturer's estimated design curve, and to determine the suitability of the current transformer for its intended duty. Special measures may be taken to ensure that the core is fully demagnetized before commencing the test.

#### 11.3.2.5 Primary Injection

Primary current injection tests are to be carried out by the Contractor. The primary injection methods employed for a particular installation are to be agreed with the Engineer.

Tests are to be carried out as follows: -

- a) Local primary injection to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.
- b) Overall primary injection to prove correct interconnection between current transformer groups and associated relays.
- c) Fault setting tests to establish the value of current necessary to produce operation of the relays. If not possible these tests are to be carried out by secondary injection applied at the wiring close to the current transformers.

#### 11.3.2.6 DC Operations

Tests are to be carried out to prove the correctness of all DC polarities, the operating levels of DC relays and the correct functioning of DC relay schemes, selection and control switching, indications and alarms.

#### 11.3.2.7 On Load Tests

In view of the hazards inherent in these tests, they shall be carried out under the direct supervision of the Employer/Engineer and/or the Purchaser.

An operation and stability test shall be carried out for on load commissioning.

Tests for restraint shall be carried out to prove the characteristic of protective systems with directional characteristics.

On load check shall be made after the protective gear has been placed in service to ensure that all connections and test links have been replaced and test leads removed, as well as to confirm the integrity of the current transformer circuits. Where necessary voltage readings shall be taken at the terminals on each relay to ensure that loop connections between the relays are complete. Special attention shall be paid to broken delta voltages and residual current circuits where zero voltage or current respectively may not be proof of the completeness of the circuit.

#### 11.3.3 Switchgear and Ancillary Equipment

Written programs for tests and checks according to points under this paragraph shall be set up and agreed between the parties.

### 11.3.3.1 General Checks

A general check of all the main switchgear and ancillary equipment shall be made and shall include a check of the completeness, correctness and condition of earth connections, labelling, arcing ring and horn gaps, painted surfaces, cables, wiring, pipework, valves, blanking, plates and all other auxiliary and ancillary items. Checks shall be made for oil and gas leaks and that insulators are clean and free of external damage. A check shall be made that loose items, which are to be handed over to the Engineer, e.g. blanking plates, tools, spares are in order and are correctly stored or handed over.

### Gas Insulated Switchgears

After erection, before putting into service, the gas-insulated metal-enclosed switchgear shall be tested as per IEC 62271-203 to check the correct operation and the dielectric strength of the equipment

### 11.3.3.2 Circuit-Breaker Tests

Circuit breaker shall be given a visual inspection.

Test shall be made also on mechanical and hydraulic operating systems.

Contact resistance test shall be carried out. In the case of multi-interrupter circuit-breakers resistance tests will be required at each interrupter or pair of interrupters as well as through the series of interrupters on each pole.

Operational tests will include local and remote trip/close and Circuit Breaker timing tests shall be carried out on all circuit breakers.

In the case of gas type circuit breakers testing will be required on the gas type system to prove the gas quantity, its dryness and its dielectric strength and alarm system. The gas leakage shall be measured at factory and checked at site.

### 11.3.3.3 Disconnectors for outdoor switchgear

Outdoor disconnectors for manual operation shall be subjected to operational tests to confirm contact pressures, contact resistance, simultaneous operation of all phases and ease of operation.

Checks shall be made on isolators of the local and remote indications and operation of auxiliary contacts.

Where applicable checks shall be made on the earth mat at operating positions and on the availability of connecting points for maintenance earth arrangements.

Disconnectors for motorised operation shall be tested to prove the motor operation, including local and remote operation, and timing tests shall also be carried out. Motor protection shall be tested.

All electrical and mechanical interlockings between disconnectors and associated earth switches, if available, shall be tested.

Earthing switches and maintenance earthing devices shall be tested to confirm the opening and closing sequences and checks shall be made on indications and manual locking devices.

### 11.3.3.4 LVAC Switchboards

General testing and inspection shall be carried out as referred to above so far as is applicable. Attention is drawn to the requirement for the functional testing and timing



testing of interlocking between incoming and bus section circuit-breakers circuits where automatic operation is specified.

Insulation tests shall be carried out with 2 kV AC for one minute test set.

Shutters, interlocking, earthing procedures and the interchangeability of components shall be checked.

#### **11.3.3.5 Voltage Transformers**

The following tests shall be carried out on electromagnetic type voltage transformers: -

- a) Insulation tests at 2 kV to earth and between windings.
- b) Checks on gas/oil relays, if there are any.

All voltage transformers shall be checked for polarity phasing and for secondary output.

#### **11.3.3.6 Busbars and Connections for Outdoor Substations**

Flexible busbars and connections shall be tested to ensure that the correct tensions, sags and clearances will be maintained over the range of environmental conditions and loads without stresses to the other equipment. If dynamometers are used to check the sags and tensions, they shall be checked both before and after use.

Rigid busbars and connections shall be tested to ensure that the busbars will not cause overloading of the supporting insulators under load conditions and under the range of climatic variations applicable to the Site, that expansion and contraction of the equipment is fully accommodated by flexible connections.

Conductivity tests are required on all connections and joints, which are made on site without exception. This may be done by voltage drop measurements while injecting a current at least 100A.

#### **11.3.3.7 Earthing System**

Tests shall be made on the effectiveness of the bonding and earthing which will include conductivity tests on selected joints, on the main earthing system, and at the connections to equipment and structures. Checks shall also be made on precautions taken to avoid corrosion attack on the earthing system.

The resistance of the earthing system to the general mass of earth shall be tested and recorded including the method, and equipment used to carry out the tests. Test probes at approximately 300 and 600 meters separation will normally be required to effectively test the earthing system. The use of transmission line conductors may be arranged to simplify these testing procedures.

Tests of the earthing resistivity shall be carried out as called in Clause 8.3.

The earth resistance shall be measured during the installation and on completion.

- a) Each earth rod after driving.
- b) The earth grid after completion and backfilling of the trenches.
- c) Each group of earth rods or earth point after completion of the connection from the test link terminal.
- d) The completed installation without any connections outside the substation.

- e) The contractor shall be called upon to provide assistance in the measurement of each resistance after earth connections to the system have been completed.

The test shall be carried out by a method and with equipment approved by the Employer and all tests are to be witnessed.

#### **11.3.3.8 Batteries, Battery Charging Equipment and Inverter**

The insulation to earth of the complete DC installation shall be tested.

Tests shall be carried out on the batteries and chargers to confirm the charger ratings and adjustment, the battery and charger alarm systems and battery capacity.

The specific gravity and cell voltages of the batteries when fully charged shall be recorded.

All functional tests recommended by the manufactures of Battery Chargers, Inverters shall be carried out.

#### **11.3.3.9 Instruments and Fault Recorders**

Instruments and instrument transformer circuits shall be checked for polarity or direction and for calibration including any interposing transformer or transducers. These checks shall be made on all current transformer ratios where applicable.

Fault and event recorders shall be tested for printing operation and paper transport. Operation shall be checked by secondary injection and initiating device operation as applicable. Stability and normal operation shall be checked after the main high voltage circuit has been commissioned.

Calibration of analog channels and testing of Digital channels shall be carried out.

#### **11.3.3.10 Interlocking**

All interlocking arrangements both electrical and mechanical shall be fully checked and tested.

#### **Fiber optic equipment**

Site commissioning tests for the fiber optic equipment such as

- fiber optic cables
- multiplexer

have to be carried out in line with the relevant standards. The bidder has to indicate in his bid complete factory and site test program for the fiber optic and telecommunication equipment

#### **11.3.4 Power Cables**

Refer Chapter 8 for cables above 3.3kV.

##### **11.3.4.1 High Voltage Test**

For cables up to 3.3 kV:

Each completed circuit of cable shall be subjected to a direct current high voltage test as follows:-

For cables installed in a three-phase, 230/400V, 50 Hz system, the test may be applied with a 2000V megger insulation tester.

For other cases, the voltage test shall be in accordance with BS.6346, Appendix B.

#### **11.3.4.2 Conductor Resistance Test**

For cables up to 3.3 kV:

The conductor resistance of each core of each completed circuit, which include through joints shall be measured and recorded. The measured values shall not be greater than the values stated in the Schedule of Particulars and Guarantees when corrected to 20°C and with suitable adjustment for the length of the route.

### **11.3.5 Transformers, Reactors and Ancillary Equipment**

#### **11.3.5.1 Main Transformers**

The following site tests shall be performed:-

1. Pressure test on tank
2. Measurement of the excitation current at any star-connected winding with low voltage (AC, 3 phase) when the transformer is completely de-magnetised.
3. Measurements of voltage ratio at all tap positions.
4. Check of vector group.
5. Measurement of winding resistance at central tapping and the extremes.
6. Measurement of insulation resistance at 5000 V DC.
7. Measurement of insulation resistance between the core and core tank at 2500 V DC.
8. Measurement of the dielectric strength of the insulation oil.
9. Re-calibration and current injection test on winding temperature indicators.
10. Applied over-voltage test at 2000V, Ac wiring, control and supervision equipment. (on motors 1000V, AC plus 2X Un)
11. Functional test on cooling plant.
12. Functional test on control & supervision test.
13. Functional test on O.L.T.C.
14. Visual checks.
15. Measurement of tangent delta of transformer and bushing separately
16. Functional test on intertripping and interlock
17. Dissolve gasses on insulation oil in main tank.

### 11.3.5.2 Earthing Transformer & Auxiliary Transformer

The following site tests shall be performed:-

1. Measurement of voltage ratio.
2. Check of vector group according to the voltmeter method.
3. Measurement of winding resistance.
4. Megger test.
5. Dielectric strength of oil.
6. Functional test of supervisory equipment.
7. Visual checks.

Where applicable the above tests shall also be carried out on shunt Reactors.

### 11.3.6 Bushing Type Current Transformers

#### (i) Magnetising Tests

The magnetisation characteristic of all current transformers shall be checked at the minimum of two points and up to a maximum of five points as necessary to identify the current transformers with reference to the manufacturer's estimated design curve, and to determine the suitability of the current transformer for its intended duty. It may note that it is not normally necessary to check the characteristic up to the knee-point for this purpose. Special measures may have to be taken to ensure that the core is fully demagnetised before commencing the test.

#### (ii) Primary Injection

Primary current injection tests are to be carried out by the Contractor. The primary injection methods employed for a particular installation are to be agreed with the Engineer.

Local primary injection tests are to be carried out to establish the ratio and polarity of current transformers as a group, care being taken to prove the identity of current transformers of similar ratio.

### 11.3.7 Site Test Civil Works

Site Tests for civil works are to be carried out as per the relevant chapter of the Technical Specifications, Civil. The Contractor shall submit a QA/QC manual for approval.

### 11.3.8 Site Test for Telecommunication and SCADA Systems

During the construction and after the installation of each item of equipment, preliminary tests shall be performed at Site, as specified herein, to establish the accuracy of the assembly and to prove the adequacy of the materials and the workmanship. After completion of the system and the preliminary tests, commissioning tests shall be carried out as Site Acceptance Tests. After the commissioning tests, the availability tests shall be performed as Tests on Completion under the Contract. All tests and test procedures with test recording sheets shall be approved by the Employer and the Engineer prior to the execution of the Tests.

The Contractor shall perform the following preliminary, commissioning and availability tests, for all items where applicable, to insure that:

- (a) The equipment has been correctly installed,
- (b) The SCADA/Telecommunication system is in effective for operation and maintenance and management of the active power system,
- (c) All necessary adjustments and settings made, and
- (d) The each equipment is in sound condition to operate under energizing conditions of the active power system.

#### **11.3.8.1 Preliminary Tests at Site**

- (1) Inspection during the installation of equipment
  - (a) General inspection of all equipment and materials
  - (b) Appearance check of all equipment
  - (c) Layout check and confirmation of arrangement of equipment
  - (d) Measurement of the insulation resistance of the main circuit
  - (e) Grounding check and measurement
- (2) Preliminary function test
  - (a) Equipment for the fiber optic telecommunication system
    - (i) Functions check
    - (ii) Operation test
  - (b) PLC equipment and teleprotection equipment
    - (i) Signal level check
    - (ii) Functions check
    - (iii) Operation test
  - (c) Telephone facility (PAX and PLTS)
    - (i) Functions check
    - (ii) Operation test

#### **11.3.8.2 Commissioning Tests**

After the preliminary tests, the Contractors shall carry out the commissioning tests in the presence of the Employer and the Engineer to demonstrate that all guarantees and technical particulars as listed in the Bid and Contract Documents have been satisfied and that the entire work is properly installed, free from objectionable leakage and correctly adjusted to operate the system as specified.

The commissioning tests shall include but not limited to the following items:

- (a) Inventory check
- (b) Operation test for data exchange between SCC and each Substation Automation system  
Confirming items: Data input/output, setting level, database at SCC, etc.
- (c) Accuracy test

Confirming items: Accuracy of received data at SCC comparing with the transmitted data from Substation Automation system.

(d) Collective System Operation Test

Followings are tested with use of the actual system established.

- Data collection, supervisory and control operation test
- Alarm and reset tests
- System restoration in abnormal conditions, failsafe function test
- Conformation expandability of software, maintenance function test

All tests and test procedures with test recording sheets shall be submitted and approved by the Employer/Engineer prior to the execution of the Tests.

### 11.3.8.3 Availability Tests

The Contractor shall provide overall supervision for the Telecommunication/SCADA content for the Availability Tests period after the Commissioning Tests.

The Availability Tests (trial operation test) shall be executed for a continuous period of 30 days. In case of suspension days by minor problems or mal-operation during the availability tests, the test period will be extended to a maximum of 60 days. This means the test minimum period is 30 days and maximum is 90 days. The rate of operation of the system established shall be not less than 99.9%, but not counting suspension times for the following system shutdown time.

- System shutdown time by periodical maintenance
- System shutdown time for exchange of information between the system operator and the maintenance service engineers of the Contractor (telephone discussion time)
- System shutdown time for travel time of maintenance engineer to the Site

During the Availability Tests period, the Contractor shall maintain and provide training assistance experts for the Employer's operational and maintenance staff.

The Availability Tests shall be executed according to the following procedure and conditions.

(a) The Availability Tests shall be commenced on a date mutually agreed by the Employer and the Contractor.

(b) The Employer will record the operation time and downtime of the system during the Availability Tests period.

(c) As a rule, the Availability Tests shall be performed continuously. In case of temporary suspension due to serious hardware or software problems, the commencement time shall be reset to zero after recommencement.

(d) The temporary suspension of the availability tests by minor corrections such as change of database, change of display, etc. would not be considered as serious problems and will not cause reset of the commencement time.

**CHAPTER 12 - GENERAL REQUIREMENTS**

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## CHAPTER 12 - GENERAL REQUIREMENTS

### 12.1 GENERAL

#### 12.1.1 General Design of Equipment

In complying with the requirements of the specification, design shall conform to the best current engineering practice. Each component part of the Plant shall be to the maker's standard design provided that this design is in general accordance with the Specification.

Generally, all equipment and materials shall be in accordance with the International Electromechanical Commission (IEC) standards, International Standardization Organization (ISO) standards or standards especially indicated in the respective Chapters.

The issues of standards valid for the contract shall be the latest issues (including amendments) current at the Bid closing date.

Wherever in these specifications the requirements are stricter than those in the standards, these specifications represent an additional requirement above that of the standard.

The essence of design should be simplicity and reliability in order to give long continuous service with high economy and low maintenance costs.

Particular attention should be paid to internal and external access in order to facilitate inspection, cleaning and maintenance.

The design, dimensions and materials of all parts are to be such that they will not suffer damage as a result of stresses under the most severe service conditions.

Fully detailed specifications of the component parts of the plant are to be submitted describing particularly the materials to be used.

Works shown upon the drawings and not mentioned or described in the specification, and works described in the specification and not shown on the drawing will nevertheless be held to be included in this contract and their execution shall be covered by the contract price in the same manner as if they have been expressly shown upon the drawings and described in the specification.

The materials used in the construction of the Plant shall be of the highest quality and selected particularly to meet the duties required to them. Mechanisms shall be constructed to avoid sticking due to rust or corrosion.

Workmanship and general finish shall be of the highest quality throughout.

All similar parts of the Plant shall be interchangeable.

All apparatus shall operate without undue vibration and with the least practicable amount of noise.

All equipment shall be designed to minimise the risk of fire and any damage, which may be caused in the event of fire, shall be as minimal as possible.

All apparatus shall be designed to prevent the risk of accidental short circuit, malfunction or damage due to vermin.

All items of equipment, which may have to be lifted for erection or maintenance, shall be provided with lifting eyes, jacking pads or alternative handling facilities.



The Contractor shall also abide by the Project Manual which documents the project organisation, details the form and handling of correspondence and documents including a numbering system, procedures for meetings and document approval, gives some guidelines on quality assurance, time scheduling and progress monitoring. The Engineer will issue the project manual to the Contractor.

### 12.1.2 Quality Assurance

The quality of the design, manufacturing and erection processes shall be assured by the Contractor in accordance with the ISO 9000 series standards. The Contractor must prove his possession of the respective certificates.

The Bidder shall prove that the quality of the design, manufacturing and erection is done in accordance with the ISO 9001. The Bidder shall submit respective certificates issued by an International Organisation at least for the equivalent list below.

- (a) Circuit breakers
- (b) Transformers
- (c) Current transformers
- (d) Voltage transformers
- (e) Disconnecting and earthing switches
- (f) Power/Earthing/Auxiliary Transformers
- (g) Breaker Switch Capacitor Bank
- (h) Surge arresters
- (h) All outdoor post insulators and bushings for current and voltage transformers
- (i) Metering, Protection & Control equipment
- (j) PLC & SCADA equipment
- (k) Power and Control equipment
- (l) Cables & Conductors
- (m) Indoor switchgear

### 12.1.3 Quality Control Manual

A manual shall be given by the contractor indicating the sequence of procedures followed in all activities in the project including manufacturing, purchasing, testing, and commissioning to ensure the quality assurance as per 12.1.2. Contractor shall ensure that the activities involve in the project are according to the quality assurance standards specified in the bidding document. This document shall be used for supervisory and monitoring purpose during the contract by the contractor and the Engineer.

### 12.1.4 Units of Measurement

In all correspondence, in all technical schedules and on all drawings metric systems International Units (SI) units shall be used. On drawings where Imperial or other units have been used it will be in order if the equivalent SI units are suitably marked in addition.

### 12.1.5 Compliance with Specification

Notwithstanding any descriptions, drawings or illustrations which may have been submitted with the Bid, all details other than those shown on the Schedule of Departures will be deemed to be in accordance with the Specification and the standard specifications and codes referred to therein.

No departures from the Specification except those shown on the Schedule of Departures and approved by the Employer are to be made without the written approval of the Engineer.

All exceptions shall be clarified and separately itemised. It shall not be necessary for the Purchaser to examine the standard literature and documents of the manufacturer to determine the existence and extend of any exceptions or deviations from specification.

### 12.1.6 Drawings

Before the work is put in hand, two copies of general drawings and diagrams showing all details of the Plant and materials to be used shall be submitted to the Engineer for approval. The wiring or connection diagrams shall be submitted for approval unless prior approval has been obtained for schematic diagrams, which shall include control and protection schematics, showing the facilities being provided and the working of the schemes.

Detailed drawings shall be submitted in quadruplicate as soon as possible after the commencement date and in any case in sufficient time to permit modifications to be made, if such are deemed necessary by the Engineer, without delaying the delivery of the Contract work. The drawings submitted shall be modified as requested by the Engineer and re-submitted for approval.

When requested by the Engineer, the Contractor shall supply at his own expense an authorized copy, of any standard pertaining to the material or equipment covered by the contract.

Any documentation submitted by the Contractor for approval shall only be in sizes A1, A2, A3 or A4 (210 X 297 mm), preferably A3 and A4. A2 and A1 shall only be used if absolutely necessary. All drawings shall be prepared using "Computer Aided Drafting". All documents shall bear a drawing or document title in a form and with a numbering system, which will be explained to the Contractor by issuing him a project manual, which will be handed over after signing of the contract.

The following documentation shall definitely be included in the documents to be submitted by the Contractor for approval by the Engineer before construction or erection of the respective part of the works may start:

- Detailed layout of all areas and equipment
- Arrangement drawings of all equipment
- Functional block diagrams for protection
- Complete circuit diagrams
- Earthing grid calculation
- Detailed construction schedule in form of a bar chart
- Cable laying diagram
- Station Design Criteria

- Soil investigations
- Codes and standards to be adopted in the design
- Loading to be adopted for the various elements of the structure
- Load factors and load combinations
- Description of the design method and theories to be adopted
- Base calculation of the structural design and general arrangement drawings
- Architectural scheme design and detail drawings, i.e. plans, elevations and sections
- Stair case details, if any
- Roofing and water proofing detail
- Doors and windows schedule
- Finishing schedules
- Structural detail drawings
- Mechanical, Electrical and Plumbing (MEP) drawings
- Earthing layout

The contractor shall submit a complete list of all drawings listing the drawing number and title, together with the date that the drawing is planned to be submitted for approval, and the date it is required on site. In the same list, the actual dates of submission of each revision as well as date and status of approvals. The Contractor shall update the list at monthly intervals.

If the Contractor requires urgent approval of some drawings to avoid delay in the delivery of the Contract Works, he shall advise the Engineer to such effect when submitting the drawing.

It shall be understood, however, that approval of the drawings will not exonerate the Contractor from any responsibility in connection with the work.

After all items of Plant have been manufactured and erected, data file on Auto CAD format or reproducible digitised drawing file, of each drawing previously approved shall be provided together with four prints on heavy gauge white paper from such drawings as may be required to show the detail and arrangement of the Plant as made and installed.

All drawings submitted by the Contractor or by any Sub-Contractor shall have the following particulars in the lower right hand corner in addition to the Contractor's name, date, scale, number and title of the drawings:

Site	PROJECT NAME CEYLON ELECTRICITY BOARD
------	--

Description of Apparatus	CONTRACT NAME
--------------------------	---------------

Contract      Engineer's  
No:              Serial No:

and :

The Engineer's serial No: should be inserted by the Contractor before submission of the drawing. The serial number and index system, detailed below, will be agreed at the first contract meeting between the Contractor and the Engineer.

The Contractor shall when submitting drawings provide an indexing system for all the drawings divided into sections for each substation and sub-divided for each type of equipment, e.g., outdoor switchgear, indoor switchgear, control and relay panels, wiring diagrams, schematics, ancillary equipment, foundation, steelwork, etc.

The index shall contain the following information for each drawing:

- (1) Drawing number
- (2) Revision
- (3) Engineer's serial number
- (4) Title
- (5) Data submitted for approval
- (6) Date returned for correction
- (7) Data approved for construction
- (8) Date final drawings submitted
- (9) Number of copies
- (10) Remarks/distribution column for use by the Engineer.

### **Drawings and Records**

The contractor shall keep on site accurate and up to date drawings and records, and shall provide the Engineer with one set of copies each. At the end of every week the Contractor shall submit to the Engineer schedules of labour, plant and materials employed on the site during that week.

### **As built documentation**

All documentation approved by the Engineer and any documents used during erection or commissioning shall be updated at the end of the commissioning period to show the as built status. This updating shall be done by hand, clearly marking any changes in red colour. Two sets of complete drawings at least shall be prepared under the responsibility of the contractor's chief commissioning engineer. One set shall remain with the Engineer while the other set is sent to the contractor's office where all modifications will be included in new neat as built documents which shall be distributed to the employer and to the engineer. Receipt and acceptance of this documentation shall be a prerequisite for the issuance of the final acceptance.

### **Photographs**

From the beginning of site works on Site the Contractor shall keep on providing photographs of the works, from positions to be selected by CEB, at monthly intervals. Up to ten (10) photographs per month shall be provided in bound photographic albums, two copies of which shall be submitted to CEB

Each photographic print shall not be less than 297 mm x 210 mm and shall bear a printed inscription, a serial number and the date when taken.

The softcopy of all photographs shall be held at the Contractor's site office, numbered and handed over to CEB on completion of the Contract.

The Contractor shall provide a number of selected photographs for submission with the Monthly Progress Report as required by CEB and also shall provide loose sets of photographs and copy negatives which may be requested from time to time by CEB. The Contractor shall provide additional photographs of the Contract Works to record or illustrate specific events at the request of CEB.

### **12.1.7 Access to Site**

The nearest deep sea port is at Colombo but the capacity and availability of dock side cranes is strictly limited and ships derricks should be capable of undertaking the unloading of all heavy cargo. The Contractor shall ensure by his own enquires that the facilities available for unloading and bearing capacity of wharf at the Port of Colombo are adequate for his proposed plant.

The Contractor shall make his own arrangements for handling and transport, and off loading at site, so as no facilities being available for him, free of cost.

Plant will generally be delivered to the sites by road. The Contractor is to make his own enquiry as to the suitability, availability and charges for railway cranes, suitability of available wagons for the transport of any loads and any restrictions imposed by clearance gauges.

The highways, road and bridges have widely varying load limits and the Contractor shall be responsible for determining the load limits existing at the time and ensuring that his Plant does not exceed such limits.

The Contractor shall be deemed to have included in his costs any temporary measures necessary to allow the transport of the Plant over existing roads and bridges.

Before moving any heavy traffic on to highways, road and bridges, the Contractor shall make suitable arrangements with the appropriate Government authorities and obtain their approval for the passage of such traffic.

In the event that any permanent reinforcement of road and bridges may be considered necessary for transport of the Plant, the Bidder shall obtain an estimate of the costs from the Government Department concerned and include this as a provisional sum in the Schedule of Prices.

The Contractor shall not use tracked vehicles or plant on any bituminous sealed road surface. Rubber tyred vehicles conforming to applicable load restrictions will be permitted to use bituminous sealed roads.

It shall be the Contractor's responsibility to ascertain the availability in Sri Lanka of suitable transport vehicle for the Plant and arrange for the provision of such vehicles as may be necessary.

Within the site areas, the Employer will maintain existing roads and the Contractor will be given use of the roads essential to his operations free of charge for normal traffic. Any damage caused by the Contractor's abnormal traffic shall be repaired at his own expense.

The contractor shall take into account the fact that the Grid Sub Stations are high security areas, where access is strictly controlled. The contractor shall follow all security procedures adapted at these installations.

### 12.1.8 Packing

Each item shall be packed properly and protected for shipment and transport from the place of manufacture to Site, and in addition for storage for a minimum of three months under the Site climate conditions.

The recommendations of the BS 1133 Packaging Code or equivalent International Standard shall be observed with particular reference to:

- Section 5 : Protection against spoilage of packages and their contents by micro organisms, insects, mites and rodents.
- Section 6 : Temporary protection of metal surfaces against corrosion.
- Section 8 : Wooden containers

Tube ends and other similar open ends shall be protected from both, external damage and ingress of dirt and moisture during transit and while awaiting erection at Site. Flanged pipes shall have their open ends protected by adhesive tape or jointing and then be covered with a wooden blank flange secured by service bolts.

Precautions shall be taken to protect shafts and journals where they rest on wooden or other supports likely to contain moisture. At such points, wrappings impregnated with anti-rust composition or vapour phase inhibitors shall be used of sufficient strength to resist chafing and indentation due to movement, which is likely to occur in transit. Protective wrappings and impregnation shall be suitable for a period of three months.

In the case of ball or roller bearings installed in any item of Plant, precautions shall be taken to avoid indentation of the bearing races.

Metal bindings of cases shall be of corrosion resistant material and shall be properly tightened and the ends crimped together by means of a purpose made tool.

Contents of cases shall be bolted securely or fastened in position with struts or cross battens preferably supported by cleats fixed to the case so that there shall be no movement.

Where parts are required to be bolted to the sides of the case, large washers are to be used to distribute the pressure and the timber shall be strengthened by means of a pad.

Where practicable, all indoor items such as electric motors, switch and control gear, instruments and panels, machine components, etc., shall be “cocooned” or covered polyethylene sheeting, sealed at the joints and the enclosure provided internally with desiccator.

All delicate equipment e.g. relays and instrument shall be removed from panels and packed separately for transport in the same consignment as the associated panels. The packing shall contain all equipment destined for the same location.

Where transformers or similar devices are shipped under oil the oil level shall be above the core and the windings and a silicagel breather shall be fixed to the tank cover or pipe work for protection against moisture entry during transport.

Each crate or package shall contain a packing list in a waterproof envelope. All items of material are to be clearly marked for easy identification against the packing list.

All cases, packages, etc., shall be clearly marked on the outside to indicate the total weight, to show where the weight is bearing and the correct position of the slings and shall bear an identification mark relating to them to the appropriate shipping documents.

Stencil marks on the outside of casings shall be indelible.

The Engineer may require to inspect and approve the packing before the items are dispatched but the Contractor shall be entirely responsible for ensuring that the packing is suitable for transit and such inspection will not exonerate the Contractor from a loss or damage due to faulty packing.

### **12.1.9 Installation, Operating and Maintenance Instructions**

When the general arrangements and details of the Plant have been finalised and not later than the erection commences, the Contractor is to submit to the Engineer for approval fully detailed installation instructions.

The details shall cover the main plant and all associated ancillary equipment as supplied under the Contract. It will not be sufficient to incorporate manufacturers' standard brochures as part of the text unless they refer particularly to the equipment supplied and are free of extraneous matter.

The information provided should include essential circuit diagrams, general arrangement and detailed drawings of the installation make mention of special materials, erection apparatus and tools where used and include schedules of lubricants and all ball and roller races employed on the Plant. The drawings and diagrams, which may be approved existing drawings reduced to a convenient size, should be bound into the volume and not inserted into cover pockets. List of contract record drawings shall be included.

If the complete text is unduly bulky, then the manual is to be appropriately sub-divided and produced in multi-volume form. When approved, four copies of the complete text, diagrams and drawings as made up in draft form are to be handed to the Engineer for distribution at Site and these are to be provided not later than the erection commences.

Handing over of originals of Operating and Maintenance Instructions shall be as per the Clause 6.6 of General Condition of FIDIC.

A further four copies are to be reproduced as a book or books of approximately A4 size and bound into durable covers inscribed in permanent form upon the front generally in the form of the title page to this document except that the references to Specification, Conditions of Contract, Drawings, etc., will be replaced by "Operating and Maintenance Instructions".

The name of the main Contractor and that of any Sub-Contractor shall also be inscribed upon the cover after the description of the Plant.

The name of the Employer and substation or other identification followed by a classification of the plant (e.g. 132 kV Switchgear), is to be inscribed upon the spine of the cover and, if the instructions are contained in several books, these are to be marked with the appropriate volume number.

## **12.1.10 Cleaning and Painting**

### **12.1.10.1 General:**

All bright metal parts shall be covered before shipment with an approved protective compound and protected adequately during shipment to Site. After erection these parts shall be cleaned with a correct solvent and polished bright where required.

Before testing, all steel pipes shall be thoroughly cleaned by an approved process. Any protective coatings shall be applied after tests have been carried out.

Pipes, valves and other similar parts of the Plant which are subject to hydraulic test and are not readily accessible for drying out are on completion of tests at the manufacturer's works to be drained out by washing with an approved de-watering oil prior to protection for shipment.

All surfaces shall be prepared before coating in accordance with ISO 1456, ISO 1458 or others as applicable.

All iron and steel structures shall be protected against corrosion in accordance with Chapter 13.

Where painting is carried out at the manufacturer's works and where erection at Site is the responsibility of the Contractor, any damage during delivery or erection at Site shall be made good to the requirements of the Engineer including, where deemed necessary, application of a complete finishing coat of an approved colour and quality paint. Such works need to be done also in line with the paint manufacturer's instructions.

Where painting is carried out entirely at Site after erection, the whole of the Plant, including bare pipe surfaces and hand railing, shall be well wire brushed down and cleaned after which all parts shall be given one coat of primer, one undercoat and at least one finishing coat of an approved colour and quality paint.

All paint shall have appropriate standard finish, requiring at least two finishing coats on prepared surfaces properly filled in to provide a smooth finish. The insides of outdoor control cubicles, cabinets, etc., where condensation is liable to occur, shall receive the same number of coats.

### **12.1.10.2 Tanks and accessories:**

Interiors of oil tanks shall be thoroughly cleaned by shot blasting or other approved methods and, where exposed to corrosion before use, shall be coated with an approved corrosion preventing compound. The internal surfaces of oil tanks that will be exposed to atmosphere in service shall be painted with an epoxy or other approved oil resisting compound.

The exterior shall be thorough cleaned by shot blasting or other approved methods and given one coat of primer, two coats of contrasting colour of durable oil and weather resisting paint and a final coat of gloss paint.

### **12.1.10.3 Radiators:**

Radiators shall be thoroughly cleaned and treated externally by phosphating or other approved rust inhibiting process and given, preferably by flood painting, the same number and type of coats specified in Sub-Clause 11.1.9.2 of this Clause. Radiators, which are hot dip, galvanised, shall be artificially weathered and given one coat of zinc chromate primer followed by the same number and type of paint coatings specified in Sub-Clause 11.1.9.2 of this Clause.



### 12.1.11 Lubrication

The Contractor is to include for the supply of flushing oil for each lubrication system when the item of plant is ready for preliminary tests and the first filling of approved lubricants for the commercial operation of the plant.

A schedule of the oil and other lubricants recommended for all components of the Contract work is to be submitted to the Engineer for approval. The number of different types of lubricants is to be kept to a minimum. Copies of this schedule shall be included in both the draft and final copies of the operating and maintenance instructions. In the case of grease lubricated roller type bearing for electrical motors a lithium based grease is preferred.

Where lubrication is effected by means of grease, preference will be given to a pressure-gun system with a separate nipple to each point. Where necessary for accessibility, the nipple is to be placed at the end of extension piping, and when a number of such points can be grouped conveniently, the nipples are to be brought to a battery plate mounted in a convenient position. Nipples shall be of the hexagon headed type complying with BS 1486 Part1 table1 type 11B or equivalent IEC/ISO. Where special greases are to be used and where high temperatures are encountered, then 'button' nipples in accordance with BS 1486 or equivalent IEC/ISO are preferably to be used.

The Contractor is to supply at least one grease gun equipment for each type of nipple provided. Where more than one special grease is required, a grease gun for each special type is to be supplied and permanently labelled.

### 12.1.12 Tropicalisation

In choosing materials and their finishes, due regard shall be given to the humid tropical conditions under which equipment is to work, and the recommendations of British Standard Code of Practice 1014 or equivalent IEC/ISO should be observed unless otherwise approved. Some relaxation of the following provisions may be permitted where equipment is hermetically sealed but it is preferred that tropical grade materials should be used wherever possible:

#### 12.1.12.1 Metals:

Iron and steel are generally to be painted or galvanised as appropriate. Indoor parts may alternatively have chromium or copper-nickel plating or other approved protective finish. Small iron and steel parts (other than stainless steel) of all instruments and electrical equipment, the cores of electromagnets and the metal parts of relays and mechanisms are to be treated in an approved manner to prevent rusting.

#### 12.1.12.2 Screws, Nuts, Springs, Etc.:

The use of iron and steel is to be avoided in instruments and electrical relays wherever possible. Steel screws are to be zinc, cadmium or chromium plated, or when plating is not possible owing to tolerance limitations, are to be of corrosion-resisting steel. Instrument screws (except those forming part of a magnetic circuit) are to be brass or bronze. Springs are to be of non-rusting material, e.g., phosphor bronze or nickel silver, as far as possible.

#### 12.1.12.3 Rubbers:

Neoprene and similar synthetic compounds, not subject to deterioration due to the climatic conditions, shall be used for gaskets, sealing rings, diaphragms, etc.

### 12.1.13 Tools

Where specified, the Contractor shall supply in steel boxes, complete with keys, any normal tools that are required for making adjustments to equipment during normal operation or maintenance.

Any special tools required for erection, commissioning, operation and maintenance of the equipment should be indicated in the price schedule with individual quantities, minimum time for delivery, and prices including the cost of delivery to the Employer's store.

These special tools shall be of alloy steel. All tools shall be stamped with an approved identification.

### 12.1.14 Spares

The Contractor shall state in the Schedule of Spares the spares that he recommends, with individual quantities and FOB prices, together with the cost of the delivery to the Employer's storage.

The Employer may order all or any of the spares so recommended at his discretion. Those ordered shall be delivered to the Engineer at the Employer's store or on the Site not later than the date of issue of the Taking Over Certificate for the item of Plant or equipment in question. They shall also be delivered within the minimum period stated in Schedule for the delivery of the spares from the date of receipt of the Employer's order.

These spares will be charged against the Provisional Sum included in the Schedule of Prices and shall be supplied at the prices listed in the Schedule of Spares subject to the qualification that, if any spares should be ordered after the date of the Taking Over Certificate in question, the price may be subject to adjustment.

All spares supplied shall be strictly interchangeable with the parts for which they are intended to be replacements and shall be treated and packed for long storage under the climatic conditions prevailing at the Site. Each spare shall be clearly marked or labelled on the outside of its packing with its description and purpose and, when more than one spare is packed in a single case or other container a general description of its contents shall be shown on the outside of such case or container and a detailed list enclosed inside. All cases, containing and other packages must be suitably marked and numbered for purposes of identification.

### 12.1.15 Inventory Records for Plant & Material

The contractor shall forward his inventory records for plant & material at the end of each month to the Employer.

### 12.1.16 Documents & Drawings to be submitted after the Contract Award

A complete Documentation Plan shall be submitted including detailed list of documents/calculations and drawings.

As a minimum, the following documents & drawings shall be submitted after the Contract award.

- a) General arrangement drawing
- b) Single line diagram
- c) Bill of material in detail.

- d) Description of system components
- e) Technical brochures
- f) Breaker control elementary diagram
- g) Disconnect switch control elementary diagram
- h) Schematic and Wiring diagrams
- i) Terminal board locations and arrangements
- j) Voltage transformer connection diagram
- k) Current transformer connection diagram
- l) Breaker Switch Capacitor Bank layout, protection and control diagrams
- m) Name plate drawing
- n) Protection stability calculations to demonstrate the adequacy of the Current Transformer cores.
- o) Detail protection schematic drawings and protection setting calculation
- p) Construction Schedule.
- q) All relevant Civil design calculations and drawings.

Other technical documents

- a) Current transformer excitation curves.
- b) Routine test reports.
- c) Factory test reports
- d) Test reports for on-site tests
- e) Operation & Maintenance Manuals
- f) Documents as required by the Engineer.

All documents/calculations/drawings submitted for review/approval shall be submitted in hardcopies as well as soft format.

The Contractor shall be responsible for any discrepancies errors, or omissions in the drawings and other particulars supplied by him, whether such drawings and particulars have been approved by CEB

### **12.1.17 Procedure for Delivery of Documentation**

The Contractor shall submit the following documentation/information to CEB for review and approval.

Within 21 days after effective date of the contract

- Detailed project specific Quality Plans and associated procedures.

Within 30 days after effective date of the contract

- Detailed Contract Programme containing design, approval of design, ordering of materials, manufacture, shop testing, delivery, civil construction, erection, site testing and commissioning.
- Detailed list of documentation submittals with documentation classification

plan.

- Detailed breakdown of the Contract Price into Cost Items
- Detailed proposal of the Monthly Progress Report format.
- Contractor's safety and security programme.

Within 60 Days after Effective Date of the Contract

- A programme of performance, material and workshop test to be carried out.
- Particulars about presentation and form to be used for the test programme shall be agreed and approved by CEB.

Within 90 Days after Effective Date of the Contract

- One set of all applicable standards / codes / specifications, etc.
- Copies of all orders placed with Subcontractors.
- Safety programme.
- Fire prevention and protection programme.
- Outline drawings of the equipment.
- Loading of foundations for all items of equipment to be supplied, and details of anchoring and supporting.
- Delivery of all drawings related to civil works.
- Preliminary drawings and schemes of connections to the part supplied under other contracts.
- Preliminary assembly drawings of the equipment with details of material intended to be used (if applicable).
- Principal electrical diagrams (if applicable).
- Detailed information (type, make, formula) of products employed to carry out the factory paints.
- RAL colour code for finish paint of all equipment.
- Detailed training programme.

Before beginning of manufacture

- Detailed manufacture drawings/documentation and software designs with all important technical data, final assembly drawings, control schemes, block and circuit diagrams and giving full information about principle of operation, cabling and wiring diagrams.

During manufacture

- Monthly progress reports,
- Notice of material tests and shop inspections,
- Certificate of inspections,
- Certificate of tests,
- Information concerning delays, claims, etc.

At least 30 Days before Shipment

- Notice to CEB giving identification, symbol, description, weight and dimensions of material in shipment.
- Bill of lading for each consignment just prior shipment.
- Instructions for loading, unloading, handling and special precautions to be observed for storage at Site.

At least 30 days before commencement of erection

- Three (3) copies of Certificates of Policy of Insurance related to the Site works.

At least 90 days before commencement of erection

- Erection instructions for approval.
- Approved erection instructions.
- Complete sets of approved drawings.
- Detailed erection programme for each component for approval.
- Site testing and inspection programme during and at the end of erection for approval.

During erection

- Monthly Progress Report
- Weekly Programme

90 days prior to Certificate of Operational Responsibility

- Operating and Maintenance Instructions for approval.

90 days before Commencement of Commissioning

- Detailed programme and site test proposal (commissioning tests) for each section.

Before Taking Over

- Spare parts storage instructions
- Final commissioning report
- Final operating and maintenance instructions
- "As-built" drawings, magnetic media copy of as-built documentation (CD-ROM).

Within 15 days after any occurrence

- Report on any damage/accident (the first brief report on the occurrence on any damage/ accident shall be submitted not later than within 24 hours).
- Any error discovered by the Contractor in his own design.
- Test certificates or test reports unless otherwise agreed upon.
- Any failure of material and equipment.
- Any delays against schedules.

The durations and time schedule can be negotiated at the kick-off meeting.

## **12.1.18 Approval Procedure**

### **Number of Copies Required**

Five (5) copies of each drawing/documentation shall be submitted by the Contractor to CEB for the approval/re-approval and construction purposes.

One (1) copy will be returned to the Contractor marked "Approved", "Approved with Comments", "Return for correction" or "Not Approved" with comments made either on the drawing itself or in the accompanying letter, and the drawing/documentation shall be amended and resubmitted for approval, clearly identifying the amendments.

### **Review and Approval of Documents**

The Contractor shall ensure that all documentation for approval are forwarded to CEB in sufficient time. The Contractor shall also ensure that documentation are submitted at least twelve weeks prior to the date required for approval to permit amendments to be made and the drawings re-submitted for approval without delaying the programme deliveries or the guaranteed completion dates of the works.

Drawings marked "Approved" and "Approved with Comments" authorize the Contractor to proceed with construction or fabrication of equipment covered by such drawings with corrections, if any, indicated thereon. Approved drawings must be available before any equipment is workshop tested or before any erection/construction work has started at Site.

## **12.2 MECHANICAL**

### **12.2.1 Nuts, Bolts, Studs and Washer**

Nuts and bolts for incorporation in the plant are preferably to conform to ISO Metric Coarse to ISO 68,261,262,272,724, 885,888 and 4759 or BS 3643, 3692 and 4190. Other sizes or threads are permitted for threaded parts not to be disturbed in normal use or maintenance. Where the Contract includes nuts and bolts of different standards, then the tools to be provided in accordance with the Specification are to include spanners, taps, and dies for these nuts and bolts.

Bolts shall fit in the reamed holes they occupy, they shall have the screwed portion of a diameter such that it will not be damaged in driving and are to be marked in a conspicuous position to ensure correct assembly at Site.

On equipment all bolts, nuts and washers shall be non-rusting material where they are in contact with non-ferrous parts in conductor clamps and fittings and elsewhere where specifically required by the Engineer.

All washers are to be included under this Contract, including devices and anti-vibration arrangements, which are to be subject to the approval of the Engineer. Taper washers are to be fitted where necessary.

Where there is risk of corrosion, bolts and studs shall be finished flush with the surface of the nuts and electro-chemical corrosion shall be avoided by bimetallic plates.

### **12.2.2 Rivets**

Rivets shall conform to the appropriate ISO and general use pan heads are preferred. Rivets on bearing surfaces are to be flat counter-sunk, driven flush. Whenever

practicable, riveting is to be done by hydraulic tools and the rivets must completely fill the holes when closed. If loose, or if the heads are badly formed, cracked or eccentric to the shank or do not bear truly on the plate or bar, such rivets are to be cut out and replaced. All surfaces to be riveted must be in close contact throughout.

### 12.2.3 Forging

All important forging are to be examined by the latest methods for the detection of defects.

### 12.2.4 Castings

All castings are to be free from blowholes, flaws and cracks as is practicable. No welding, filling or plugging of defective parts is to be done without the sanction of the Engineer and then only with his approval in writing.

All cast-iron is to be of close-grained quality and is to be corrosion-resistant for those parts in contact with seawater. Cast-iron is not to be used for any part of the equipment which is in tension or which is subject to impact stresses. This clause is not intended to prohibit the use of suitable grades of cast-iron for parts where service experience has shown it to be satisfactory.

### 12.2.5 Welding

Where fabrication welds are liable to be highly stressed, the Contractor is to satisfy the Engineer before such welding commences, that the welders or welding operators are qualified in accordance with the requirements of the appropriate section of BS 4872, Part 1 or equivalent IEC/ISO Standard Specification.

The Engineer will inform the Contractor of the stages at which inspection will be required. It will be the Contractor's responsibility to notify the Engineer when one or more of the inspection stages will be reached and no further work is to be carried out until the specified stage has passed the Engineer's inspection.

In addition to the above, the Engineer reserves the right to visit the Contractor's Works at any reasonable time during fabrication of the items of Plant and to familiarise himself with the progress made and the quality of the work to date.

All tests are to be carried out in accordance with the relevant ISO or other approved Standards. Where required by the Engineer, non-destructive examination of the finished weld is to be made. If the examinations be by radiograph means, then the recommendations of BS EN 1435 or equivalent IEC/ISO where applicable are to be followed and the resulting negatives are to be made available to the Engineer.

### 12.2.6 Chromium Plating

The chromium plating of those components of the Plant where specified and where offered by the contractor is to comply with the requirements of ISO 1456 & 1458 or BS 1224.

## 12.3 TECHNICAL STANDARDS

The standards, which shall be used in this contract, are listed below. Any standards proposed in place of or in addition to those specified should be added.

### 12.3.1 .General Technical Specification

I.E.C.	B.S.	Title
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3643	ISO metric screw threads
3692	ISO precision hexagon bolts screws and nuts
4190	ISO metric black hexagon bolts, screws and nuts
4872-1	Fusion welding of steel
BS EN 1435	Methods for radiographic examination of fusion-welded butt-joint in steel & circumference joint in steel
BS EN ISO 1461	Hot dip galvanising
182/184	Galvanised wire
443	Thickness of coating for galvanised wire
1224	Chromium plating
148	Oil for transformers and switchgear
1133	Packaging Code
BS EN 837 –1	Burden tube pressure and vacuum gauges
2765	Dimensions of temperature detecting elements and corresponding pockets.

Information Copy - Not for Bidding



### 12.3.2 HV Switchgear

I.E.C.	B.S.	Title
60044-1		Current Transformers
60044-2		Inductive voltage transformers
60437		Radio interference test on high-voltage insulators
60099		Surge arresters for a.c. systems
60871		Shunt capacitors for a.c. power systems having a rated voltage above 1000 V
60168		H. V. post insulators
60273		Characteristic of indoor and outdoor post insulators
60383-2, 60305		Insulators for overhead lines
60865		Short-circuit currents - Calculation of effects
60694		Common specifications for high-voltage switchgear and controlgear standards
60265		High-voltage switches
60060		High-voltage test techniques
60034		General requirements for rotating electrical machines
60270		High-voltage test techniques
60376		Specification of technical grade sulfur hexafluoride (SF6) for use in electrical equipment
60512		Connectors for electronic equipment
60269		Low-voltage fuses
60137		Bushings for alternative voltages above 1000V
62271-203		High-voltage switchgear and controlgear
62271-102		High-voltage switchgear and controlgear
62271-100		Specification for a AC circuit breakers
	159	Busbars and bus bar connections
61089	215	Aluminium conductors
	2898	Busbars, conductors and connections
	7884	Specification for copper and copper-cadmium stranded conductors
	3288	Insulator and conductor fittings for overhead power lines

### 12.3.3 Small wiring and Auxiliary Electrical Apparatus

I.E.C.	B.S.	Title
	6231	Specification for PVC insulated cables for

		switchgear control wiring
60269		HRC Fuses
60529		Enclosures for electrical apparatus
	5685	Specification for electricity meters
60439		Specification for factory built assemblies of switchgear and control gear (up to 1000V ac)
60947		Low-voltage switchgear and controlgear
60228		Copper conductors in Insulated cables and cords
60287		Electric cables
60811		Common test methods for insulating and sheathing materials of electric cables and optical cables
60885		Electrical test methods for electric cables.
60034		Rotating electrical machines
60051		Direct acting indicating analogue electrical measuring instruments and their accessories
60898		Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations
60269		Low-voltage fuses
	1376	Specification for colours of light signals

**12.3.4 Batteries, DC Distribution Boards and chargers**

I.E.C.	B.S.	Title
	88	Specification for cartridge fuses for voltages up to and including 1000 V a.c. and 1500 V d.c. General requirements
60146		Semiconductor convertors
60439		Distribution Switchboards
60623		Secondary cells and batteries containing alkaline or other non-acid electrolytes
60947		Low-voltage switchgear and controlgear

**12.3.5 Protection, Control and Metering**

I.E.C.	B.S.	Title
60038		IEC Standard Voltages
60664		Insulation Co-ordination for equipment within low-voltage systems.
60068		Environmental Testing.
60255		Electrical Relays

60870	Telecontrol equipment systems.
60871	Shunt capacitors for a.c. power systems having a rated voltage above 1000 V
61000	Electro Magnetic Compatibility.
61850	Communication networks and systems in substations
61131-3	Programmable controller Part3: Programming languages

### 12.3.6 Earthing Systems

	B.S.	Title
CP – IEEE 80	7430	Earthing

### 12.3.7 Power Line Carrier, Fiber Optic Communication System and SCADA Equipment

	B.S.	Title
60495		Single sideband power-line carrier terminals
60353		Line traps for a.c. power systems
60481		Coupling devices for power line carrier systems
60834		Teleprotection equipment of power systems
60870		Telecontrol equipment and systems
60794		Optical fibre cables
60495		Single sideband power-line carrier terminals
60353		Line traps for a.c. power systems
60481		Coupling devices for power line carrier systems

### 12.3.8 Power and Control Cables

I.E.C.	B.S.	Title
60028		International standard of resistance for copper
60055	6480	Impregnated paper insulated cables
60060		High-voltage test techniques
60071		Insulation co-ordination
60227		PVC - insulated cables (non-armoured) for electric power and lighting
60228	6360	Copper conductors in Insulated cables and cords
60229		Tests on cable oversheaths
60287		Electric cables

60331,60332		Tests for electric cables under fire conditions
60466		A.C. insulation-enclosed switchgear and controlgear
60507		Artificial pollution tests on high-voltage insulators
60502		Power cables with extruded insulation
	6622	Electric cables. Armoured cables with thermosetting insulation for rated voltages from 3.8/6.6 kV to 19/33 kV. Requirements and test methods
60949		Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects
60811		Common test methods for insulating and sheathing materials of electric cables and optical cables
	5467	Specification for armoured cables
	6346	PVC-insulated cables for electricity supply
	6121	Mechanical cables glands for plastic insulated cables
	183	Specification for general purpose galvanized steel wire strand
	6234	Specification for polythene insulation and sheath of electric cables
	2484	Specification for straight concrete and clayware cable covers
	5346	ISO metric trapezoidal screw threads
	BS EN 10257	Zinc or zinc alloy coated non-alloy steel wire
	2627	Specification for wrought aluminium
ICEA S 108-720-2018		Standard for extruded insulation power cables rated above 46 through 500kV AC

**12.3.9 Transformers**

I.E.C.	B.S.	Title
60060		High-voltage test techniques.
60076		Power Transformer

60137		Bushings for alternative voltages above 1000V
60214		Tap-changers
60236		designation of electrostatic deflecting electrodes of cathode-ray tubes
60289		Reactors
60296	148	Insulating oils for transformers and switchgear
60422		Maintenance guide for insulating oils in service
60529		Degrees of protection provided by enclosures (IP Code)
	61	Specification for threads for light gauge copper tubes and fittings
	3600	Specification for dimensions and masses per unit length of welded and seamless steel pipes and tubes for pressure purposes
	4504	Circular flanges for pipes, valves and fittings (PN designated). Ferrous
	BS EN 60044	Specification for voltage transformers
60567		Oil-filled electrical equipment
60599		Mineral oil-impregnated electrical equipment in service
62155		Tests on Hollow Insulators
<b>12.3.10</b>		<b>Inspection and Testing</b>
I.E.C.	B.S.	Title
60068	2011	Basic environmental testing procedures
62271-203		High-voltage switchgear and controlgear
60060		High-voltage test techniques
60502/60840/62067		Power cables with extruded insulation
	6360	Specification for conductors in insulated cables and cords
<b>12.3.11</b>		<b>Civil Engineering, Building works and Services</b>
BS 308		Engineering drawing practice
BS 5950		The use of structural steel in building
BS 1192		Construction drawing practice
BS 5628		Code of Practice of the structural use of masonry
BS 5720		Code or Practice for mechanical ventilation and air

	conditioning in buildings
BS 5588	Code of Practice for fire precautions in the design of buildings
BS 5930	Code of practice for Site Investigations
BS 5964	Methods for setting out and measurement of buildings: permissible measuring deviations
BS 6031	Code of Practice of Earthworks
BS 6399	Code of Practice for dead and imposed loads
CP 3	Code of basic data for the design of buildings
CP 102	Waterproofing of buildings.
BS 5400 Part 5	Composite construction in structural steel and Concrete
BS 5390, 5618 part 3	Walling
CP 143	Sheet roof and wall coverings
BS 8004	Foundations
BS 8110	The structural use of concrete
SLS 522	Water for Concreting
BS 1474	Aluminium Sections
BS 476 Part 8	Fire Resisting Doors
ISO 898-1	Bolts & Nuts
ISO 630	Hot rolled structural steel sections
ISO/EN12944	Paints and varnishes -- Corrosion protection of steel structures by protective paint systems
BS/DIN EN 10027-1	Designation system for steels
BS 4449	Characterization of waste
BS 4483	Specification for steel fabric for the reinforcement of concrete
BS 4466	Steel fabric for the reinforcement of concrete. Specification
BS 1881	Testing concrete. Methods of testing hardened concrete for other than strength
BS 6319	Testing of resin and polymer/cement compositions for use in construction. Method for preparation of test specimens
BS 5481	Specification for unplasticized PVC pipe and fittings for gravity sewers
BS 6651	Code of practice for protection of structures against lightning
BS 4660	Specification for unplasticized PVC underground drain

	pipe and fittings
BS EN 752	Drain and sewer systems outside buildings. Generalities and definitions
BS EN 124	Gully tops and manhole tops for vehicular and pedestrian areas. Design requirements, type testing, marking, quality control
BS 6297	Code of practice for design and installation of small sewage treatment works and cesspools
BS 1722	Specification for fences
BS 4102	Specification for steel wire for fences
BS 6399	Loading for buildings. Code of practice for dead and imposed loads
BS 6266	Fire protection for electronic equipment installations. Code of practice

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## **CHAPTER 13 - CIVIL WORKS AND BUILDING SERVICES**

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## CHAPTER 13 - CIVIL WORKS AND BUILDING SERVICES

### 13.1 CIVIL WORKS

#### 13.1.1 Preliminary works

##### 13.1.1.1 Site Survey

The Contractor shall collect for himself site levels, sub-soil data and other information to enable him to estimate the bearing capacity, foundation requirements, etc., for use in the preparation of the Bid.

After the award of the contract, the Contractor must make his own site surveys to collect all the information's to prepare layout drawings.

The Contractor shall be responsible for all setting-out, irrespective of any checking by the Engineer.

The Contractor shall inform the Engineer within 24 hours whenever a new setting-out peg is established or an existing one destroyed, and shall regularly furnish the Engineer with layout plans showing all current setting-out and survey stations.

The Contractor shall keep duplicate copies of all his field books and survey calculations written in the English language for inspection by the Engineer.

The tolerances shall be ruled BS 5606 and BS 5964. The Engineer may at his discretion alter or specify new tolerances as necessary.

The Contractor shall survey the site of the new substation to obtain the following.

- (1) Location of datum of setting out and levelling.
- (2) Establishment of site boundaries and reduced site datum level.
- (3) Position and condition of any approaches, bridges and access roads to and over the site, including highest recorded flood level (from local knowledge).
- (4) Existing site levels on a 5 meters grid; and resultant contours at a meter vertical interval.
- (5) Drainage pattern of the area

The Contractor shall survey the sites of the substations to obtain details of above items site survey plan at a scale of 1: 500 shall be prepared, showing the survey results and the proposed layout of the new works. The plan shall be sent to the Engineer for his approval.

##### Final survey

After completion of the work contractor should do a complete detail survey of the substation including all the parts completed to the date of handing over. Engineer should be provided 3 hard copies and a soft copy.

##### 13.1.1.2 Sub soil Investigations

After award of the contract, the Contractor is to ascertain for himself the nature of the sub-soil conditions of the work sites. By means of boreholes and trial excavations etc. Samples shall be taken as necessary and tested to determine the physical and chemical characteristics of various strata and of the ground water. The sub-soil investigation should include determination of the design bearing pressure, recommendations for foundations with relevant design parameters and material to be used for the foundations.

In case of individual pad foundations, allowable bearing capacities at a location shall be recommended considering different sizes of foundations. Allowable bearing capacity of a foundation shall be assessed so as to limit the total settlement of 25mm in sandy soil while this limitation shall be increased to 35mm in cases of clayey soil. In cases of alternative sandy and clayey strata like sedimentary alluvial deposit, total settlement of individual pad foundations shall be limited to 25mm when recommending allowable bearing capacities.

In case of raft (mat) foundations, which shall be constructed to support for several rows of parallel columns where over half of plan area of the structure foot print is covered with individual pad foundations of said columns, settlement of foundations shall be limited to 50mm and 65mm in sandy soil and clayey soil respectively.

The safe bearing capacity of the sub-strata may be modified at his final design stage when the full site survey and investigation have been completed and the final layout, structural details etc. agreed. No variation in contract price will be made due to any variation in the bearing capacity leading to modification of foundation design at the final design stage.

Special attention shall be paid to the Ground water table and chemical composition of the ground water and soil in the substation area.

Extent of site investigation shall depends on many factors such as nature, size and complexity of the project, variability of subsurface condition of the ground. However, the following should be considered as a minimum requirement, assuming uniform conditions over the Site, but should be extended if many inconsistencies are encountered.

- (1) At least one borehole shall be advanced up to 3m below the bed rock level (at least 3m through the bed rock). For other boreholes, investigation shall be undertaken below all deposit that may be unsuitable for foundation purpose like soft compressible soil strata up to a competent stratum, and depth of investigation shall be decided by the engineer at site based on factors such as types of foundations to be adopted, variability of subsurface conditions, etc..
- (2) At least two boreholes shall be advanced at control building area, and the spacing between them shall be within 10m to 30m. For the other structures, borehole exploration shall be carried out at least at one location per each structure having heavily loaded such as main transformers, gantries, etc..
- (3) Borehole records shall describe and indicate level of all soils encountered and indicate the natural water table level. Rock core records shall specify total core recovery (CR), Rock Quality Designation (RQD), Unconfined Compressive Strength (UCS), Point Load Index (PLI).
- (4) Where applicable, samples of soil shall be obtained from all soil strata or at 2 meters intervals in a single stratum and tested to determine physical and chemical properties, particularly with respect to substances, which would react with concrete or other materials to be used for the foundation works.
- (5) Laboratory tests on disturbed soil samples collected during borehole investigation shall be carried out to determine index properties of soil like particle size distribution of granular soil and Atterberg limits of clayey soil for every stratum encountered in the subsurface. As per Engineer's request, laboratory tests on undisturbed soil samples collected while advancing

borehole shall be carried out to determine strength and deformational characteristic of soil without any variation for the contract price.

- (6) Where applicable, insitu soil tests shall be applied to all soil strata or at 1m intervals in a single stratum. Standard Penetration test shall be carried out in sandy soils and over-consolidated clayey soil while field vane tests shall be carried out in normally and slightly over-consolidated clayey soils.
- (7) Ground water samples shall be obtained from each Borehole and tested in accordance with approved practice.
- (8) Electrical resistivity of the soil shall be verified on four samples, in accordance with approved practice (e.g. IEEE 80).

Appropriate laboratory tests shall be carried out on all soil and ground water samples to an extent approved by the Engineer. All tests shall be in accordance with an approved standard, e.g. British Standard 1377.

Records of ground borings and trial excavations, results of insitu tests and laboratory tests to determine the physical and chemical properties of the soil and ground-water samples shall be incorporated into a comprehensive sub-soil investigation report. This shall include recommendations on the type of foundations and on the design bearing capacity of the sub-soil at founding levels for each site. Three copies or records and the report shall be sent to the Engineer.

The Sub-soil investigations shall be undertaken by a reputed Institution approved by the Engineer. A qualified geologist or materials engineer shall be in attendance at all times when borings are being driven or samples extracted. Laboratory tests shall be carried out at an establishment approved by the Engineer. Recommendations for foundations and land formation shall be given by a geotechnical expert.

### **13.1.2 Site Clearance**

#### **Cutting and removing trees & shrubs**

The Contractor shall clear all areas required for the work. All unwanted materials, debris, etc. shall be removed from the employer's premises. But shall take all reasonable precautions to prevent damage to existing road construction and to existing surfaces, buildings and other facilities in the area which do not need to be demolished.

Bushes, undergrowth, trees and hedges which are not specifically noted on the drawings or in the contract for preservation shall be uprooted and burnt or otherwise disposed of. Holes left by uprooting shall be promptly filled with suitable material and compacted.

#### **Removing existing equipment, dismantling steel structures**

Equipments and support steel structures, which are to be removed shall be removed carefully and handed over to the Kotugoda stores. Removing, dismantling, handling, transporting and handing over shall be done by the contractor as instructed by the Engineer. Any damages or losses shall be rectified by the contractor at his own cost.

#### **Demolishing & removing of existing Masonry/concrete structures**

Unwanted foundations shall be demolished or up-rooted. The Contractor shall clear all areas required for the work. All unwanted materials, debris, etc. shall be removed from the employer's premises. But shall take all reasonable precautions to prevent damages to the other structures.

### 13.1.3 Site formation and up keeping

#### Cutting and filling earth

##### Excavation

The whole excavations shall be carried out to the widths, lengths and depths shown on the approved drawings and in accordance with BS 8004 and BS 6031. No unlicensed or indiscriminate digging will be permitted. If top layer of soil is not suitable for the construction it shall be removed or stabilised as recommended by the investigator.

The Contractor may excavate by any method considered suitable, subject to the Engineer's approval, and shall allow for the use of types of plant most suited for excavation in any location and at any time.

The Contractor is to provide all strutting and shoring necessary for the safe execution of the Works.

The Contractor shall allow for risk meeting while excavating through any sort of soil, which may be encountered, including rock.

Materials from the excavation may, if approved by the Engineer, be used by the Contractor in the construction Works. Other excavated material shall be back filled where required or deposited where directed anywhere on site. Surplus materials shall be removed from the site by the Contractor.

The Contractor shall at all times keep the site free from all surplus materials, rubbish and offensive matter.

In foundation bottom 150mm layer of excavation in thickness shall be left undisturbed and subsequently removed only when the concrete is about to be placed in order that softening or deterioration of the surfaces of the bottom of the excavated area by exposure may be avoided as far as possible.

The bottom of all excavated areas shall be trimmed, levelled and well rammed. Concrete shall not be deposited thereon until the bottom has been inspected and approved by the Engineer.

##### De-watering

All excavation works are to be kept dry and clean, in order that work is not affected or interfered with by water entering the excavations. The Bidder is to allow in his Bid for the costs of pumping, de-watering or other methods of dealing with the water during and after excavation.

Arrangements made for dealing with water in excavations shall be approved by the Engineer. They must ensure that the de-watering of excavations can continue during the placing of concrete or the execution of any other works, which could be affected by water in excavations. Adequate precautions must be taken against washing out of cement and concrete or to prevent the work being disturbed in any way.

Water from pumping or other dewatering methods shall be properly drained away from the site or disposed of by tankers, so as not to inconvenience users of adjacent properties or sites.

No concrete, masonry, brickwork or other materials shall be placed or built until the surfaces are properly drained.

##### Filling and Reinstatement

If it is required to fill the land to level the formation level contractor shall get approved the filling material and method of construction before the commencement of the work.

Material to be used as fill or backfill shall be well graded granular material and shall have a following grading curve.

SIEVE SIZE	% PASSING
75mm	100
37.5mm	85- 100
10mm	40-100
5mm	25-80
600 µm	8 - 45
75 µm	5 - 20
Material shall have Liquid Limit less than 45% and Plasticity Index less than 18. Soaked CBR value at 95% of maximum dry density obtained by means of modified proctor compaction test shall be greater than 10%	

Filling for trenches, excavations and levelling of the site shall be deposited in layers not exceeding 250 mm un compacted thickness, each layer watered when necessary and well rammed or otherwise compacted to within 95% of the maximum dry density obtained by the use of a modified Proctor Compaction Test.

Any filling material shall not be contaminated with aggressive materials which are harmful for structural material to be used for construction of foundations. Soluble sulphate content and acidity level of filled ground shall comply with the requirements specified for DC-1 class of ground condition as specified in BS8500-1

Where excavations whether in rock or other material, are made to a greater depth than detailed, the intervening space shall be brought up to the proper level in plain concrete at the Contractor's expense.

Any formation encountered in the excavations which, in the opinion of the Engineer is not sufficiently strong to carry the loads which will be imposed on it, shall be excavated to an adequate load bearing stratum and replaced with mass concrete.

All equipment for determination of the density of filled areas shall be supplied by the Contractor. All tests shall be carried out in the presence of the Engineer. The tendered price is deemed to include for this.

Unless otherwise described, directed or permitted, imported filling shall consist of pervious naturally occurring material, free from mud, silt, clay, peat, vegetable or injurious matter and water soluble salts harmful to copper and other metals. Filling shall be imported only from approved areas.

**Stability of Fill and Embankment**

The Contractor shall be responsible for the stability of embankments, which formed either by cutting or filling, and precautions taken to protect the earthworks from deterioration under adverse weather conditions. Wherever applicable the recommendations contained in the following codes of practice shall be followed in calculations, detailing and performance of the earthworks and drainage.

Earthworks - British Standard Code of Practice BS 6031.

Embankments shall not be formed over inclined ground surfaces without previously forming the founding surface, on which the fill material will be placed, to a benched profile.

All top surfaces of earthwork shall be finished off level and regular and the sides of cuttings and embankments shall be properly trimmed to the detailed slopes. The soil stability of such slopes etc. shall be ensured.

The Contractor is to allow for embankments and cutting slopes to be well forked, raked and stabilised as protection from erosion to the approval of the Engineer.

The Contractor shall construct where necessary open ditches, bunds, culverts, etc., to divert and protect the site in both the short and long-term from flash floods.

If any slips occur in the excavations, banks or filling during the execution of the Works or during the period of maintenance from any cause whatsoever, the Contractor shall execute the necessary remedial work in such manner, and with such materials as approved by the Engineer, at the Contractor's expense.

The Contractor shall make good all settlement of filling that may occur up to the end of the period of defects liability at his own expense.

### Explosives

Explosives may only be used when specified or approved by the Engineer. If approved, their use shall comply with the following:

- (1) All local by-laws and regulations.
- (2) The Contractor shall store explosives in a licensed store or magazine provided with a separate compartment for detonators. Explosives shall be handled only by currently licensed shot fires. The Contractor shall ensure that there is no unauthorised issue or improper use of explosives brought on the Site.
- (3) Explosives shall be used in the quantities and manner recommended by the manufacturers. The written approval of the Engineer shall be obtained for each location or series of locations where the Contractor wishes to use more than 5 kg of explosives in one blast. Such approval shall not in any way relieve the Contractor of his liabilities under the Conditions of Contract.
- (4) When blasting is carried out the Contractor shall ensure, by adherence to proper safety distances and by the use of heavy blasting mats where necessary, to prevent the dispersal of material, that no damage is caused to persons, animals or property on or off the Site. Special care shall be taken when blasting in wet ground to ensure that individual explosions are reduced to such a size as to preclude damage to any buildings or structures.

### **Earth retaining structures**

Retaining structures shall be designed and constructed in accordance with latest version of BS8002. In designing gravity and cantilever retaining walls, passive earth pressure at front side of the wall shall be omitted. Structural design of reinforced concrete retaining

walls shall be designed as per BS8110:Part1:1997. Following factors of safety shall be considered in case of checking against stability of retaining walls

Factor of safety against sliding 1.5

Factor of safety against overturning 1.5

Bearing pressures underneath foundations shall not exceed the allowable bearing capacities recommended in relevant geotechnical investigation reports

### **Anti Termite soil treatment**

Anti termite treatment with more than 10 years guarantee shall be done for the buildings specified in scope of works including 3m to either side of the building

### **Land escaping & tree planting**

Suitable trees shall be planted in available vacant areas where necessary grassing to be done to protect erosion.

### **Surface chipping**

Stone chipping used for substation surfacing are to be clean hard crushed stone graded from 20 - 40 mm. The formation in areas where stone chipping are to be used shall be well compacted to the approval of the Engineer, and treated with an approved total weed killer, used in accordance with the manufacturer's instructions.

Stone chipping shall be laid and lightly compacted to a minimum finished thickness of 100 mm.

## **13.1.4 Cable Trenches & Ducts**

### **Fiber optic, control and power cable trenches & ducts**

The Contractor is responsible for all civil works required for cable runs between switchgear and building. In concrete cable trenches, Main cable trenches shall be rack types with sufficient working space. Cable entries into buildings shall be through ducts or in concrete cable trenches. Trench covers outside buildings shall be of reinforced concrete designed for the maximum likely imposed loads appropriate to their location. Concrete cable trenches shall be adequately sloped and adequate capacity of drainage system shall be provided to soak water. Expansion joints shall be provided in suitable lengths.

Power cable which pass under roads, car parking areas, hard standing areas or where they would otherwise be at risk shall be laid in ducts. A 100% additional capacity shall be installed for future use and the whole surrounded in a minimum of 150 mm thick C25 concrete. Conduits provided shall be sized to suite the cables provided. All other main cable trenches shall have additional capacity of 30% future use.

Cable entries into buildings shall be sealed to prevent the entry of any water, dust, vermin, etc., using suitable materials. Cable entry to the control building shall be provided for future requirements.

Ducts



All cable ducts shall be laid in straight lines and regular gradients between cable pits, as directed. All ducts shall be kept clear from soil, debris and other obstructions during and after laying.

Cable ducts may be pitch fibre, PVC, plastic or other material approved by the Engineer and obtained from an approved manufacturer.

After the cable ducts have been completed, duct shall be fully swabbed- out and all foreign matter removed. All rough edges shall be removed from duct entry and exit points. A pull wire of adequate section shall be used. Cables and duct may be lubricated with an approved lubricants such as talc.

The fiber optic duct should be resist to mice and fiber duct should be perfectly fitted to the end panel.

### **Concrete Beds and Casings**

Concrete beds and casings to cable ducts and under roads, buildings, floors and foundations shall be of lean concrete and of 150mm minimum thickness. Elsewhere the ducts shall be laid on and surrounded with approved granular material of 150mm minimum bed thickness and 300 mm minimum cover.

### **Cable Pits**

Cable pits shall be provided at interval not exceeding 100 meters and also at the bends of all cable ducts.

Cable pits may be constructed of bricks; concrete blocks, in-situ concrete or precast concrete chamber rings and cover slabs. In each case, the material shall be in accordance with the relevant sections of this Specification. Cable pits shall be sized according to their depth, to provide sufficient working space and access for maintenance. When constructed of block work, they shall be rendered internally with sand/cement mortar finished with smooth vertical surfaces.

Where precast concrete rings are used they shall be surrounded with concrete 150 mm thick.

Galvanised malleable iron steps are to be provided in all cable pits over one meter deep and built in as work proceeds.

Rates shall include for all necessary crossings shifting existing any obstructions etc.

Power cables shall be laid on and surrounded with sand fill in unlined trenches. Pre-cast concrete cable protection covers & PVC marker tape shall be provided over the full width and length of cables in sand filled trenches. Pre-cast concrete marker posts shall be provided along cable runs at 5 meters centres and changes in direction.

Rates shall include for all necessary crossings shifting existing any obstructions etc.

## **13.1.5 Steel support structures**

### **Galvanized steel support structures**

Galvanised steel structures shall be provided under this Contract for supporting the insulators, switchgear, overhead conductors, bus bars, earth wires and other equipment and fittings generally as shown on drawings.

The structure shall include all necessary access ladders or step bolts to give access to the various levels equipment and shall incorporate all necessary earthing.

The design and arrangement of supporting structures shall be subject to approval of Engineer; such structures shall be rigid and self-bracing against all dead, wind, pull off and other applied loads. Whenever such an arrangement can be adopted, structures shall be braced by horizontal beams at intermediate or high level to provide an integrated framework such that all bending moments shall be distributed in the structures with zero over turning moments at ground level. At or near ground level, all uprights shall be provided with holding down bolts provided under this Contract.

The whole of the rolled structural steels shall comply with ISO 630, grade E 275 and E 355. The steel shall be free from blisters, scales and other defects. The grade of steel to be used for the structural work shall be approved by the Engineer before commence the design work

Minimum thickness of Main members and bracings of the lattice structures shall not be less than 6mm and 5mm respectively.

Size of standard clearance boltholes shall be in accordance with BS5950-1:2000. The design to be such as to keep the number of different parts as small as possible and is to facilitate transport, erection and inspection.

Pockets and depressions likely to hold water shall be avoided, and all parts of the structures shall be properly drained.

Steel sections forming the framework shall be heavily galvanized in accordance with the BS EN ISO 1461.

The bolts and nuts shall be complying with the ISO 898-1.

The contractor shall submit details of nuts and bolts to be used in construction to the Engineer for approval.

Bolts and nuts shall be galvanized and fitted with spring washers. Taper washers are to be added where necessary. Threads of bolts shall be spun galvanized and the threads of nuts shall be oiled.

All members shall be cut to jig and holes shall be drilled or punched to jig. Parts shall be carefully cut and holes accurately located so that when the members are in position the holes can be accurately aligned before being bolted up. Drifting of holes will not be permitted.

Stress diagrams and calculations shall be submitted as required by the Engineer and the dispositions and sections of all members and the design of joints and fittings shall be submitted to approval. All steel structures shall be designed in accordance with BS5950-1:2000.

#### Load Combinations for Design Purposes

The basic wind speed to be considered for wind load calculations shall be taken as mean hourly wind speed of 25.3 m/s unless local meteorological records show that a higher value is appropriate. Wind load calculation on structures whenever required shall be carried out with reference to BS6399-2:1997.

The design calculations shall include the computation of stresses in all structural components and shall show how all loads are transferred to the foundations.

The structures shall be designed to meet the maximum of the total forces calculated from the following loading.

- Dead weight
- Wind loading
- Short circuit force
- Loads arising during assembly and erection.

Following factors of safety to be applied for all loads when carrying out structural design of structures

Steel structures and their foundations                      2.5

For stability calculation of all foundations, following factors of safety shall be considered

Factor of safety against sliding                                      1.5

Factor of safety against overturning                                1.5

Bearing pressures underneath foundations shall not exceed the allowable bearing capacities recommended in relevant geotechnical investigation reports

Consideration shall be made in sizing members to eliminate excessive deflection or vibration during service.

Effective slenderness ratio of members shall not exceed the following:

Main members	120
Bracing and other members	200
Redundant members	250

All structures shall be designed so that no failure or permanent distortion shall occur when tested with an applied force equal to 2.5 times the loading associated with the simultaneous applications of any of the load combinations listed below.

Load Combination 1 - High Wind

- (a) Dead weight
- (b) Wind pressure of 1640N/sq.m applied to 1 1/2 times the projected area of the members of lattice structures.
- (c) A wind pressure of 970N/sq.m applied to conductors and electrical equipment.
- (d) Tensions associated with line terminating tower to be as defined in Section "Line termination".
- (e) Conductor temperature at time of short-circuit 150°C.

Load Combination 2 - Short Circuit, Maximum Normal Wind

- (a) Dead weight
- (b) A wind pressure of 820N/sq.m applied to 1 1/2 times the projected area of the members of one face of lattice structures.

- (c) A wind pressure of 485N/sq.m applied to conductors and electrical equipment.
- (d) Tensions associated with line terminating tower to be as defined in Section "Line termination"
- (e) Conductor temperature at time of short-circuit 150°C per 1sec on adiabatic conditions.

#### Load combination 3 - Stringing at Minimum Temperature and No Wind

- (a) Dead weight
- (b) Tensile force from the conductor(s) on one side of the gantry, which constitutes the greatest danger to the gantry or its component parts during stringing.
- (c) An additional vertical load of 1kN (corresponding to the weight of linesman with tools) applied in the most unfavourable way.
- (d) Minimum conductor temperature 7°C.

Details and fastenings shall be designed to have a factor of safety against failure not less than the main members of the structure.

For purpose of calculating the maximum wind load, which may be applied to structures. It shall be assumed that the windblown in any horizontal direction. The associated wind forces on the gantries or electrical equipment and structures are to be calculated using IEC 826 or approved equivalent.

The force due to short circuit current is to be based on the maximum force resulting from a "2 phase to earth" short circuit using the design fault level in section 1.5 and with appropriate factors to cover:

- (a) A fully asymmetric condition.
- (b) The relationship between system frequency and natural frequency of the vibration of the equipment concerned.
- (c) A dynamic factor for sudden application of the short circuit faults. Providing the bus bar design contains no spans with natural frequency of approaching system frequency the force on conductors resulting from a two phase to ground short circuit may be obtained from the equation

$$F = \frac{4 \times 0.2 \times I^2}{d}$$

Where

F = Force in N/m

d = Conductor spacing in meters

I = Maximum 3 phase current in kA

4 = Stress factor

#### Line Termination's

Slack spans from overhead line terminating towers complete with tension insulator strings and conductors shall be supplied by the contractor. Connections from these slack spans to the substation equipment shall be made under this Contract. Substation structures onto

which slack spans are terminated shall be suitably designed for this additional loading. The fixings required to terminate the slack spans shall be provided under this Contract.

In addition to any other loads the line terminating structures shall be designed to withstand the pulls of line conductors and earth wires when applied at any angle up to 45° from the bay centreline, the following maximum tensions are to be used:

- |      |             |                     |
|------|-------------|---------------------|
| (i)  | Conductors  | 6.6kN per each wire |
| (ii) | Earth wires | 4.5kN per each wire |

In case where strung bus is available, tension of conductors in strung bus shall be omitted. Tensions in strung bus conductors shall be selected such that the line terminating structure can bear this additional load when line side conductors and earthwires are not available.

### General

The standards of workmanship, materials and design are to be equal to those laid down in BS5950-1:2000. Steelworks shall be fabricated from new sections unless agreed otherwise in writing by the Engineer.

The Contractor shall make the following submittals to the Engineer:

Production mill sheet and quality control tests sheets for each delivery of structural steel.

Full details of the results of material tests.

Full details of steel types and types of nuts and bolts to be used.

Full details of erection procedures.

Full details of proposals for all main welds, arrangement of welded assemblies and welding procedure.

Approval of welders including all tests for welders

Full details of protection system to be used for steelwork.

Test results for paint thickness.

Results for structural deflections under test loads.

The design of all structures shall be as specified and, in addition, is to ensure that in the event breakage of either one earth wire or one stay wire the factor of safety is not less than 1.5. Supplying & erecting of steel structures

### Materials

Samples of all materials shall be tested and copies of the test reports giving physical and chemical properties issued to the Engineer for approval. These tests shall prove the compliance of the material for the purpose intended in accordance with the approved standard. Where tests are carried out by an independent laboratory, the source of origin of the material shall be stated and if different sources of supply are contemplated additional tests shall be carried out.

### High Strength Friction Grip Bolts

The manufacture and use of high strength friction grip bolts shall be in accordance with ISO 7411. The tightening of bolts by the part-turn method is not permitted. No bolt that has been fully tightened and then un-tightened may be retained in the permanent works and shall be replaced.

All high strength friction grip bolts shall use a load-indicating washer to register the correct shank tension in the bolt. The type of load-indicating washer used shall be subject to the Engineer's approval and must be used in accordance with the manufacturer's instructions and recommendations. If required Engineer may call for tests to prove the adequacy of the washers proposed.

### Connections

Shop connections shall generally be electric arc welded or bolted. Site connections shall be bolted as shown on the drawings unless specifically approved by the Engineer.

Bracing connections shall develop forces not less than 50 percent of the effective capacity of the member.

All connections between main members shall have a minimum of 2 bolts per connections and the gusset plates shall have a minimum thickness of 6 mm.

Fabrication and erection shall conform at all stages to the standard approved by the Engineer and allowance should be made for the Engineer to inspect the steelwork during fabrication and before shipment to site.

Bolted construction shall be tested for dimensional accuracy before dispatch to site by the complete assembly of a frame or truss in the shop. Bolted connections shall be fabricated with due attention to the calculated mode of action of the joint and where an eccentricity cannot be avoided members must be adequate to resist the bending stresses induced.

All steelwork shall be fabricated to the following tolerances below:

On length 1.3 mm

Twist and deviation from the required profile shall not exceed 1 in 1000.

### Welding

Welding of structural steelworks shall be by an electric arc process. The procedure to be followed, plant and equipment to be used and the testing and inspecting to be applied, shall all be to the satisfaction of the Engineer and shall conform generally with BS EN 1011 and with further details contained in the Specification. Electrodes for metal arc welding shall comply with BS EN 499.

Welded construction shall be carried out in workshops under approved conditions by experienced operators and where continuous supervision is exercised. Machine welding will be allowed where approved machines are in use, correctly controlled by qualified operators. Where the Engineer approves site welding, this shall not adversely affect the efficiency of the welding and, where necessary, effective protection and other safeguards, as shall be agreed with the Engineer.

### Welding Procedure.

Details of the proposed welding procedure accompanied by a diagram showing the build-up of all main welds, together with the details of the manufacture, classification, code and size of electrodes to be used, shall be submitted to the Engineer for his approval.

Welding shall be such that distortion is reduced to a minimum, and local distortion is rendered negligible in the final structure.

Butt welds in flange plates and/or web plates shall be completed before the flanges and webs are welded together.

Approval of the welding schedule and procedure shall not relieve the Contractor of his responsibility for correct welding and for the minimising of distortion in the finished structure.

All welds shall be finished full and made with the correct number of runs, the welds being kept free from slag and other inclusions, all adhering slag being carefully removed from the exposed faces immediately after each run.

(1) Fusion faces

Fusion faces, angle of bevel, root radius and the like shall be properly prepared to give the approved mild forms. The fusion faces shall be carefully aligned and the correct gap and alignment maintained during the welding operation. In the preparation of the fusion faces, shearing shall be limited to metal thickness not greater than 8 mm. All fusion faces shall be prepared by machining, or where approved, by the use of special flame cutting apparatus. Faces shall be kept clean and protected.

(2) Butt welded joints

All main butt welds shall have complete penetration and, except on tubes where it is impracticable, shall be welded from both sides, the back of the first run being suitably gouged out.

The ends of the welds shall have full throat thickness. This shall be obtained on all main welds by use of extension pieces adequately secured on either side of the main plates. Additional metal remaining after the removal of the extension pieces shall be removed by machining, or by other approved means, and the ends and surfaces of the welds shall be smoothly finished.

(3) Intermittent welds

Intermittent weld shall not be permitted without the approval of the Engineer.

Cleaning and Steelwork Protective Coating

The Contractor shall provide all hoists, slings, cradles, ladders scaffolds, plant and machinery required for the carrying out of the painting and in particular, he should pay special attention to his requirements for painting the structural steelwork on site. The suitability and capacity of all plant and equipment used for the carrying out of the painting shall be to the satisfaction of the Engineer.

The Contractor shall select a system of steelwork protection, which shall conform to the recommendations of BS 5493 Protective coating of iron and steel structures against corrosion or equivalent standard. The selected system shall have a life to first maintenance of 20 years under the environmental conditions at the site, which shall for purposes of classification by BS 5493, be taken to be:

- External - Exterior exposed non-polluted coastal atmosphere (Table 3, Part 3)
- Internal - Interior (of building) normally dry (Table 3, Part 6)

The Contractor shall submit for the Engineer's approval a full specification for the protective coating system proposed which shall include details of the materials, methods of surface preparation, methods of application, coat thickness, remedial treatment for damaged surfaces, etc. The Contractors shall be responsible for every aspect of the system between purchase of raw steel and project completion.

Where possible and practicable coatings shall be applied under controlled, workshop conditions and on-site work shall be kept to a minimum. If the final surface finish of the

protective coating system is not a high gloss, decorative finish of an approved colour, the Contractor shall provide such a finish using paints, which are compatible with the protective coating system. Full details of any decorative paint finishes shall be submitted to the Engineer for approval.

The whole of the steelwork shall be cleaned and prepared for protection coating by an approved blast cleaning method and all rust, grease, mill scale and harmful matter shall be removed. The surface shall be blast cleaned to comply with the requirements of one of the ISO 8501.

Dirt and grease shall be removed by emulsion cleaners followed by thorough rinsing with water, or by steam cleaning, or by controlled high-pressure water jets. The Contractor shall not use solvents or detergents.

Blast-cleaning shall be carried out whenever possible after fabrication but when this is not possible, or when some time is allowed to elapse before painting, then the cleaned steel shall be protected by application of a single coat of a suitable prefabrication weldable primer within 4 hours of blast-cleaning (2 hours of out door blast-cleaning). All dust residues and debris shall be removed from the steel surface after blast cleaning before the protective coating is applied.

All primers and paints shall be standard proprietary products manufactured by one approved supplier. The materials shall be applied without adulteration and in accordance with the manufacturer's recommendations. Priming paints shall be applied by brush. No thinners or diluents shall be allowed in the painting areas, except as recommended by the manufacturer of the paint system approved by the Engineer. Solutions for cleaning brushes shall be coloured for identification purposes.

All painting at the works of the steelworks fabricator or his specialist painting Sub-Contractor shall be done in a clean, dry building, the air temperature of which shall not be allowed to drop below 5°C. No painting shall take place when the relative humidity is over 90% and a wet-dry bulb thermometer shall be kept to record the relative humidity. No painting shall take place with condensation on the steelwork or, if in the open, during rain, fog or mist.

Paint shall only be applied to clean dry surfaces. No further coats of paint shall be applied until the previously painted surface is hard dry and in a fit condition as recommended by the manufacturer of the paint system. Each coat of paint shall be different in colour.

Any damaged paintwork shall be cleaned down and re-treated as recommended by the paint manufacturer before further paint coats are applied.

If galvanising is used, the whole of the fabricated steelwork shall be blast cleaned, treated in an acid pickling bath and then hot dip galvanised. The density of Zinc coating shall be 7.14 g/cm<sup>3</sup>.

To check on the galvanising, two token plates of comparable thickness shall be treated under the same conditions as the work itself, so as to be representative of that work, and shall be delivered to site for testing.

#### Treatment of Bolted and Welded Joints

Provision shall be made to ensure that no paint is applied until after erection to contact surfaces for joints using high strength friction bolts or to within 50 mm either side of joints to be welded.



The appropriate areas of the cleaned steelwork in such cases shall be protected at works with lanolin resin, which shall be removed with white spirit immediately prior to bolting up or site welding.

After erection the welded areas and the edges of site joints shall be cleaned down, primed and painted all in accordance with the standard specified.

## **Galvanising**

### General Requirements

This article defines the minimum requirements for galvanizing as well as for surface cleaning and preparation for the protective coating of galvanized steel surfaces.

All steel for outdoor use is to be galvanized and further painted if requested by the Engineer. The galvanizing procedure shall be started only after having finished all chipping, trimming, fitting and bending. Also, all drilling punching, cutting and welding shall have been completed and all burns removed.

All steel including bolts, nuts and washers, shall be galvanized at the manufacturer's premises by means of hot-dipping in accordance with internationally recognized standards such as BS EN ISO 1461-2009 and BS 729 or equivalent approved by the Engineer.

Where members are of such length that they cannot be dipped in one operation, great care shall be exercised to prevent warping. All holes in material shall be free of excess speller after galvanizing. All material shall be safeguarded against embrittlement during galvanizing. Zinc coating shall be uniform in thickness and so applied that it will adhere to the surface of the steel.

Major damage to galvanizing shall be cause for rejection. Material on which galvanizing has been damaged shall be re- dipped unless the damage is minor and local and can be repaired by applying galvanizing repair paint, to the satisfaction of the Engineer.

If particularly specified for protection during transport and erection. Material on which galvanising has been damaged shall be re-dipped unless the damage is minor and local and can be repaired by applying galvanizing repair paint, to the satisfaction of the Engineer. If particularly specified for protection during transport and erection, all galvanized steel members shall be coated with a suitable pre-primer with minimum thickness of 40 micron and matching the primer to be applied after erection.

If not otherwise specified, galvanized steel surfaces shall be chromated with approximately 3-micron thickness.

Single items such as cable trays, fences, etc. may be galvanized and PVC covered if so approved by the Engineer.

### Cleaning and surface preparation

Prior to painting the galvanized steel surfaces shall be carefully brushed with fresh water in order to remove all foreign matters such as salt, white rust and zinc corrosion products, dust, sand and dirt.

After erection and prior to the painting at site, the surfaces shall be cleaned thoroughly by the use of mechanical steel brushes and fresh water to remove all foreign matter.

After cleaning, all surfaces shall be checked for any damage caused to the galvanizing. Minor damage shall be carefully freed from dust and shall be touched up with a zinc-chromate primer as specified. Major damages and welding seams shall be sand- blasted

and painted with zinc rich primer such as specified in below; in specific cases re-galvanizing may be required.

Performance and application for painting at site

General requirements at site

All surfaces to be painted must be moisture-free and painting shall not take place when:

- The surface temperature is above 40<sup>0</sup>c
- The relative humidity is above 85% or the surface temperature is closer than 3<sup>0</sup>C or below the dew point
- It is raining
- Sandstorms occur to such extent that wet paint might be affected.

Paint shall be applied only to clean, dry surfaces after approval of the Engineer. Painting shall commence within four hours after cleaning, if not otherwise approved, and paint shall be applied evenly to be free from runs, sags, laps, skips or other defects.

There must be no delay between the applications of successive coats but each coat must be thoroughly dry before the next coat is applied. Before additional coats are applied to painted surfaces, the existing paint shall be cleaned of all foreign matters and then suitable sanded, if necessary, according to directions given by the plant manufacturer and subject to approval of the Employer/Engineer. Successive coats shall be of different colour shades.

All finishes shall be clean and in good, sound condition. Completed surfaces, which do not meet the levels, as set forth in these Specifications shall be re-coated at the cost of the Contractor.

The dry film thickness 100 microms for all coats as specified below shall be considered as a minimum unless otherwise directed and regular dry film thickness shall be checked by employing the instruments as stated above.

To ensure the suitability of paints the Contractor shall execute sample tests at site.

These tests shall be carried out at a very early stage of the contract period and no paint shall be ordered before final selection of the paint is subject to the approval of the Engineer, depending on the results of the above mentioned site tests.

#### Painting of Galvanized Towers and Outdoor Steel Structures

All galvanized steel in areas other than C1 and C2 corrosivity environments (as per ISO/EN 12944) should be protected with an appropriate paint coating with Epoxy Primer. The durability of the coating should be considered as more than 15 years as mentioned in ISO/EN 12944. The corrosivity environment category of the site should be referred from the site environmental conditions of the scope of work of this contract document. All the work and material should comply with ISO/EN 12944.

Other exposed metal surfaces should be painted with suitable anti corrosive paint coating with Epoxy Primer as requested by the engineer under the provisions of ISO/EN 12944.

In height restricted areas, it is necessary to apply red and white bands for the towers and structures above specified height, in accordance with Annex 14, Aerodromes, Chapter 6, paragraph 6.2.5 of the International Standards and Recommended Practices issued by the International Civil Aviation Organization, and is subject to the Engineer's approval.

#### Surfaces of Stub Angles and Caps

The stub angles shall be galvanized as described above. Prior to galvanizing, all stub angles shall be sandblasted.

Painting should be applied in the zone 50 cm above and 50 cm below concrete level.

- 1) 1 coat of primer as described in the product specification.
- 2) 3 coats of 125 microns, each to be applied, 2-pack coal tar epoxy paint
- 3) After setting of the stub angles and concreting foundation caps the sealing of the joint shall be performed by an acrylic type sealer (approximately 1.5cm thickness around the stub angle).
- 4) 2 coats of 2 pack coal tar epoxy paint, 125 micro each covering approximately 10 cm above the concrete level and coating the foundation cap in total (including approximately 5 cm of the vertical surface of the foundation) shall be applied
- 5) After erection the intermediate and final coat as for the galvanized steel painting shall be applied as described above up to the joint of the stub angle
- 6) Surfaces of steel piling cases:  
Steel piling cases shall be sandblasted and treated by bituminous fill etc. down to 50 cm below ground level
- 7) Bidder may also propose other measures to protect the stub angles from corrosion, e.g. proposing special type of steel.

#### Transportation and Storage of Steelwork

All steelwork shall be transported, lifted and generally handled in a manner that does not affect the shape or surfaces of the section. Lifting slings shall be of nylon rope; chains and hooks shall not be used in contact with the steelwork. The position of lifting points used on sections shall be such that the stress induced in the sections does not exceed one half of the yield stress of the materials.

Steelwork shall be stored in clean, dry conditions off the ground. Separate pieces of steelwork shall have spacer blocks between them.

#### Erection

The Contractor must provide all temporary works, of any kind whatsoever, he shall deem necessary to ensure the correctness of alignment, plumbing and stability of the various frames and members.

During erection the work shall be securely bolted or otherwise fastened and, if necessary, temporarily braced to provide safety for all erection stresses and conditions, including those due to erection equipment and its operation. No permanent bolting of high strength friction grip bolts shall be done until proper alignment has been obtained.

#### Inspection and Tests

The Contractor shall supply to the Engineer details of all steelwork and accessories in order that inspection can be effected. Details shall include dates, times and places of manufacturing, rolling, fabricating, painting, galvanising and all other processes. The details shall be given to the Engineer at least 7 days prior to such inspections taking place.

All the tests shall be carried out by the Contractor. The Contractor shall prepare test sample to suit the appropriate testing methods all tests and inspection results shall be submitted to the Engineer within 24 hours of the test completion.

Inspection and Testing of Welds to be inspected shall not be painted or otherwise obscured until they have been inspected.

Inspection and Testing of Paint

Tests shall be carried out to the appropriate sections of BS 3900. Tests for final dry film thickness (DFT) shall be carried out over 10% of the painted area. Over such test areas, readings shall be taken on a grid 200-mm square and recorded.

The contractor shall carry out tests, which are requested by the Engineer as specified in relevant British Standards.

Testing of Welding Operators

Only welding operators who satisfy the appropriate tests shall be employed on welding. Should an operator fail in the first test, two further tests shall be undertaken immediately and to qualify the operator must satisfactorily pass both these tests.

Responsibility and Guarantees

The Engineer shall have access at all times for inspection of the work and all pertinent materials during preparation and progress of the work. Should any work or material be found to be defective or not in compliance with the Engineer's requirements, correction or replacement shall be done by the contractor at his own cost.

**13.1.6 Concrete Work, Foundations & Piling Work**

**Concrete Work**

All reinforced concrete structures except road crossing structures including control building shall be designed and detailed as per BS8110:Part1:1997. In this case, partial safety factors for loads and load combinations shall be considered as per BS8110:Part1:1997. In case of road crossing structures, loads, partial safety factors for loads and load combinations shall be considered in accordance with latest revision of BS5400.

Concrete Trial Mixes

Grades of concrete to be used in the Works shall be as shown below. The criteria given are designed to produce a workable homogenous plastic mixture and to ensure at least 50 years of service life under the particular exposure conditions at the site. Where adequate workability is difficult to obtain at the maximum water/cement ratio allowed, an increased cement content and/or the use of plasticizers or water-reducing admixtures may be considered at no additional cost to the Employer. Cement contents in excess of 550 kg/cu. m shall not be used.

Concrete	Max. Size	Min. Cement Content	Max. Free Water/Cement Ratio
Grade	Agg. mm	kg/m <sup>3</sup>	

C32/40	20	320	0.55
C28/35	20	280	0.60
C25/30	20	260	0.65
C20/25	20	240	0.70

Grade of concrete, free water/cement ratio and minimum cement content shall be decided pertaining to BS 8500 based on factors: design nominal cover; exposure class, maximum aggregate size; service life of the structure. In this case, exposure condition (exposure class) shall be classified as per BS8500-1.

Nominal cover to outer most reinforcement shall be decided in accordance with BS8500 for the durability requirement, and selected nominal cover shall be satisfactory with the structural and fire requirements

For aggressive ground conditions, which are severe than DC-1 class as categorized in BS8500, special considerations shall be taken when deciding maximum free water/cement ratio, minimum cement content and cement type to be used. Design of concrete mixes for such aggressive ground conditions shall be in accordance with BS8500

The Contractor shall submit not less than 3 weeks before the commencement of manufacture of preliminary trial design mixes the following information to the Engineer in respect of each grade of concrete.

- (1) Grade of concrete
- (2) Title of particular trial mix.
- (3) The grading of the aggregates.
- (4) The ratio by weight of all the constituents of the concrete.
- (5) The expected compacting factor and slump.
- (6) Full details of the proposed site quality control.
- (7) Full details of the proposed laboratory for testing.

The Contractor shall also confirm his proposed testing regime and acceptance criteria for the Preliminary Trial Mixes. If the proposals not be approved by the Engineer, and then the Contractor shall comply with the paragraph on preliminary test cubes and the two following paragraphs.

At least four weeks before commencing any Concreting in the Works, the Contractor shall make trial mixes using samples of aggregates and cements typical of those to be used. If possible, the Concreting plant and the means of transport to be employed in the Works shall be used to make the trial mixes and to transport them a representative distance. A clean dry mixer shall be used to make the trial mixes and the first batch shall be discarded.

Preliminary test cubes shall be taken from the proposed mixes as follows:

For each grade a set of 6 cubes shall be made from each of 3 consecutive batches. Three from each set of six shall be tested at an age of seven days and three at an age of 28 days. The cubes shall be made, cured, stored, transported and tested in compression in accordance with BS 1881. The test shall be carried out in a laboratory shall be approved by the Engineer.

If it is proposed to use an admixture in the mix then for each grade of concrete a batch shall be made with a double dose of the additive. For each of these batches 3 cubes shall be made and one tested at 7 days and 2 at 28 days to determine the likely effect of error in dispensing.

The trial design mix proportions shall be approved if the average strength of a set of 9 cubes tested at 28 days exceeded the specified characteristic compressive strength by current margin less  $3.5 \text{ N/mm}^2$ . The results of the seven-day cube tests shall be used to give an indication for future use of the strengths likely to be achieved at 28 days. They shall not be used to satisfy the 28 days preliminary test cube strength requirements.

The current margin for each particular type of concrete mix should be determined; it may be taken as having the smaller of the values given by (1) or (2).

(1) 1.64 times the standard deviation of cube tests on at least 100 separate batches of concrete of nominally similar proportions of similar materials and produced over a period not exceeding 12 months by the same plant under similar supervision, but not less than  $1/6$  of the characteristic strength for concrete of grade 7, 20 or 15, or  $3.75 \text{ N/mm}^2$  for concrete of grade 20 or above.

(2) 1.64 times the standard deviation of cube tests on at least 40 separate batches of concrete of nominally similar proportions of similar materials and produced over a period exceeding 5 days but not exceeding 6 months by the same plant under similar supervision, but not less than  $1/3$  of the characteristic strength for concrete of grade 7, 10 or 15, or  $7.5 \text{ N/mm}^2$  for concrete of grade 20 or above.

Where there are insufficient data to satisfy (1) or (2) above, the margin for the initial mix design should be taken as two-thirds of the characteristic strength for concrete of grade 7, 10 or 15, or  $15 \text{ N/mm}^2$  for concrete of grade 20 or above. This margin should be used as the current margin only until sufficient data are available to satisfy (1) or (2) above. However, when the required characteristic strength approaches the maximum possible strength of concrete made with a particular aggregate, a smaller margin but not less than  $7.5 \text{ N/mm}^2$  may have to be permitted for the initial mix design.

At each test no cube strength shall fall below the appropriate minimum specified in the Contractor's designs.

Before commencing the Works the Contractor shall submit to the Engineer for his approval full details of the mixes he proposes to use, with their anticipated average strength, which must be based on the satisfactory results of these preliminary tests.

The Engineer shall if he so desires be present at all preliminary tests. The Contractor shall inform the Engineer of his intention to carry out such tests and the time and place of the tests at least 24 hours before they take place.

Neither the mix proportions nor the source of supply of materials shall be altered without the prior approval of the Engineer except that the Contractor shall adjust the proportions of the mix as required to take account of permitted variations in the materials. Such approval shall be subject to the execution, to the Engineer's satisfaction, of trial mix procedures set out herein.

### Ready-Mixed Concrete

Ready-mixed concrete as defined in BS8500-1, which batched off the Site, may be used only with the agreement of the Engineer and comply with all requirements of the Contract.

The concrete shall be carried in purpose made agitators operating continuously, or truck mixers. The concrete shall be compacted and in its final position within 2 hours of the

introduction of cement to the aggregates, unless a longer time is agreed by the Engineer. The time of such introduction shall be recorded on the delivery note together with the weight of the constituents of each mix.

Unless otherwise agreed by the Engineer, truck mixer units and their mixing and discharge performance shall comply with the requirements of BS8500-2.

## Materials

### Cements

The type of cements and combinations to be used shall be considered in accordance with BS 8500 based on durability and structural requirements.

Cement shall be of recent manufacture and shall be used within a period of 3 months from production.

Before supplying cement to Site or receiving ready-mixed concrete, the Bidder/Contractor shall submit to CEB, the manufacturer's statement of Specification and test certificate together with date of manufacture of any cement to be used. CEB reserves the right to take samples and order any additional / re-tests in accordance with BS EN 196-1 and BS EN 196-2.

The Bidder shall obtain prior approval from CEB for the brand name, manufacture and source of the cement which he proposes to use in the Works and the method of delivery. The Contractor shall not place the order for cement before the Engineer's approval is obtained.

All cement shall be obtained from the same source for any particular part of a structure.

The Contractor shall not use cement varying from that used in the preparation of trial mixes until any further trial mixes required by the Engineer have been made and tested and shown to comply with the specification.

The cement shall be tested to determine the total alkali content in accordance with BS EN 196-2

The equivalent weight of sodium oxide shall not exceed 0.6% of the weight of cement.

The above restriction shall be waived if the proposed aggregate is proved without doubt to be non-reactive.

The cement shall be delivered to site packed in sealed bags or proper containers, of which there shall be 20 to the ton, bearing the name of the brand and manufacturer and the number of the consignment. The approximate weight of the cement shall be legibly marked on each bag. The Contractor shall make the necessary arrangements for deliveries to be made sufficiently frequently to ensure freshness and in sufficient quantities to ensure that there is no suspension or interruption of the concreting work at any time.

The Contractor may use cement delivered in bulk; delivery arrangements shall be to the Engineer's approval and each delivery must be accompanied by a manufacturer's test certificate.

Each consignment of cement shall be brought to the site in sufficient time to allow any tests to be carried out before the cement is used.

Cement in bags shall be unloaded under cover and stored in a well-ventilated and weatherproof building used exclusively for this purpose. The floor of the building shall be at least 150 mm off the ground and an air space shall be left between the floor and bottom layer of bags.

If delivered in bulk an approved type of cement silo shall be used.

Each consignment shall be stacked separately so as to permit easy access for inspection and a record shall be kept so that each consignment may be identified. Storage shall be arranged so that the cement is used in order to delivery.

### Test Certificates and Samples

All cement shall be certified by the manufacturer as complying with the requirements of the appropriate specification. The Contractor shall, when required by the Engineer, obtain for him the manufacturer's test certificate for any consignment as soon as possible after delivery.

For every 50 tones of cement delivered to site and whenever required by the Engineer the Contractor shall take samples, under supervision, from the cement stored on, or delivered to the site. The Contractor shall test such samples as specified in this document.

### Aggregates

Before the Engineer can approve any aggregate source, the Contractor shall furnish the following data.

- (1) Petrological group of rock
- (2) Rock type within the group
- (3) Shape
- (4) Surface texture
- (5) Silt content
- (6) Grading curves
- (7) Specific gravity
- (8) Impact value
- (9) Water absorption
- (10) Soundness
- (11) Salt content
- (12) Alkali reactivity

The fine and coarse aggregates shall comply with BS 882.

The sources for all aggregates shall be approved by the Engineer.

### Physical Requirements

- (1) The weight of voided shells in fine aggregate shall not exceed 5%.



- (2) The weight of the clay and fine silt fraction (smaller than ASTM sieve No. 200) shall not exceed 5% by weight of coarse aggregates or 10% by weight for fine aggregates.
- (3) Absorption of fine and coarse aggregate shall not exceed 5% as measured in accordance with BS 812 or similar standard.
- (4) The soundness of all aggregates shall be proved by a sodium sulphate test in accordance with ASTM C88-73, from which the loss over 5 cycles shall not exceed 10% for fine aggregates or 12% for coarse aggregates.
- (5) The apparent specific gravity of aggregates as determined by an approved test, such as in BS 812, shall not be less than 2.5.
- (6) Los angles abrasion shall not exceed 37%.

Where quarries with aggregate from bedrock, especially limestone of the Dolomite type, the rock shall be checked for surface alteration to hardpan. This may affect the surface for well over a meter depth and result in salt concentrations near the surface. Such rocks are also prone to other undesirable characteristics including pockets of clay, salt, chalk or other friable material. Rigorous initial physical inspection is essential.

#### Chemical Requirements

- (1) Fine and coarse aggregates shall not be potentially reactive with alkalis, and shall be tested in accordance with BS 812.
- (2) Fine and coarse aggregates shall not contain more than 0.5% by weight of acid soluble sulphates (as  $SO_3$ ).
- (3) Fine aggregate shall contain no more than 0.1% by weight of chlorides (as NaCl) and coarse aggregate more than 0.03%. Should these figures be exceeded the aggregate may still be considered acceptable in this respect provided the total sodium chloride concentration is not greater than 0.32% by weight of cement in the mix, irrespective of the origin of the chloride.

The aggregates shall be stored at mixer positions in such a manner that intermingling of different sizes and types of aggregates is prevented. The stockpiles are to be protected from rubbish or windblown dust.

Heaps of fine aggregate shall be capable of draining freely. Wet fine aggregate shall not be used until, in the opinion of the Engineer, it has drained sufficiently to ensure proper control of the water/cement ratio.

#### Sampling and testing

The Engineer shall have the right to request the Contractor, at any time, to draw samples of aggregates from stockpiles on the Site or any other location to be indicated by the Engineer. All sampling and testing shall be in accordance with BS 812 or to American standards when no appropriate BS exist.

For each new source of aggregate and for each class of aggregate to be used sampling and testing shall be done at the rate of six samples and set of test for each new source and each new class. The Contractor shall allow for the whole range of tests to be carried out. For routine sampling and testing from an approved source the rate shall be sample per 50 cubic meter of aggregate to be used or sample per month whichever is greater. Such testing shall include those tests form BS 812 as are considered useful by the Engineer for comparison with the results of the initial set of tests but the Contractor shall allow for the full range to carried out.

Testing is to be carried out at an independent laboratory approved by the Engineer or else on the site in the presence of the Engineer's representative where approved by the.

### Water

The water used for making concrete, mortar and grout shall be clean, fresh and free from injurious amounts of soil, vegetable or organic matter or any other dextrous substance in suspension or solution. The mix water shall be continually monitored for salt content and the concrete mix designed accordingly to limit total salt content.

The water should comply with the requirements of SLS 522.

### Admixtures

Admixtures shall not be used without the approval of the Engineer.

Before the use of any admixture can be approved the Contractor must prove by trial mix procedures that the concrete will in no way be adversely affected even when twice the recommended dose is batched.

### Plant

The concreting plant shall be suitably in type, capacity and design for its purpose. The performance of the plant and its disposition shall be to the satisfaction of the Engineer. The plant shall be maintained regularly and stand by plant shall be available to avoid any delay in the progress of the works.

### Concrete Strength Requirements

All concrete mixes shall be in accordance with the requirements of BS8500 and BS 8110 as designated on drawings approved by the Engineer.

At least 7 weeks before concrete construction is programmed to commence the Contractor shall submit for approval all the details of concrete mix designs for each proposed grade of concrete. No concrete construction may be commenced until this data is approved by the Engineer.

The strength requirements for each grade of concrete proposed in the design shall be proven by means of preliminary trial tests as specified in BS8500, BS EN 206, BS EN 12390 and BS 1881. The minimum cement content and the maximum free water-cement ratio shall be in accordance with the specification.

The Contractor's designs and drawings shall show clearly the characteristic strengths, and permissible deviation proposed for each grade of concrete to be used.

The Contractor shall carry out frequent tests to the satisfaction of the Engineer to check the relationship of the strength of concrete cured under site conditions to that cured under laboratory conditions.

### Mixing

All concrete except where specifically permitted by the Engineer in writing shall be mixed in weigh batch mixing machines. The machines shall have a large water storage tank with a gauge or that a predetermined quantity of water can be injected direct into the mixer drum.

The dry concrete ingredients shall be mixed until a uniform colour is obtained after the addition of the water the concrete shall be mixed for a further 4 minutes or until a uniform colour is achieved. The total water in the mix shall not exceed the amount used in the trial mix.

In computing the quantity of water to be added, due account must be taken of the water contained in the aggregates. The amount of water shall be sufficient to ensure through hydration, good workability and high strength.

The contractor shall take all precautions to the satisfaction of the Engineer to protect the concrete from the injurious effects of the elements.

### Workability

The concrete shall be of such consistency that it can be readily worked into the corners and angles of the framework and around reinforcement without segregation of the materials or bleeding of free water at the surface. On striking the framework it shall present a face, which is uniform, free from honeycombing, surface crazing or excessive dusting, and which shall not, in the opinion of the Engineer, be inferior to the standards laid down in later clauses in this section. In order to satisfy the Engineer that adequate for the requirements of the Specification, the Contractor shall carry out a series of workability tests on the preliminary trial mixes required elsewhere in this Section. These tests shall be carried out in accordance with BS EN 12350, or such other procedure as approved by the Engineer.

The samples to be tested shall be obtained from the batches used for the preliminary test cubes. In addition the Contractor shall supply for each of the grades of concrete a section of framework complete with reinforcement fixed in position and generally representative of the sections commonly to be employed in the Works. The capacity of this trial section of formwork shall be at least half a batch of concrete but in any case not less than 1/4 cubic meter. The formwork shall comply with the requirements of this Specification for formwork. The mould shall be filled in the presence of the Engineer with concrete of the same mix and batch from which the preliminary test cubes are made and shall be compacted in the same manner with the same equipment as are proposed for the Works. This procedure shall, if necessary, be repeated with modified mixes until the appearance of the concrete after striking the mould is acceptable to the Engineer, after which it shall be used as the standard for that grade.

When specific workability is called for a check it shall be maintained by measuring slump at the rate of one test for each 10 cubic meters of concrete or three tests for each day of concreting.

### Transportation

The concrete shall be discharged from the mixer and transported to the Works by means that shall be approved by the Engineer and which shall prevent adulteration, segregation or loss of ingredients, and ensure that the concrete is of the required workability at the point and time of placing.

The concrete shall be placed in the positions and sequences indicated on approved drawings, in the Specification or as directed by the Engineer, within one hour of mixing.

All formwork and reinforcement contained in it shall be clean and free from standing water, immediately before the placing of concrete.

The Engineer shall be given 24 hours notice in order that he may check the work.

Except where otherwise directed, concrete shall not be placed unless the Engineer is present or he has previously examined and approved the positioning, fixing and condition of the reinforcement and of any other items to be embedded, the cleanliness, alignment and suitability of the containing surfaces, and the adequacy and condition of plant.

The concrete shall be deposited as nearly as possible in its final position and in such a manner as to avoid segregation displacement of the reinforcement, formwork or other embedded items. Placing shall be continuous between specified or approved construction joints.

All small concrete pours shall normally be carried out in the late afternoon unless otherwise permitted by Engineer.

Where chutes are used to convey the concrete, their slopes shall not be such as to cause segregation and suitable spouts or baffles should be provided to obviate segregation during discharge. Concrete shall not be allowed to fall freely more than 1.5 meters except with the approval of the Engineer. Where pneumatic placers are used the velocity of discharge shall be regulated by suitable baffles or hoppers where necessary, to prevent segregation damage and distortion of the reinforcement, other embedded items and formwork, caused by impact.

Upon arrival at the place of deposition the concrete truck driver must present to the Engineer a chit from the concrete batcher stating (a) the grade of concrete, (b) the workability (c) the aggregate size (d) type of cement and (e) time of batching of the concrete.

If concreting is not started within 24 hours of approval being given, approval shall again be obtained from the Engineer. Concreting shall then proceed continuously over the area between construction joints. When in-situ concrete has been in place for 4 hours, or less as directed by the Engineer depending upon the mix, type of cement and weather conditions, no further concrete shall be placed against it for a further 20 hours.

Concrete, when deposited, shall have a temperature of not less than 5°C and not more than 32°C. It shall be compacted in its final position within 30 minutes of discharge from the mixer when the time shall be within 2 hours of the introduction of cement to the mix and within 20 minutes of discharge from the agitator.

Except where otherwise agreed by the Engineer, concrete shall be deposited in horizontal layers to a compact depth not exceeding 450 mm where internal vibrators are used or 300 mm in all other cases.

When trucking or chutes are used they shall be kept clean and used in such a way as to avoid segregation.

### Compaction

The concrete shall be fully compacted throughout the full extent of the layer. It shall be thoroughly worked against the formwork and around reinforcement and other embedded items, without displacing them. Successive layers of the same lift shall be thoroughly worked together.

All concrete shall be compacted to produce a dense homogeneous mass. Unless otherwise agreed by the Engineer, it shall be compacted with the assistance of vibrators. Sufficient vibrators in serviceable conditions shall be on site so that spare equipment is always available in the event of breakdowns.

Vibration shall not be applied by way of the reinforcement. Where vibrators of the immersion type are used, contact with reinforcement and all inserts shall be avoided, so far as is practicable.

Concrete shall not be subjected to vibration between 1 and 10 hours after compaction.

Unless otherwise directed by the Engineer, approved power driven vibrators of the immersion type shall be used. They shall be inserted at such distances apart or applied in such a manner as will ensure that the concrete being placed.

Vibrators shall penetrate the fully depth of the layer and where concrete is placed over previously placed concrete not more than 4 hours old the vibrators shall enter and re-vibrate that layer to ensure that successive layers are well knitted together.

Over-vibration, causing segregation, surface laitance or leakage through formwork, shall be avoided. Immersion vibrators shall be withdrawn slowly to prevent the formation of voids. Vibrators shall not keep damage to formwork or other parts of the structure, or displace the reinforcement or other embedded items.

Internal vibrators shall be capable of producing not less than 10,000 cycles per minute and external vibrators not less than 3,000 cycles per minute.

### Construction Joints

Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated on the drawings and approved by the Engineer.

When not indicated on the drawings the following generally rule shall apply:

Joints in columns are to be made at the underside of floor members and at floor levels. Haunches and column capital are to be considered as part of and continuous with the floor or roof.

Floors joints in the floor system are to be located at or near the quarter points of the span in slabs and beams, except where otherwise instructed.

Walls Vertical joints away from corners. Horizontal joints above sprays or openings.

Whenever the placing of the concrete is discontinued other than at the exposed faces, this discontinuity shall form a construction joint. Construction joints are to be made only along a horizontal or vertical plane except that in the case of inclined or curved members they shall be at right angles to the principal axis.

Care shall be taken to prevent offsetting of the joint and to ensure water-tightness. The joints shall in every way satisfy the requirement of the Engineer, and be fully detailed on drawings prior to submission for approval.

When work is resumed adjacent to a surface, which has set, the whole surface shall be thoroughly roughened. It shall be cleaned of all loose and foreign matter and laitance and washed with Water immediately before placing the fresh concrete, which shall be well compacted, against the joint.

### Construction Bays

The Contractor shall agree with the Engineer, prior to the commencement of Concreting, upon the sequence of placing concrete and the positions of vertical and horizontal joints, whether shown or not on the drawings.

In general, slabs in excess of 6 meters in length and/or width and wall exceeding 6 meters in length shall not be poured in one operation and subsequent adjacent bays shall not be concreted within 7 days. The maximum area of any pour shall be 100 m<sup>2</sup>.

In the light of experience the Engineer may consider the above pour size limits to be excessive and will have the authority to reduce them.

As an alternative to alternate bay construction, shrinkage gaps of up to 0.1 meter in width may be left at 6 meters intervals; the shrinkage gaps shall not be concreted until concrete on all sides is at least 7 days old.

Expansion joints shall be fully detailed on construction drawings before submission for approval.

Expansion joints shall be filled with bitumen impregnated fibber board to full depth and width. The infilling will be permitted to use as permanent formwork only for second casting. Where the fibber board is exposed it shall be cutback for a depth of at least 2 cm from the chambered edge, filled and pointed with a resilient liquid polysulphide polymer sealant to the manufacturers instructions.

Where dowel bars are indicated on the Drawings forming part of a joint, they shall be held securely horizontal and perpendicular to the joint during Concreting.

Dowel bars shall be plain mild steel bars conforming to BS 4449. They shall be straight and coated with approved bond breaking compound, which shall consist essentially of 66% of 200 penetrating bitumen blended hot with 14% light creosote oil and, when cold, brought to the consistency of paint by the addition of 20% solvent naphtha, or other approved compound.

Plastic caps used in expansion joints shall be rigid and securely fixed to the dowel to prevent the ingress of concrete during casting of the slab. The packing used within the cap shall be an inert, compressible material. All dimensions must be shown on Drawings prior to submission for approval.

#### Joining New Concrete Work to Existing

Existing concrete shall be broken out as described or directed and scabbled to form a suitable key for the new concrete. Where necessary the reinforcement in existing concrete shall be exposed, cleaned and bent to its correct shape. New reinforcement shall be securely wired to the existing.

Immediately before new concrete is poured, a cement wash shall be applied to the existing concrete faces.

#### Curing

Concrete shall be protected during the first stages of hardening from the harmful effects of sunshine, drying winds, cold, rain or running water. The protection shall be applied as soon as practicable after completion of placing by a method to be approved by the Engineer.

The Contractor shall put forward his proposals for curing concrete to the Engineer for approval, before any Concreting work commences.

On vertical surfaces, the curing membrane shall be applied immediately after removing the formwork.

No concrete shall be allowed to become alternately wet and dry. The temperature of curing water shall be same as the concrete + 5 ° C. General concrete shall be wet-cured for at least 7 days with a further 4 days of dry protection.

#### Additional Requirements in Hot Weather

##### GENERAL

In hot weather the Contractor shall present for the Engineers approval his proposals for dealing with the following problems:

- (1) Reduced workability
- (2) Excessive Plastic shrinkage
- (3) Rapid strength gain but possible low final strength
- (4) Rapid drying-out of concrete

### Mixing

Aggregate stockpiles shall be shielded from the direct rays of the sun or cooled by spraying with water; and water tanks and pipes shall be insulated to ensure that the temperature of concrete when deposited shall not exceed 32°C.

With the approval of the Engineer admixtures may be employed to retard setting time or enhance workability, or induce early bleeding etc.

Concrete batched off-site shall be transported to site by truck mixer. The mixer rotating only after it arrives on site. Alternatively, the aggregates and 80% of the required water may be batched off-site with the cement and remaining water being added on site not more than 15 minutes before the pour commences. Concrete transporters shall be kept as cool as practicable.

### Placing

Placing shall not commence until sufficient standby pumps and vibrators are on site to cope with breakdowns.

No concrete shall be batched until formwork is ready and all reinforcement fixed in place approved by the Engineer.

The area of each concrete pour frontage shall be kept to a minimum and suitable means shall be provided to avoid premature stiffening of concrete placed in contact with hot dry surfaces. Where necessary the surfaces, including reinforcement, against which the concrete is to be placed, shall be shielded from the rays of the absorption by the surfaces of water from the fresh concrete.

In hot weather concrete shall be deposited in horizontal layers to a compacted depth not exceeding 300 mm and internal mechanical vibrators shall be used.

Due to rapid stiffening in hot weather all clean-up operations such as application of resin cure membranes and dust reducers, and surface finishing, etc. shall follow closely behind final tamping.

### Curing

All concrete shall be covered for at least 14 days after placing and kept continuously wet for the initial 7 days. The temperature of curing water shall be within 5°C of that of the concrete. Air shall not be permitted to circulate between concrete and curing materials.

### Testing

Initially, the Contractor shall double the number of test cubes made. Half of them shall be cured under site conditions in order to ascertain the relationship between site-cured samples and lab-cured samples. The number of slump tests shall initially be twice that normally required. Air temperature shall be measured every two hours, and the temperature of every batch of concrete shall be recorded as it is deposited at the work place.

Testing methods are to be in accordance with the relevant BS standard except as approved or requested by the Engineer.

The Engineer shall have the right to order that any materials which, do not meet with his approval shall not be used in the work. The Contractor shall have the right to sample, test and give his opinion on such materials. If after this, the materials which rejected by the Engineer shall be immediately removed from the Site by the Contractor.

The Contractor shall provide the Engineer with facilities for materials testing on Site. The facilities may be those normally used by the Contractor.

All testing facilities on site shall be calibrated at regular intervals in the presence of the Engineer, and whenever deemed necessary by the Engineer.

#### Testing of Concrete Delivered to Site or Mixed at Site

One set of at least six (6) test cubes for every 20 m<sup>3</sup> or every daily pour of concrete or as directed by CEB.

The compression strength tests shall be carried out after seven (7) days for the first two cubes of each set, and after 28 days for the second two cubes of the set, and – if requested - the last two cubes of each set may be tested in case of failure of a cube.

- Slump tests are to be executed for every truck load supplied during concreting and as per CEB's instructions, provided concreting is proceeding.
- Concrete temperature is to be recorded at the arrival of concrete at Site.
- Bimonthly or for every 750 m<sup>3</sup> of concrete cast, the Bidder/Contractor shall prepare the following for durability testing, which - after approval of CEB - may be carried out through the concrete supplier:
  - Rapid test for chlorides
  - Rapid test for sulphates
  - A Trial panel, from which at 28 days 3 Nos. Cores, 75mm diameter and 75 mm long, shall be taken for water absorption testing (to BS 1881)
  - 3 Nos. blocks, 200 x 200 x 120 mm thick, for water penetration testing (to DIN 1048)
  - 4 Nos. cubes, 150 mm, for rapid chloride permeability testing (to AASHTO T-277) /curing of samples shall be as close to the current Site practice as possible.

The cubes shall be made, cured, stored and tested in compression in accordance with BS EN 12390. The tests shall be carried out in a testing laboratory approved by the Engineer. The laboratory must provide evidence that its equipment and procedures comply with BS EN 10002 and BS 1881. The calibration test reports of testing machines and details of the qualifications of all laboratory staff shall be submit for approval if requested by the Engineer.

Reports of all tests made shall be supplied direct from the laboratory to the Engineer within 24 hours of the cubes being tested. The Engineer on site shall have the authority to stop all further concrete work until acceptable test results are forthcoming.

Up-to-date records shall be kept by the Contractor at the Works of positions in the Works of all batches of concrete, of their grade and of all tests cubes, cores and other specimens



taken from them. Copies of these records shall be supplied to the Engineer at weekly intervals or upon request by the Engineer.

### Compliance of Works Test Cubes with Specification

When submitting proposed testing regimes the Contractor shall also detail his proposed acceptance criteria for the Engineers approval. When this is not forthcoming the Contractor shall comply with the next two paragraphs below.

The rules of compliance for Works cubes are different to those for Trial Mixes. Compliance with the characteristic strength shall be assumed if the conditions given in both (1) and (2) are met:

(1) The average strength determined from any group of four consecutive test results exceeds the specified characteristic strength by

3 N/mm<sup>2</sup> for concrete of grade C20 and above (i.e.) characteristic strength = 20 N/mm<sup>2</sup>).

2 N/mm<sup>2</sup> for concrete of grade C15 and below (i.e.) characteristic strength = 15 N/mm<sup>2</sup>).

(2) The strength determined from any test result is not less than the specified characteristic strength minus.

3 N/mm<sup>2</sup> for concrete of grade C20 and above

2 N/mm<sup>2</sup> for concrete of grade C15 and below.

The quantity of concrete represented by any group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches.

When a test result fails to comply with (2), only the particular batch from which the sample was taken shall be at risk.

Compliance criteria remain the same irrespective of varying rates of sampling of the same grade concrete in different structures.

Where a minimum or maximum cement content of a designed mix is specified and compliance is assessed by observation of the batching or from auto graphic record, the cement content shall not be less than 95% of the specified minimum or more than 105% of the specified maximum.

Where compliance of cement content is assessed from the results of analysis tests on fresh concrete, the cement content shall not be less than 90% of the specified minimum or more than 110% of the specified maximum.

### Failure of Concrete to Meet Test Requirements

If the strength of the specimen is less than the appropriate specified minimum crushing strength or if, in the opinion of the Engineer, the concrete fails to meet the specified requirements in other respects, the concrete in that part of the Works of which, it is a sample will be considered not to comply with the specified requirements.

As and where directed by the Engineer, cylindrical core specimens shall be cut from the hardened concrete in the Works for the purpose of examination and testing. The Engineer shall approve the cutting equipment and the method of doing the work. Prior to the preparation for testing, the specimens shall be made available for examination of the Engineer. Testing of the core shall be in accordance with approved standards.

The Engineer also makes recourse to such non-destructive means of testing as ultrasonic pulsing and Schmidt rebound hammers.

If the specified requirements have not been met the Contractor shall propose such remedial action as may be required. Such action is subject to the Engineer's satisfaction and approval. If no satisfactory remedial measures are proposed by the Contractor and approved by the Engineer then the Engineer shall order the removal of all work not complying with the Specification at the Contractor's expense. Before proceeding with similar work the Contractor shall submit to the Engineer for his approval details of action proposed to ensure future concrete to be placed in the Works would comply with the Specification.

### Formwork

Forms shall be so designed and constructed that the concrete can be properly placed and thoroughly compacted. The forms shall conform accurately to the required shape; position and level, subject to the tolerance specified and to the standards of finish of hardened concrete as specified later in this Section.

The Engineer may request the Contractor to provide sample panels of formwork for approval, at the Contractor's expense.

When concrete is to be vibrated, special care shall be taken to maintain the stability of the formwork and the tightness of the joints during vibrating operations.

The materials and position of any ties passing through the concrete shall be approved by the Engineer. The whole or part of the ties shall be capable of being removed so that no part remaining embedded in the concrete shall be nearer the surface of the concrete than the specified thickness of cover to the reinforcement. Any holes left after the removal of ties shall be filled unless otherwise directed by the Engineer with concrete or mortar of approved composition.

All forms shall be removed without damage to the concrete. The use of mould oil or other material to facilitate this shall be subject to the approval of the Engineer. All formwork for pits, ducts and holding down boltholes must be so constructed that it can be easily collapsed to facilitate withdrawal after the initial set of the concrete.

The Contractor's proposed method for the construction and fixing of the formwork for bolthole pockets shall be submitted to the Engineer for approval before construction. The top of the shuttering shall be suitably covered to prevent entry of excess grout, materials used for curing, etc.

Solid timber must not be used for forming holding down boltholes. Bolthole former may be made of plywood, expanded metal, polystyrene or other method approved by the Engineer, who may require the Contractor to carry out a test pour, using the proposed bolthole former.

The Engineer shall be informed in advance when the Contractor intends to strike any formwork.

The time at which the formwork is struck shall be Contractor's responsibility. The formwork may be struck when the concrete has in the opinion of the Engineer attained a compressive strength of not less than 10 N/mm<sup>2</sup> or twice the stress to which it will then be subjected whichever is the greater.

In the absence of cube test results the minimum periods before striking form work for concrete made with ordinary Portland cement shall be according to the table 6.6 of BS 8110.

Formwork shall be constructed so that the side forms of members can be removed without disturbing the soffit forms and if props are to be left in place when the soffit forms are removed these props shall not be disturbed during the striking.

The Contractor shall state precisely on his plans which of the type of finished described hereunder he intends to use in the various locations. Any defective concrete finish will be rejected. The Engineer may at his discretion order the defects to be cut out and made good.

Plastering of defective concrete, as a means of making good will not be permitted, except that in the case of minor porosity in the surface the Engineer may approve a surface treatment by rubbing down with cement and sand mortar of the same richness as in the concrete. This treatment shall be made immediately after removing the formwork.

### Formed Finishes for Concrete

#### (1) Type F.1

This finish is for surfaces against which backfill or further concrete will be placed. Formwork shall consist of sawn boards, sheet metal or any other suitable material, which will prevent the loss of grout when the concrete is vibrated.

#### (2) Type F.2

This finish is for surfaces, which are permanently exposed to view but where the highest standard of finish is not required. Forms to provide a Type F.2 finish shall be faced with wrought and thickened board with square edges arranged in a uniform pattern. Alternatively, plywood or metal panels may be used if they are free from defects likely to detract from the general appearance of the finished surface. Joints between the board and panels shall be horizontal and vertical unless otherwise directed. This finish shall be such as to require no general filling of surface pitting, but fines, surface discoloration and other minor defects shall be remedied by methods approved by the Engineer.

#### (3) Type F.3

This finish is for surfaces prominently exposed to view where good appearance and alignment are of special importance. To achieve this finish, which shall be free of board marks, the formwork shall be face with plywood or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Whenever possible joints between sheets shall be arranged to coincide with architectural feature, sills, window heads or drainage in direction of the surface. All joints between panels shall be vertical and horizontal unless otherwise directed.

Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. The joints shall be arranged and fitted so that no blemish or mark is imparted to the finished surface. Unfaced wrought boarding or standard steel panels will not be permitted for Type F.3 finish. Permanent forms shall be constructed of slabs or blocks of precast concrete, natural stone, brickwork or other approved material as directed. Such slabs or blocks shall have an exposed surface of the quality shown on the Drawing and as specified. They shall be fixed to the structure by approved means and the joints between them shall be made tight with mortar or other means of preventing leakage. The use of internal metal ties shall not be allowed.

#### (4) Type F.4

This finish is identical to Type F.3 except that internal metal ties are permitted.

### Uniformed Finishes to Concrete

(1) Type U.1

This is a screeded finish for surfaces of roads or of foundations, beds, slabs and structural members to be covered by backfill, subsequent stages of construction, bonded concrete, topping or cement mortar beds to receive paving and on exposed surfaces or paving where superior finish is not required. It is also the first stage for finished Type U.2 and U.3. The finishing operations shall consist of levelling and screeding the concrete to produce a uniform plane or ridged surface, surplus concrete being struck off by straight edge immediately after compaction.

(2) Type U.2

This is a floated finish for surfaces of beds and slabs to received mastic paving or block or tile paving where a hard smooth steel-trowel led surface is not required. Floating shall be done by hand or machine. Care shall be taken that the concrete is worked no more than is necessary to produce a uniform surface free from screed marks.

(3) Type U.3

This is a hard smooth steel-trowel led finish for surfaces of concrete paving, tops of walls, exposed surfaces of engine and plant foundations and in the vicinity of holding down bolt chases, copings and other members exposed to weathering, surface bed and slabs to receive thin flexible sheet and tile paving bedded in adhesive and seatings for bearing plates and the like where the metal is in direct contact with the concrete. Trowelling shall not commence until the moisture film has disappeared and the concrete has hardened sufficiently to prevent excess laitance from being worked to the surface. The surface shall be trowelled under firm pressure and left free from trowel marks.

### Surface Treatments

Where concrete is to be treated with sodium silicate or a similar dust preventive coating this must be carried out within 14 days of the Concreting of the foundation and be applied in accordance with the manufacturer's instructions.

### Reinforcement

Steel reinforcement shall be one of the following:

- (1) High Yield steel bars complying with BS 4449 (or 4482) or
- (2) Hot rolled or cold deformed bars complying with BS 4449, or approved by the Engineer.
- (3) Welded steel mesh reinforcement complying with BS 4483 or similar approved.
- (4) Bars greater than 32 mm diameter will not generally be used.

Reinforcement shall be stored clear of the ground on sufficient supports to prevent distortion of the bars. Mild steel and high tensile steel are to be stored separately.

The Contractor shall supply the Engineer with a certificate for each consignment from the steel manufacturers showing that the steel meets the requirements of the Specification. One tension test and one bond test shall be made for each lot of 50 tones or less supplied for the permanent Works.

Steel reinforcing bars shall be kept clean and shall be free from pitting, loose rust, mill scale, oil, grease, mortar earth, paint or any material which may impair the bond between the concrete and the reinforcement, or which may cause corrosion of the reinforcement or disintegration of the concrete.

Reinforcement may be bent on site, or alternatively off the site, by an approved method. The Contractor shall arrange for bending equipment suitable for bending both mild steel and intermediate grade bars. Mild steel shall be bent at temperatures in the range 5<sup>0</sup>C to 100<sup>0</sup>C. High tensile steel shall only be heated or welded when the manufacturer given written guarantees as to its subsequent performance. The shapes of the bends and lengths must comply as specified on the Drawings and Bending Schedules as approved by the Engineer.

The Contractor shall provide any chairs or other subsidiary reinforcement necessary to keep the reinforcement in its correct position. The concrete cover over such subsidiary reinforcement shall not be less than that over the reinforcement generally.

The Contractor shall provide adequate scaffold boards to ensure that the reinforcement is not displaced by being walked upon during the placing of the concrete or other operation.

Mesh reinforcement shall be fixed flat in the works over the whole of the areas indicated on the approved drawings. Adjoining sheets of mesh shall overlap by at least 300 mm.

Loose small pieces of fabric shall only be used where they are essential for fitting into small confined parts of the Works. Areas of fabric reinforcement shall be net with no allowance included for laps or waste. Fabric reinforcement shall be delivered to site only in flat sheets.

Bends, cranks and other shapes of reinforcement shall be to the dimensions specified; otherwise all bars shall be truly straight. Bending of reinforcement shall be carried out round a former having a diameter of at least four times the diameter of the bar.

The bending dimensions shall comply with BS 4466 unless otherwise specified on the bending schedules.

Cover blocks used for the correct positioning of reinforcement shall be of a type approved by the Engineer. They shall be rigid, inert and capable of supporting the reinforcement in its correct position with the required cover without deforming. They shall not impair the finish on the concrete nor cause the formwork to deform locally.

Steel templates shall be used to position the anchor bolts.

Reinforcing bars shall be tied together at every intersection using 16 SWG soft pliable annealed steel wires. Immediately prior to Concreting all reinforcement shall be wire brushed to remove all wind-blown contaminants such as salt.

Concrete cover to all reinforcement (including stirrups) shall be as specified in BS 8110 and BS 8004. In addition, the cover should never be less than the diameter of the main bar or nominal maximum size of the aggregate.

The Engineer shall have the right to select at any time samples of steel reinforcement for testing in accordance with the relevant approved standard.

The Contractor shall provide fully dimensioned bending Schedules giving the location and bending of every bar shown on the drawings. Unless otherwise stated on the Bending Schedules all bars shown will be dimensioned in accordance with the national or international standard to be approved by the Engineer, e.g. British Standard 4466.

### Foundation Bolts

The foundations bolts shall be mild steel or High strength steel of an approved manufacture and shall be fitted with tubes, washer plates, anchor angle, flats, double nuts etc. Drawing showing the foundation bolt arrangement shall be approved by the Engineer

and sent to site with the foundation bolt assemblies and template in good time for being built into the foundations.

### Prevention of Corrosion below Ground

The Contractor is to ascertain whether or not the sub-strata contain any corrosive qualities, which will have a deleterious effect on reinforced concrete. If such conditions are evident, only an additive approved by the Engineer is to be incorporated in the concrete mix in the proportions according to the manufacturer's recommendations.

### Grouting of structural steel works and plant

No grouting shall commence without the written approval of the Engineer. At least 12 weeks before and grouting is due to commence, the Contractor shall submit full details to the Engineer for his approval. Before plant grouting commences the Contractor shall check that the proposed methods and materials are acceptable, and that no special resin additives or similar are necessary.

### Grout under Base Plates

Only non-shrink, non-gaseous grouts, which shall be either cementitious or epoxy grouts, may be used. Grouts deriving their non-shrink properties from metal oxidising (i.e. an increase in volume due to oxidation) shall not be allowed. Minimum compressive and flexural strengths of the non-shrink grouts shall be as follows:

Type of grout	Consistency	Compressive strength N/mm <sup>2</sup>		Flexural strength N/mm <sup>2</sup>	
		7 days	28 days	7 days	28 days
Cementitious	Flowable	45	65	8	10
Epoxy	High flow	80	>80	25	>25

Compressive strength shall be in accordance with BS 1881, Part 116 and BS 6319, Part 3 (epoxies), the cubes size shall be 100 mm, and the flexural strength shall be tested in accordance with BS 4551.

On receiving confirmation from the Engineer that the final alignment check has been completed, the Contractor shall complete the grouting under the steelwork and/or plant base plates, ensuring that the grout completely fills the space and that it is thoroughly compacted and free from air pockets. Grout or concrete shall be cured by covering with moist hessian for a period of five days. The hessian shall be wetted at least twice in each 24 hours.

Exposed surfaces of grout and concrete beneath items of plant shall be prepared and given two coats of oil and alkali resistant coating. Grout or concrete shall not be placed when the air temperature or the temperature of the concrete is lower than 5<sup>0</sup>C.

Edge formwork shall be fixed around each base plate generally to the level of the top of the plate unless specified to the contrary by the Engineer. The clearance space between the formwork and the base plate shall normally be 75 mm but exact clearance shall be decided on the site for each operation. On the site from which the grout is to be poured forms shall be at least 150 mm high in order to provide a head to placing.

The exposed edge of the grout or concrete shall be chamfered or bull nosed with a steel trowel where so indicated on the drawings.

The formwork shall to be struck without the approval of the Engineer, and normally this will to be given within 24 hours of grouting.

Any grouting that in the opinion of the Engineer is defective shall be cut out and replaced at the Contractor's expense.

## **Foundations**

### **Switchgear & Takeoff Structures**

Shall be reinforced concrete

### **Main Transformer foundation**

In transformer foundations, provision shall be made for the catchments of oil spillage from the transformers resulting from mechanical or electrical failure. Oil separators shall be provided to prevent pollution of streams, ground water, irrigation ditches and other watercourses by leaking or ejected oil.

Each transformer shall be protected from the potentially damaging consequences of a catastrophic failure in any of the transformers by providing firewalls between adjacent transformers. Fire precautions shall be provided for the extinguishing of burning transformer oil.

The oil pits shall be adequately connected by oil pipes and discharge the oil or water in to an oil separator, which should be equipped with oil, and mobile water removing pump. Oil resisting paint shall be applied inside the pit.

The foundations supporting the transformers shall incorporate built-in haulage bollards, rails, slipways, etc., for the purpose of unloading and locating the transformers in their required positions.

Each transformer foundation shall be surrounded by a low wall enclosing a. The pit within the low wall shall be such that the entire oil content of the transformer can be accommodated. The stone chipping layer to be provided over the pit should be of 35 mm single sized. It shall be at least 200mm thick and lay over galvanised steel grating installed over the pit.

The oil pit of the transformer foundation should be designed and constructed as a water retaining structure and in accordance with BS 8007 with allowable crack width less than 0.2 mm.

Standards of design, materials and workmanship are to be equal to or better than those laid down in British Standard 8110 and 8004.

### **Earthing & Auxiliary Transformer**

Shall be Reinforced concrete.

### **Piling work**

#### General

This Article applies to the foundation design/static analysis in view of necessary piling works. Piling works shall be based on the findings of the soil investigations and/or information given in writing by CEB. Piles shall be designed for the required design loading (uplift, compression and horizontal loads) in line with the approved foundation design.

Earthwork as well as all concrete and reinforced concrete work shall be as specified under the relevant items.

The static analysis/pile design shall normally be in accordance with DIN EN 1536, DIN 1045, 1054, 1055, 4014 and 4026, or BS 8004, BS 8110 and other applicable DIN or British Standard.

### Materials

All materials to be used for the piling works shall meet the requirements as specified below. Cement to be used for concrete piles shall be selected according to the recommendations of the soil investigations report. Sulphate resistant Type Cement (SRC), or under certain conditions, 'Moderately Sulphate Resistant Cement' (MSRC-type II to ASTM-C150) based on the recommendations of the Geotechnical Engineer and approved by CEB, shall be used. All cements are to be in accordance with either DIN 1164, DIN EN 196, BS or the American Standards ACI, ASTM C150.

### Reinforcement

Only deformed high tensile steel shall be applied.

### Execution of Work

Generally, cast-in-situ (bored) piles with temporary casing method as per DIN EN 1536, DIN 4014, DIN 1054, BS 2004 and BS 8004 will be permitted for execution. Immediately after drilling, the reinforcement has to be placed, ensuring a minimum concrete cover of 75 mm, and the pile has to be cast.

Spacers to be used shall be of the concrete type only. Other materials shall only be used upon explicit approval of CEB.

### Drilling Operation

Where required, temporary casing pipes shall penetrate ahead of the removal of soil, likewise during drilling above the ground-water table.

In the vicinity of underground water, additional water has to be filled up during the drilling. The hydro-static head pressure shall be at least 1.0 m above the ground water table when filled boring tools are extracted.

Casing shall extend to a sufficient depth below the stiff/solid strata to adequately seal off the unstable soil material.

Casing pipes shall not be deepened by means of jetting.

Immediately after the drilling, the reinforcement has to be placed, providing a concrete cover of 75 mm, and the pile has to be cast.

Temporary casing shall be removed by vibration method. Other methods of casing removal shall not be permitted, except in some cases/piles, where casing removal by vibrator will affect the existing services/buildings. In such cases, CEB may approve the rotation method for casing removal.

Concreting is to be done through tremie-pipes or equivalent devices to prevent segregation. Concreting of each pile shall be a continuous operation and no (cold) joints shall be permitted. The continuous flow of concrete shall be ensured by using pumps or other suitable means to be approved by CEB.

Each pile shall be installed to the correct lengths as shown on the drawings or when the pile reaches the socket in the recommended bearing strata. Piles shall be installed accurately in their required locations. In vertical direction, piles shall not vary more than



one (1) percent from the perpendicular. In plan, pile shall not deviate more than 75mm in any direction at piling platform level.

The Bidder/Contractor shall submit to CEB before start of piling works, a detailed description of the equipment, materials and procedures that will be used for the piling work.

The description shall include equipment specifications, including catalogue data manufacturer's published specifications, loading capacities, protective devices, and test apparatus, detailed installation procedures test procedures, as well as references concerning previously completed piling work.

Installation procedures shall be such that adjacent piles shall not heave or move laterally. All installation procedures shall be subject to CEB's approval. Permanently installed shells shall be cut off at the pile cut-off level.

Daily records of each pile shall be produced by the Bidder/Contractor. The records shall give detailed information on the type, diameter, length, location, penetration into bearing strata, piling platform level related to zero level, date driven, date of casting volume of concrete consumed, depth from piling platform level to toe, cut off level, top concrete level, length of temporary casing, length of permanent casing and details of any obstructions encountered. Records shall be submitted in duplicate to CEB every following working day by 09 00 HRS.

Each cast-in-situ pile shall be filled with quality concrete up to at least 60 cm above the cut-off level of the pile to allow for complete removal of slush and other foreign matters etc. from the main pile and thus obtain sound and uniform concrete. Pouring concrete into the pile shall be carried out using the tremie pipe method as well as the concrete pump. Pouring concrete into pile shall only be stopped once complete removal of slush and other foreign matter has been ensured, or as directed by CEB.

The heads of concrete piles shall be incorporated with in-situ concrete pile caps, etc. and the concrete in the head of the pile shall be carefully broken away from the reinforcement which shall then be cleaned and straighten as shown on the Drawings or as directed. The pile shall be cut off at the specified level and the concrete surface must be horizontal, plane and free from all loose aggregate.

The top portion of the pile reinforcement shall be protected with PVC pipes, polythene sheet wrapping or equivalent means to prevent damages to the epoxy coating of the reinforcement when trimming the pile heads.

### Permanent Casings

For soils in areas classified as category 5 according to BRE Digest 363, permanent casings shall be provided. The permanent casing length shall be 2.0 m below ground surface. Should the ground water table be at 2.5 m below ground level, casing will be extended to become 3.0 m below finished ground surface. This procedure shall be applicable for areas not affected by tidal effects. For areas affected by tidal effects, casings shall project 0.5 m below the lowest water level anticipated.

### Basics for Test Piles

The Bidder/Contractor shall carry out successful foundation load tests in order to prove the suitability of the pile foundation selected. The results of the tests shall be submitted in a format for approval by CEB.

The following types of tests are to be considered:

a) Piling Type Tests (Preliminary Pile Test)

Prior to piling commencement the Bidder/Contractor shall install two test piles of each type of pile proposed.

The piles shall be considered as acceptable in case the obtained load-settlement/heave-diagrams do not indicate movements beyond permissible limits as per Bidding Documents or the relevant Standards.

Other (working) piles shall not be installed until the load tests have been conducted and the results evaluated.

Type test piles shall not be utilised within the works and shall be treated in such a way that they do not obstruct the further works.

b) Piling Foundation Routine Test (Working Pile Test)

The Bidder/Contractor shall perform routine tests on at least 2% of the working piles, with a minimum of 2 tests for each pile type.

Details for Pile Tests

Loading

The Bidder/Contractor shall execute the test piles using the same equipment, which he intends to use for execution of all the piles. The test piles should be of the same length and same type as the piles proposed for the project. Loads shall be applied in the direction of the resultant force acting on the pile.

The loading tests of piles shall be in accordance with the procedure outlined in DIN 1054, DIN 4014 and DIN 4026 as well as ISSMFE recommendation on "Axial pile loading tests". Part 1, static loading.

Type tests (preliminary pile tests) are to be loaded to either 250% of the anticipated design load, or to the ultimate bearing load. At least two load cycles have to be made during type testing, the first reaching from 0% to 100% and the second - after off-loading - to 250% of the design load. Load steps shall normally not exceed 25% of the design load.

For routine tests (working pile tests) a loading to 150% of the design load is required. At least two load cycles have to be carried out, the first reaching from 0% to 100%, and the second - after off-loading to 150% of the design load. Load steps shall be worked out in line with the latest guide lines of the ICTAD, whereby following load steps/cycles shall normally be applied:

LOAD (%)	TIME	SETTLEMENT CONDITION
0		
25	1 hr	$S \leq 0.25$
50	1 hr	$S \leq 0.25$
75	1 hr	$S \leq 0.25$
<b>100</b>	<b>1 hr</b>	<b><math>S \leq 0.25</math></b>
50	15 min	OFF LOADING
<b>0</b>	<b>15 min</b>	<b>OFF LOADING</b>
<b>0</b>	-	-
<b>100</b>	<b>1 hr</b>	<b><math>S \leq 0.25</math></b>
125	1 hr	$S \leq 0.25$
<b>150</b>	<b>1 hr</b>	<b><math>S \leq 0.25</math></b>
175	1 hr	$S \leq 0.25$
200	1 hr	$S \leq 0.25$
225	1 hr	$S \leq 0.25$
<b>250</b>	<b>24 hr</b>	<b><math>S \leq 0.25</math></b>
200	15 min	$S \leq 0.25$
150	15 min	OFF LOADING
100	15 min	OFF LOADING
50	15 min	OFF LOADING
0	1 hr	OFF LOADING

Vertical movements have to be measured by means of at least three dial gauges; horizontal movements have to be measured by two dial gauges only, with a precision of 1/100 mm. On every increment, settlements shall be recorded after 30", 2', 4', 8', 15', 30', 1h. Movement of the pile head shall be less than 0.25 mm within that hour, or until 2 hours have elapsed, whichever occurs first, before the application of the new load increment.

### Test Reports

Reports on pile testing shall be submitted to CEB and shall contain, among others, the following information:

- Layout of test equipment and description
- Pile identification, diameter and length
- Sketch of soil conditions and ground water location
- Complete records of level, load cell and dial gauge readings against date and time throughout the test, preferably in tabulation
- Graphs of load and settlement/heave versus time

- Graphs of settlement/heave versus load
- Remarks concerning any unusual occurrences during the loading of the pile
- Test reports on integrity testing of piles shall include clear sample diagrams of acceptable signals for comparison purpose, as well as sample graphs indicating defects or doubts on the integrity of the pile.

#### Evaluation/Conclusion

The settlement of preliminary piles shall not exceed  $1/10^{\text{th}}$  of the pile diameter after final test load is applied. In case, the pile shows higher settlement, the Bidder/Contractor must investigate the matter and accordingly, pile must be redesigned.

Alternatively, the Bidder/Contractor may scale down the safe design load, and the pile layout shall be revised with the modified pile capacity.

The settlement of Working Pile shall satisfy the following two conditions:

- Total settlement shall not exceed 12mm, and
- Residual settlement shall not exceed 6mm after final test load had been applied.

In case, the pile shows higher settlement, the Bidder/Contractor must revise the pile layout at that location and in addition, two more piles shall be selected and tested near the failed location. In case, the additional tests also do not show satisfactory results, safe design load shall be scaled down and accordingly, pile layout of the concerned area/building shall be revised.

#### **Driving of Piles**

##### **Pre-Cast Driven Piles**

Driven piles shall be executed as per DIN 4026. Pile driving will not be allowed before CEB receives from the Bidder/Contractor the following reports and calculations for approval:

- Calculation of refusal
- Proposal for the minimum penetrated depth of the piles through the ground
- Complete information about the driving and the hammers to be used.

Piles shall not be driven until the excavation has been completed to the grade required for footings or pile caps. Piles shall be driven in the exact locations shown on the drawings to be submitted by the Bidder/Contractor and approved by CEB or as may be directed by CEB.

The Bidder/Contractor shall be responsible for the accuracy of location of each pile and the grade of the off-cut. Driving shall be done with fixed leads, which will hold the pile firmly in position and in axial alignment with the hammer. Driving tolerances shall not be more than one per cent out of plump and not more than 5 cm out of place. Driving of each pile shall be continuous without intermission until the pile has been driven to refusal or to total penetration for the last ten blows not exceeding the design penetration unless otherwise approved by CEB. Any piles that are split, warped, buckled, damaged or imperfect in any way shall be removed and discarded. If any driven pile shall have been raised by the subsequent driving of any adjacent pile or by any cause, the raised pile shall be re-driven to its original penetration and resistance. The refusal shall be with HILEY formula or any other dynamic formula subject to the approval of CEB.

Debris from pile cut-offs and damaged piles shall not be buried in required fill under slabs at grade or in required embankments, but shall be disposed by the Bidder/Contractor off the Site of the work.

A record of the driving of all piles shall be kept by the Bidder/Contractor, and a signed copy submitted to CEB daily. The records shall show the pile type, length, location, penetration for driving stages and the results of any tests.

After driving, the concrete heads of the piles are to be stripped off, to the elevation required, the binders removed, and the main reinforcement bent to form an anchorage into the concrete of the pile cap. Care must be taken in breaking out concrete that no damage is done to the lower section Driven Cast-In-Situ Piles

General of the piles.

Driven Cast-In -Situ Piles are created by driving a temporary tubular steel casing, closed by a removable steel shoe at its bottom end, to the required depth into the ground. The soil is thus both displaced and compacted and the void for the pile created. Reinforcing and concreting for the pile shall be done in line with the guidelines for cast in situ bored piles and the casing shall eventually be withdrawn.

Material Details

Casings shall be free from distortion and shall be strong enough to be driven without damage. Shoes to be used (and later remaining in the ground) shall be made from sufficiently strong and durable material. The shoe shall provide a watertight joint with the casing during driving.

Driving of Casings

Casings shall be driven at adequate spacing to prevent damages to piles, which have recently been cast and thus still contain un-set concrete. The length of driven piles shall be at least as per the design schedule. Any change in pile lengths shall immediately be brought to CEB's attention.

Driving of each casing shall be a continuous, not interrupted operation. After unavoidable interruptions during driving, it has to be ensured that the casing is finally driven to the specified design depth and driving resistance. Sufficient information shall be provided on the efficiency and energy of the driving equipment. Dynamic evaluation and analysis shall be provided where requested by CEB.

Weight and fall of the hammer/ram and the number of blows for each 25 mm of penetration shall be recorded, as well as the "Set".

Hammer blows shall only be applied along the line of the pile axis and the impact surface shall be perpendicular to the pile axis.

Set

Set limits shall be defined based on the working load, factor of safety soil condition and driving equipment. During measurement of the "set", exposed parts of the casing shall not be damaged or deformed and the dolly, helmet, etc., shall be in good condition. Set, i.e. the achieved penetration during driving and the temporary compression after completion of driving shall be measured and recorded for each pile. The set shall be recorded either as the number of blows resulting in a penetration of 25 mm or the penetration in millimetres achieved by imposing 10 blows.

Driving sequence and risen piles

The sequence of pile driving shall minimise any possible detrimental effect on other piles in the vicinity. The permissible uplift of any pile due to the driving of other piles shall be limited to 3 mm.

Regular measurements (at least in weekly intervals) shall ensure that no adjacent piles have been effected detrimentally during piling work.

If any pile has been displaced or indicates a higher than permissible uplift, load tests have to prove the design capacity of such piles. If the design capacity cannot be reached, the Bidder/Contractor shall propose remedial actions or design adjustments accordingly.

Once the casing has been driven to the design depth, the reinforcement cage shall be installed. Reinforcement details shall be as for bored cast in situ piles.

Concreting shall be facilitated by pump, flexible hose, tremie-pipe or by bucket, as per the approved method statement. Concrete quality and consistency shall be provided in line with guidelines for cast in situ piles.

#### Extraction of casing

Temporary casings shall be extracted while the concrete within them remains sufficiently workable to ensure that the concrete is not lifted. Vibrating casing extractors must only be used if their application has been accepted in the method statement.

When the casing is being extracted, a sufficient quantity of concrete shall be maintained within the casing to ensure that pressure from external water or soil is exceeded and that the pile is neither reduced in section nor contaminated.

Concrete shall be topped up as necessary while the casing is extracted until the required head of concrete to complete the pile in a sound and proper manner has been provided. No concrete is to be placed once the bottom of the casing has been lifted above the top of the concrete.

#### Basics for Pile Testing after Driving

The Bidder/Contractor shall carry out successful foundation load tests in order to prove the suitability of the pile foundation selected as detailed for bored piles above. The results of the tests shall be submitted for approval by CEB.

In addition, and after installation of the working piles, the integrity of all driven piles (100%) is to be checked successfully by means of sonic pile testing equipment.

#### **13.1.7 Lightning protection**

Approved earthed screens, shall be provided to protect the equipment from direct lightning strikes. The screens shall be of stranded hard drawn copper wires of not less than 35sq.mm total cross section, or stranded galvanised steel wires of not less than 7/3.5mm cross section and connected to provide low impedance paths to earth.

The layout of the earth wires shall be such that generally, equipment's to be protected lie within areas bounded by lines drawn from the earth wire at 30° to the vertical in a plane perpendicular to the axis of the earth wire.

The earth screens shall be suitable for extension to protect the substation equipment's to be installed in future stages of development.

Connections shall be made of copper strip of 30mm x 5mm cross-section between the overhead earthed screen wire and the main substation earthing system at each support.

Earth wires shall be held in clamps with free, pin type joints between clamps and supports.

Connections shall be provided for the terminations of the earth wires of the overhead lines including bimetal connectors where necessary.

The necessary stays, fittings and anchors shall be provided under this Contract including, if required, flying stays and additional masts to ensure clearance of not less than 9144 mm (30 ft.) over roadways for breaker or transformer removal.

#### Lightning Protection for Control building

A complete lightning protection system for the control building shall be constructed in compliance with BS 6651.

An air termination network shall be installed on the surfaces of the roofs. No part of the roofs shall be further away than 10m from the nearest horizontal protective conductor. Salient points of the structure such as air conditioning installations, vent pipes railings, gutters, and steel constructions etc. shall be connected to the network.

Down conductors shall be distributed around the outside walls of the building with a maximum distance of 20m and all main metal parts near the down conductors shall be connected there to. Each down conductor shall; be provided with test joints in such positions that periodic testing is easily possible.

All connections and joints shall be installed mechanically and electrically effective (clamped, screwed or welded) to suit the local climatic conditions.

For every building, at least, one ring of ground conductors shall be installed and interconnected.

Materials,

Air terminations: Tinned copper 8mm diameter

Earth terminations: Copper 8mm diameter with lead coating minimum 1.2mm thick as protection against corrosion

Ground rods: Tinned copper weld or stainless steel 3000x30mm diameter

Potential equalizing bars: tinned copper 500x50x5mm

All support and connections shall be made of best suitable materials.

#### Copper

Copper and copper alloys shall comply with the British Standards and approved standard relevant to the form and use for which the material is intended.

Copper components shall be placed so that neither in no case shall they come in direct contact with aluminium nor shall it be possible for water or consideration to pass off copper on to aluminium.

### **13.1.8 Water supply & drainage system**

#### **Water supply system**

The Contractor will be responsible for the provision and installation of a water supply serving the substation buildings. Shaded from direct sunlight, a 2.0 cubic meter header tank. should be constructed and space and ladder should provide for maintenance this overhead tank.

Contractor shall provide public water service or a deep tube well with sufficient capacity. An automatic controlled pump for tube well shall fill 4m<sup>3</sup> underground tank with proper

insect tight venting and a second automatically controlled pump shall raise water to the header tank.

Internal plumbing system shall be connected either to public water system well or tube well as instructed by the Engineer

In case a public water supply is available, under ground tank (2 m<sup>3</sup>) with proper insect tight venting & automatically controlled pump main stopcock shall construct to raise the water to a shaded roof tank

Every tank or cistern shall be provided with a stopcock in the supply pipe adjacent to the fitting. Pipe to header tank shall not be less than 25 mm bore and pipes to wash basins and WCs shall be not less than 15 more bore.

Every cistern, sink, basin etc., shall be provided with a stopcock in the supply pipe adjacent to the fittings. Each basin and sink is to be provided with water.

All drainage design, materials and workmanship shall be in accordance with approved standards and Codes of Practice.

### Water Pipes

PVC pipes shall generally be used throughout of an approved type. They shall be secured to the structure. Pipes to wash hand basins and WC cisterns shall be 15 mm bore and supply pipes to header tanks 25 mm bore.

Plastic piping and fittings shall be permitted where adequately protected or where risk of impact is small.

Overflow pipes shall be taken from the tops of cisterns and set to discharge in a prominent position.

### Sanitary Fittings

Wash hand basins shall be supported on pedestals or cantilever brackets cut and pinned to the walls or screwed to 30mm timber chambered backboards, which shall be plugged and screwed to the walls. They shall be provided with 35mm bottle traps with brass cleaning eye and lining soldered on, or alternatively, similar PVC fittings.

Cistern supporting brackets shall be screwed to 30mm timber chambered backboards, which, shall be plugged and screwed to the walls. Overflow pipes from WC cisterns shall be 20 mm bore.

Glazed ware shall be of best quality type and manufacturer shall be approved by the Engineer. Fittings shall be securely fixed in an approved manner.

Taps and all visible metal fittings shall be chromium plated, heavy-duty quality. Drinking fountain outlets shall be clearly labelled. All fittings shall be individually isolated with a stopcock in the water supply pipe.

On completion of the works, all sanitary fittings shall be left in a clean and proper condition.

After completion, drains shall be subjected to an air test, in which a pressure equal to 150 mm of water is to be applied for a period of five minutes without dropping below 125mm head. Any defects revealed shall be made good at the Contractor's expense.

## **Waste water sewerage system**

### Drain Pipes



Drainpipes shall be PVC pipes and fittings of approved manufacture and shall be jointed with sleeves or sockets. PVC pipes provided should be black unplasticised PVC complying with BS 4660 or 5481, or equivalent standard.

Concrete beds and casings to drain pipes under roads shall be of week concrete and of 150mm minimum thickness. Elsewhere the pipes and ducts shall be laid on and surrounded with approved granular material.

### Manholes

Manholes shall be generally in accordance with BS EN 752. Galvanised malleable cast iron step irons are to be provided and built in as work proceeds.

Manhole covers shall comply with BS EN 124 and in roadways or heavily loaded areas shall be heavy duty, area with non-vehicular access to be medium duty.

### Septic Tank & soakage pit

The septic tank, where main drainage is not available, shall be constructed in an agreed position at least 20 meters from any building. The design shall be to recognised standards such as BS 6297 and approved by the Engineer. The tank shall have separate fresh air inlet and outlet pipes and be provided with access openings. The effluent from the tank shall discharge, depending on the type of subsoil, to a soak away pit or either through evapour-transpiration beds or up flow filter, a soak away pit shall be covered by a concrete slab, with access through a manhole cover.

In impermeable type soil, where a soak away will not function efficiently, either evapourtranspiration beds or unflow filter shall be provided, for effluent disposal from the tank.

The system shall be properly ventilated by continuing the soil pipe above the highest branch upwards above roof level.

All drains shall be laid in straight lines and regular gradients as described. Great care shall be exercised in setting out and determining the level of the drains. All drains shall be kept clear from earth, debris, superfluous cement and other obstructions during and after lying. And shall be provided with eyes, inspection covers, etc. to ensure that every length can be rodded effectively in the event of a blockage.

#### **13.1.8.1 Surface water drainage system**

##### General

Embankments and cuttings shall have drainage facilities at their top or bottom. The formation level of switchyard area shall be formed with uniform cross-falls of about 1 in 300 in the same direction as the natural drainage path of the surrounding Area Provision shall be made for the disposal of surface water from roads.

A surface water drainage system covering the switchyard shall be installed. The system may be discharged to natural watercourses or to soak ways as approved.

Surface water from roofs of buildings shall be drained to down pipes connected with the site drainage system.

The number of runs and out falls and pipe sizing must be sufficient to cope with the severest precipitation, with a factor of safety of 1.2. Within Switchgear and other areas. It is to be ensured by the contractor that the surface water discharged from the substation does not cause any damage to the properties through which such water is discharge up to natural water courses as approved.

The Contractor shall ascertain whether main foul drainage is available locally, and if so, arrangements are to be made to connect the substation toilets into this system. Where main drainage is not available foul drainage shall terminate at suitably dimensioned septic tank and soakage pits.

#### Gradient

Drains shall have the following minimum gradient.

Open ditch for storm water 1/200

Other drainage systems 1/400

The minimum velocity shall exceeds 0.75 m/sec. The sectional shapes have to be determined by the water carrying requirements and must have the most favourable hydraulic qualities so as to remove the drain water in a proper manner without settlements. Manholes shall be provided at each places where change in direction take place and at not greater than 80 m canters.

### 13.1.9 Construction & Maintenance of roads

#### General

All the road work shall comply with ICTAD Specifications of construction and maintenance of roads and bridges.

The Contractor shall ensure that the roads are levelled graded, properly compacted with appropriate rollers, and surfaced with asphalt or concrete to ensure that the finished road is suitable for the maximum foreseeable imposed loads expected from vehicles transporting the various items of plant and electrical equipment. In detailing the layout of the roads and parking areas, special attention must be given to the travelling of vehicles delivering plant, stores, spares and other materials and equipment.

Material for the hard-core shall consist of natural stone broken to pass a 100-mm ring. It shall be free from dust, rubbish, wood, vegetable or other injurious matter.

Broken stones and aggregates shall consist of hard crushed natural stone or gravel of approved sizes.

Bituminous Wearing courses shall be suitable for the extreme soil condition in the area and shall comply with an authoritative and approved standard appropriate to the locality of the work. The details and grading of the aggregate and the binder contents shall be submitted to the Engineer for approval. Sealing grit will be applied as required.

#### Road carriage way

##### Preparation of Formation

The upper 300-mm of the formation shall be of suitable soil; otherwise the Contractor shall improve it to strength of greater than 156 CBR by blending it with granular materials such as gravel and sand.

The formation shall be rolled to an even and uniform surface, which shall be parallel to the finished surface of the road or path. Rolling shall be carried out with a 4 to 7 ton power driven roller unless otherwise ordered or permitted by the Engineer.

#### Sub-Base

After the formation has been properly made, rolled and approved by the Engineer, a sub-base consisting of well graded natural sand, gravel or rock or mixtures thereof shall be

laid in accordance with standards to give a finished thickness of at least 200 mm or as described or directed.

### Prime Coat

For the prime coat 0.5 to 1.5 lit/m<sup>2</sup> liquid bitumen shall be sprayed on in accordance with the best practice fitting to the locality of the work.

### Bituminous Surface

Two layer of bituminous surfacing of 75 mm overall thickness shall be laid in accordance with the approved standard.

### Roadsides

In-situ concrete kerbs or pre-cast concrete kerbs set on a concrete bed are to be laid on each side of the roads, to define the limits for vehicular access.

All drains, sewers, cable ducts and other necessary work below road formation level shall be completed, inspected and passed by the Engineer before any road work is started.

Concrete paving slabs shall comply with a relevant approved standard.

Trench covers shall be minimum of 50 mm thick and provided with handles or holes for lifting purposes. They shall be reinforced to the approval of the Engineer. The reinforcement shall be in the middle of the covers with 25mm cover to the edges. Trench covers shall comply with the relevant standard as approved.

Where concrete covers are required for trenches crossing roads, these shall be designed for the heavy wheel loads expected on them and shall be reinforced with mesh fabric or mild steel bars as necessary.

### Walk ways

Walk ways to buildings should have a width of 1.5m -2m.

#### **13.1.9.1 Approach road**

The contractor shall construct or upgrade the approach to site that is road from main road to the gate of the substation to allow heavy vehicles to site. The minimum carriage way width shall be 7m and road shall surface with asphalt or concrete.

#### **13.1.9.2 Structures (Culverts, Bridges retaining walls) for approach road.**

Shall be follow the guide lines of the road development authority and shall comply with ICTAD Specifications on Roads and Bridges.

#### **13.1.9.3 Access road and structures**

Access roads are the roads within the switchyard area. Road shall properly graded, compacted and surfaced. Access roads shall be either concrete or asphalt.

The Contractor's proposed site layouts shall allow for 5 m wide vehicular access to the control building and electrical equipment, for installation and subsequent maintenance. In 220 kV grid substations the access road should be arranged in a ring and where impossible, the reversing space shall be made available. Roads shall be surfaced with concrete or asphalt as approved by the engineer. All the cable trenches crossings canal crossings road side constructions shall be considered.

#### **13.1.9.4 Public road up to the approach road of grid substation**

The contractor shall renovate or upgrade the public road up to the approach road of grid substation to allow heavy vehicles to site.

### **13.1.10 Fence and Gate**

### 13.1.10.1 Chain link fence and Gate

Chain link fences shall be constructed of galvanised steel wire, in accordance with drawings and shall be of such manufacture that when any one segment is cut, remaining segments within the pattern retain their rigidity. The bottom of the fence shall be fixed down with staples to a continuous concrete sill, or to rocky ground, in accordance with BS 1722, Part 10.

Steel wire for mesh and line wire shall comply with grade A of BS 4102. All mesh shall be of galvanised steel wire of 3.55 mm diameter.; with a length of side not exceeding 50 mm. Line wires shall be of galvanised steel wire of the same gauge to adequately support the mesh rigidly. Line wire shall be provided at the top and bottom of the mesh and at two evenly spaced intermediate levels. The line wires shall be strained tightly by eyebolt strainers or winders at each straining post and secured to intermediate posts of stirrup wires passed through holes in the posts. The top wire shall be doubled. Mesh and line wires shall comply with BS 4102. Chain link mesh shall be strained between straining posts by means of stretcher bars and tied to line wires in accordance with Clause 3.5 of BS 1722, Part 10.

Straining posts and struts shall be of Galvernised steel to the same standard as above. The posts shall be set in concrete in the ground. The posts shall have cranked tops set at 45° to the posts, to which shall be attached three strands of galvanised barbed wire to BS 4102. Barbed wires shall be strained between straining posts with eyebolts and fixed to intermediate posts with stirrup wires. Droppers shall be fitted at the centre of each Bay of the fence to prevent the wires being bunched together. Intermediate posts shall be provided at centres not exceeding 3 meters. Corner posts and struts shall be provided at all ends, corners, changes in direction, adjacent to gateposts and at intervals not exceeding 35 meters. All fence fittings shall be galvanised.

#### Gates

The dimensions of the gate shall be accordance with the drawing.

The gate should be remotely operable either swinging or sliding as approved by the engineer. Following functions should be incorporated with the gate design.

- Manual release key in case of power failure.
- Self-locking in closed position.
- Automatic stopping function against obstacle.
- Adjustable time setting for automatic close-up function.
- All events/alarms should be indicate in audible or visible indicators.

The gates shall be fitted with a vertical drop bolt on each leaf, a sliding bar lock with padlock eyes and a padlock to prevent movement of the sliding bar lock.

The padlocks shall be included in the overall locking system. All these fittings shall be galvanised. The vertical drop bolts are to drop into galvanised steel tubes cast into the road, to secure the gates when in both closed and open positions.

Gateposts shall be made from galvanised steel RHS shall be capped and set in concrete in the ground. Gate hinges (pivots) shall be heavily galvanised They shall comply with Clauses 2.8.5 and 2.8.6 of BS 1722, Part 10, or other approved details.

### 13.1.10.2 Galvanized Barbed Wire Fence, Boundary Wall & Gate

#### Galvanized barbed wire fencing

The straight spans are to be erected with intermediate posts which are spaced at 10 ft. centre to centre where the number of intermediate posts in a straight span exceeds ten (10) a strutted post shall be placed. Two corner Posts, supported with 02 strutted posts on either side of the spans shall be used in every corners. Barbed wire shall comply with the requirements of BS 4102.

### Casting of the Posts

Contractor may cast fence posts either at site itself, or at any other place convenient to him. Contractor has to inform the Engineer the place he intends to cast the posts and shall allow. All the fence posts shall be cast as per the give drawing. Contractor shall maintain type F.3 finishes as per the specification given under concrete. The Engineer shall approve the formwork and reinforcement before concreting. The contractor shall get approved the posts before transport to the site.

No pole shall be erected before 28 days from the date of its casting

After the excavation of the foundation, post should be placed in it and aligned so that the straight portion of it is exactly vertical and outside face should be exactly in line with the other posts in the same span. Placing of concrete in the foundation shall be done only after the alignment of the Post/Posts are approved by the Engineer.

Each strand of barbed wire should be sent through the holes provided in the posts and struts, and tensioned by the turnbuckles. Turn Buckles shall be fully galvanized to the satisfaction of the engineer. Turn buckles shall be connected to each of barbed wire on both sides of each straining post and set of corner posts at each corner i.e. 22 Nos. of turn buckles for each straining post and each set (02) of corner posts. Each strand shall be adequately tensioned to the satisfaction of the Engineer.

### Gate

A gate consisting of two sashes complete with gateposts & locks, bolts and other accessories as per Drawing shall be supplied and erected at the entrance to the land.

The fence of the gate shall be terminated with two corner posts just adjacent to the gateposts, with suitable adjustments to the foundations of the two corner pots.

Both sashes of the gate and all other accessories of it including bolts, locks & hinges shall be fully galvanized, to the satisfaction of the Engineer. It is preferable if the gate sashes could be galvanized after the fabrication. However, if it is not possible, welding, cuts and any other form of connections done after the galvanizing

The gateposts shall be concreted at site, as concrete used for posts should be grade 25 while that for foundations shall be Grade 10. Gateposts shall be plastered to a semi rough finish with cement mortar not less than 15mm thick, and applied with two coats of weather sealed paint of which, make and colour to be approved by the Engineer.

Galvanised barbed wire shall conform to BS 4102 or similar approved material.

### Boundary Wall

A boundary wall shall be constructed in places where barbed wire fencing is not appropriate or as requested by the engineer. The boundary wall shall be 2.6m tall and minimum 200mm thick (brick or block). It should be finished with semi rough plastering and two coats of weather shield painting. At every 3m, a suitably reinforced stiffener column should be provided and all the columns should be connected with a tie beam on top of the wall. On top of the tie beam, an anti climbing arrangement such as embedded

rods with pointed head or barbed wire should be provided as approved by the engineer. The boundary wall should be supported on a suitable foundation, depending on the soil condition.

Shall be carried out according to the relevant clause of this specification.

The Contractor shall be required to produce full design calculations for the foundations,

### **13.1.12 Construction of Buildings**

#### **Control Building & Other Buildings**

building structures, etc. and detailed working drawings and bending schedules, etc. He shall be responsible for the detailed design, strength and safety of the structures, to meet the structural, acoustic and environmental requirements of the buildings and other works. He will be responsible for ensuring that the design satisfies the requirements of all authorized local and national bodies. Design calculations and detailed drawings must be submitted to the Engineer for approval before the relevant construction work is carried out and at least six weeks before the relevant drawing is required at site. Design calculations shall be in accordance with an approved method of computation and should take account of the most unfavourable combination of dead load, live load, and wind load. Live loads shall be in accordance with BS 6399. Wind load calculation shall be carried out with reference to BS6399-2:1997.

Civil engineering works and services shall be designed and constructed in accordance with British Standards or Sri Lanka Standards and Codes of Practices where BS is not available

The Bid shall include, a schedule of standards and codes to be followed in design and construction of the works. Copies of these codes and standards shall be made available to the Engineer and Employer during the design and construction period on site,

The Standards and/or Codes of Practice employed throughout the Works, where they do not conflict with the local by-laws.

As far as practicable the standards or codes adopted shall be consistent throughout any section of the works except in meeting superior specified requirements.

The Contractor shall investigate the existence of any regulations and local by-laws governing the proposed works in Sri Lanka and he shall be deemed to fully comply with such requirements, which are effective 30 days prior to the date of Bid submission.

The buildings are to be designed with ease of operation and maintenance as a major factor. Materials, workmanship and finishes must be of an appropriately high standard. In considering the various materials, details, construction methods, etc., The Bidder must investigate the availability, delivery and transportation to the sites of all materials, plant, labour, etc., to enable the program to be maintained.

A New substation building shall have reinforced concrete frames, If the Bidder wishes to propose an alternative form of construction, any combination of reinforced concrete, structural steelworks, etc. will be considered, provided that the buildings are completely weatherproof and satisfy all other requirements of this specification. All walls and roofs shall be fully insulated, to produce maximum thermal transmittance U. values of 1.14 (watts/m<sup>2</sup>/°c for walls and 0.57 for roofs. Architectural treatment of the new buildings shall be satisfied the requirement of relevant local authority or Urban Development Authority of Sri Lanka.

### Fire criteria

Non-combustible or fire-resistant components shall be used in the construction.

To provide resistance to the collapse of the structure in the event of a fire, and also to avoid a fire occurring in one room to spread in to adjacent rooms. All structural elements of the building shall have the following minimum fire resistance:

#### Single Storied Structures

External walls and columns	1 hr
Internal walls and columns	1 hr
Roof	Non-combustible
Ceiling	1 hr
Two story building	
External walls and columns	2 hrs
Internal walls and columns	2 hrs
Roof	Non-combustible
Ceiling	2 hr

Doors and windows shall have a minimum fire resistance equal to the walls in which they are located.

### Super structure (Structural frame & walls)

Shall have reinforced concrete frames with 225 mm thick walls of brickwork.

#### Brick work

Bricks shall comply with relevant SLS standards.

Brickwork shall comply with chapter 6 of ICTAD Specifications for Building Works Volume 1 (ICTAD Publication No SCA/4-Vlume 1)

#### Lime

Lime for mortar shall be hydrated grey-stone lime in accordance with BS 890 for hydrated calcium lime.

The Contractor shall forward copies of Manufacturers certificates to the Engineer, which in addition to certifying compliance with BS 890 shall give details of the type of lime. If lime is delivered as lime putty, the certificate shall state whether quicklime or hydrated lime was use in its manufacture.

All lime shall be efficiently protected against deterioration during transport and whilst stored on site. Different types or brands of lime shall be stored separately in dry conditions in a manner that allows it to be used in the order of delivery.

When lime putty is to be used the Contractor shall obtain the approval of the Engineer of his arrangement for transport handling and storage. Precautions shall be taken to prevent contamination and drying out of lime putty stored on site. Lime putty made from hydrated lime (powder) should stand for at lest sixteen hours before use.

### Mortar for Brick work

Sand for mortar shall be naturally occurred material complying with BS 1199. It shall be stored on clean surfaces in such a manner as to allow adequate drainage, and to prevent contamination by other materials.

The Contractor shall obtain certificates of compliance with BS 1199 from the supplier and submit copies to the Engineer. If requested, the Contractor shall also supply to the Engineer the additional information called for in BS 1199. If certificates or control information is not available the Contractor shall carry out his own regular tests to the satisfaction of the Engineer.

Mortar for use with brick work shall be mixed in the proportions of 1:1:6 cement, lime, sand by volume. Mortar may be mixed by hand or mechanically. Hand mixing shall be carried out on a clean, watertight platform. The ingredients shall be mixed thoroughly in the required proportions, first dry and then with the addition of water until a uniform colour and suitable consistency is obtained. The mortar shall be used within hour of the addition of the mixing water and any mortar not then used shall be discarded. For internal walling the mortar may be mixed in the proportions of 1:2:9 cement, lime, sand by volume.

Plasticisers when added to mortars shall be used strictly in accordance with the manufacturer's instructions after Engineer's approval.

#### Jointing

External fairfaced walls shall be weather struck: faces of walls which, are to be plastered or rendered shall have their joints raked out to form key. All other wall faces and partitions shall be flush jointed. All jointing shall be completed with pointing as the work proceeds.

#### Lintels

The brick work over all openings in walls shall be supported on reinforced concrete lintels. All lintels shall be the same width as the brick works into which they are being built.

#### Building in Frames

Openings in masonry for doors, windows, air conditioning unit's ventilators and fans etc. shall be properly marked out and built in as the work proceeds with approved anchors. The fittings shall be propped and strutted where required.

The back surface of timber fittings shall be coated with an approved timber preservative before fixing.

The back surface of steel and galvanised fittings shall be coated with a bituminous paint before fixing.

All fittings shall be bedded in 1:3 cement sand mortar 12 mm thick.

#### Cement, Brick work and Plaster

When so described or directed internal surfaces of fair-faced block plastered wall shall be prepared and painted with one coat of anti-suction primer, followed by one undercoat and one finishing coat of PVA based plastic emulsion paint.

Exterior surfaces of fair faced block work walls and concrete columns at the new substation buildings shall be prepared and painted with two coats of an approved stone paint.

All paint shall be of an approved type and suitable for its required purpose, with surface preparation and paint application being strictly in accordance with the manufacturers' instructions.



## Doors & windows

Shall be as specified in schedule of finishes. Particular attention must be given in the design of the buildings to fire prevention and safety of the personnel at all times. Access doors and escape doors shall be provided and fitted with panic bolts where necessary, so that operating and maintenance staff can always exit safely from the buildings in fire emergencies of any nature or location. Hydraulic door closures shall be fitted to all doors in air-conditioned areas.

### Aluminium Windows and Doors

Aluminium windows and doors shall be obtained from an approved manufacturer and of a type, design, colour and finish to be approved by the Engineer. All opening windows shall be provided with integral fly-screens, which shall be removable for cleaning, and maintenance.

Aluminium windows and door frames are to be formed of extruded aluminium sections to BS 1474 and of aluminium alloy type H9 or such other alloy approved by the Engineer as being suitable for the climatic and atmospheric conditions prevailing at the Site.

The construction of aluminium windows, including weather-stripping, hardware, etc., is to comply with the requirements of BS 4873 or other approved standard.

Where possible, aluminium windows and doors shall be fixed after all structural and wet finishes are completed but in any case they shall be kept clean and protected from damage at all times. Splashes of cement, plaster, etc., which occur on the aluminium during the construction period shall be immediately cleaned off.

Care shall be taken during dispatch and storage on site to prevent damage to the windows and doors.

Allowance shall be made when fixing frames for expansion to aluminium members so as to prevent distortion of frames or cracking of glass. The perimeter of the frame shall be pointed with approved mastic.

Aluminium doors shall be approved manufacturer and to be guaranteed against defects for 12 months.

### Aluminium Patent Glazing

The clauses above referring to approved type, finish, expansion, protection, etc., for aluminium windows shall also apply to patent glazing.

The minimum patent glazing shall comprise extended aluminium bars of adequate section to suit the span required and incorporating such condensation channels, cord grooves, glazing rebates and continuous aluminium wings as may be necessary. Shoes or stops must be provided to prevent the glass sliding out. Glass shall be secured on the internal face against grassed asbestos cords in the performed channels and on the external face with continuous aluminium wings bolted through the bars. Approved proprietary trimming or sealing strips to be provided as necessary.

### Other Materials

Materials not herein fully specified and which may be offered for use in the Works shall be first class quality and of such kind as is generally used in first class work. The Engineer shall have the right to determine whether all or any of the materials offered or delivered for use in the works are suitable for the purpose. External ferrous metalwork shall be galvanised.

All plates and sections shall be true to form, free from twist and straightened before any fabrication work is started on them. Each piece of work shall be distinctly marked before dispatch accordance with a marking diagram to be provided by the Contractor.

#### Fire resisting steel doors

Doors shall be fabricated from steel sheet covering a framework of angle sections. Steel doors shall be galvanised after fabrication. Doorframes shall also be galvanised steel all fire resistance doors shall be insulated and fitted with panic latches, which are lockable from outside.

Steel doors shall be effectively sealed to reduce the leakage of heat ingress of dust as far as practicable using heavy duty seals which shall be guaranteed for a minimum period of five years from date of commissioning. Doors and seals shall be designed that replacement of worm seals can be achieved easily on site.

Fire resisting doors, frames and furniture shall be of approved manufacture and satisfy the test requirements of BS 476 Part 8.

#### Timber

Timber for carpenter or joiner's work shall be hardwood of approved class 1 quality All timber shall be subject to inspection by the Engineer, piece by piece, both before and after finishing. The Contractor shall provide all necessary labour and facilities for the inspection of timber.

#### Preservative

Where appropriate, timber shall be treated with an approved preservative against rot or termite attack. The backs of frames to be fixed to walls and all other bedding surfaces shall be painted two coats preservative before fixing. All fixing blocks, pallets and other hidden timber shall be so treated prior to fixing.

#### Workmanship

The quality of workmanship shall comply with BS 1186, Part 2. All carpenters' work shall be left "from the saw" unless otherwise described or directed. All joiner's work shall be wrought and finished with a clean, even, smooth surface.

Any carpenter's or joiner's work which shrinks, splits, fractures, parts in the joints or shows any other defect shall be removed or replaced to the satisfaction of the Engineer.

#### Timber Doors and windows

Doorframes shall be framed, rebated, rounded, moulded and grooved. The frames shall be fixed in by metal anchors, secured to timber pallets, nailed to grounds, or screwed and plugged to surrounds.

Architrave's shall be moulded and shaped and shall be greater in thickness than any skirting that abuts them. They shall not be installed until after the wall coverings have been formed.

Flush doors shall be solid cored. Skeleton-framed flush doors will not be accepted but proprietary makes of cellular cored doors may be used if approved by the Engineer.

Facings shall be either veneered or suitable for painting. Where hardwood veneers are used, these shall be specially selected and matched for figure of grain.

All doors shall be limped and edged with hardwood strips.

The core of solid core flush doors shall be of laminated timber strips laid alternatively with respect to grain. Alternatively, blackboard may be used. Particular attention shall be taken to select a timber for the core, which has a small ratio of movement with regard to moisture content.

#### Builder's Ironmongery

All necessary builder's ironmongery shall be of patterns selected by the Engineer from samples submitted by the Contractor. The selected items shall be provided and fixed by the Contractor in the best manner.

#### Pin Tumbler Cylinders

Pin tumbler cylinders shall be of a type approved by the Engineer. The cylinders shall be made of brass and chromium plated. The lock manufacturer shall supply the cylinders required to comply with the locking system referred to below and shall supply the required special keys ready for use. The Contractor shall provide three keys for each individual lock and twelve master keys. All keys shall be labelled with the room number, building code or master key number, as appropriate, and shall be handed over to the Engineer on completion of each building.

#### Door Closures

Door closures shall be of the overhead hydraulic type. They shall be of an approved type and provided with fine-adjusting facilities. The size of the door closer shall be relative to the weight of the door leaf and shall be approved by the Engineer.

#### Door Fittings

All metal fittings such as hinges, locks, door handles, door bolts, etc. shall be made for heavy duty and mounted in adequate numbers. The brand of the selected fittings for doors shall be approved by the Engineer. Sample shall be kept at site for future comparison. Hinges shall be of steel, brass or aluminium, with washers, selected appropriately. Where necessary, doorstoppers shall be provided.

Cylinder mortise lock and latch sets shall be fitted to all internal doors. Lever handles shall be fitted to both sides of internal doors. Panic latch sets with external cylinder locking shall be fitted to all single external doors and to one leaf of external double doors. These locks shall incorporate a finger pull or handle externally to facilitate opening. The other leaf of external double doors shall be fitted with internal bolts.

Cylinder mortise lock and latch sets shall have a spring bolt operated by lever handles and a dead bolt operated by way.

#### Locking System

Door locks in the buildings on this Project shall be suited and master keyed to an overall locking system plan for doors and gates discussed and agreed with the Engineer.

Keys are to be supplied according to the agreed locking system plan and handed over to the Engineer against receipt only. Written notice of this shall be given to the Engineer, with one copy of all key receipts.

#### Glazing

Glass used for control building and guardroom shall be wired cast clear sheet of 6 mm thickness, Glass shall be free from all defects, obtained from an approved manufacturer. Glass shall meet fire resistance of BS 476 part 22 for more than 60 minutes integrity. The

Contractor shall show on his drawings the thickness of the glass proposed for the various locations. Obscured glass shall be roughcast; plain rolled or figured obscured glass.

Glass used for Engineers office shall be 5mm thick clear sheet.

Glass in glazed internal doors shall be bedded in wash-leather. For external timber doors, approved genuine linseed oil putty shall be used. The edges of the glass shall be embedded in the back putty, and then secured by glazier's springs. The front putty shall stop 2 to 3 mm from the sight line of the back rebate, so that the paint can seal the edge of the putty to the glass without projecting. The surface of the putty shall be painted within 28 days of glazing. No glazing shall commence until rebates have been painted with primer.

Glazing compound for aluminium windows shall be generally of an approved polysulphide type. The glass shall be bedded against the frame on the external face with the compound and secured on the internal face with extruded aluminium bedding, screwed or clipped and studded to the frame in an approved manner so as to securely retain the glass. Glazing compound or an approved proprietary type of plastic trim shall be used where necessary to ensure a weatherproof seal.

Allowance shall be made when fixing frames for expansion of aluminium members so as to prevent distortion of frames or cracking of glass. The perimeter of the frames shall be pointed with approved mastic.

On completion of the works, all broken or cracked glass shall be replaced and all glass cleaned inside and outside, to the satisfaction of the Engineer.

## Roof and ceiling

### Roof trusses

All metals and metalwork components whether fabricated on or off site shall conform to the requirements of the relevant British Standards or any other standards to the approved by the Engineer.

Metalwork articles shall have a good finish, and be free from scale, rust, damage or other defects.

Components shall be properly assembled and jointed in a neat and functional manner. Welded connections shall be ground off as necessary to present a clean smooth finish without detriment to the strength of the connection.

Particular attention shall be given to the protection of metalwork from degradation caused by the environment in which it is to be used. Galvanizing, surface coating or such other treatment suitable for the metalwork under consideration shall accomplish this.

### Asbestos Cement Roofing

(a) The Asbestos cement sheets shall be of the best quality, compressed, of Ceylon manufacture, complying in every respect with the latest BS's. For asbestos cement slates and sheet except where it is otherwise specified asbestos cement sheet shall be with the large (145 mm) corrugations and a thickness of not less than 6mm Asbestos cement sheets with the smaller (72mm) corrugations when permitted, shall have a thickness of not less than 5.6 mm.

(b) The Asbestos cement sheets shall be fixed with galvanised hook bolts not less than 6 mm thick galvanised iron limpet washers and an additional bitumen washer, to

purling spaced not more than 1350mm for sheets with the larger corrugations and not more than 900mm for sheets with the small corrugations. End laps shall not be less than 150mm for roof pitch of 25 degrees and above and not less than 225 mm for roof pitch below 25 degrees. The side laps shall be 1 1/2 corrugations for sheets with large (145mm) corrugations and 1 1/2 corrugations for sheets with small (72mm) corrugations. The maximum overhand beyond purling at gable ends shall be not more than 150 mm. Laying of the sheets shall be started from the bottom leeward corner and to avoid gaps under the laps at the corners certain sheets shall be mitred. The corner of the first shall not be cut. All the remaining sheets on the bottom row shall have their top leeward corners mitred. Each sheet in the intermediate course shall have two corners, i.e. top leeward and bottom windward corners mitred. The sheets shall be so fixed as to close on the ridges and the hips.

(c) Ridges shall be of asbestos cement having the same corrugations as the roofing sheets, while the hips may be plain. They shall be of the adjustable type where necessary to fit in closely with slopes of the roof and fixed as specified for roofing sheets.

### Flashing

Unless otherwise specified, the junctions of all sloping roofs and walls are to be finished with No. 22 B.W.G. (0.711 mm) galvanised iron sheet flashing, one edge dressed over the roof to a width of not less than 300 mm, the other edge turned up to a height not less than 150 mm and tucked into a chase cut in the wall and pointed in cement and sand 1:2.

Lead flashing where specified shall be of milled lead sheets weighing not less than 24.4 kg. Per square meter, one edge dressed over the roof to a width of not less than 300 mm, the outer edge turned up to a height of not less than 150 mm and nailed to wooden plugs with copper nails. The upper edge shall be covered with an apron of the same material over-lapping it by 100 mm. The top edge of the apron to be tucked into a chase cut in wall 37 mm deep fixed with lead wedges and the joint finally filled with cement sand 1:2.

### Zn/Al roof sheeting

Aluminium for profiled roof sheeting and flashing shall be manufactured from alloy in hard temper conforming to BS EN 485,515,573 NSW Specification not less than 0.47mm thickness and with a colour coated surface finish. Profiled sheeting shall conform to BS CP 5427.

Fastening shall be by means of aluminium hook bolts or other approved fixed in accordance with BS CP 143-15 and recommendations of the manufacturer. Laps shall be sealed as necessary.

### Painting on Metal Surfaces

#### a) General

This article cover, besides the painting of work fabricated at site, also repair painting have damaged surfaces originally corrosion protected at the manufacturer's premises.

#### b) Pre-treatment and Paint System

All surfaces shall be carefully dried and cleaned prior to painting; in particular, removal of all foreign matters such as salt, grease, dust, sand, dirt, and rust (if applicable) is of utmost importance.

On all metal surfaces of ferrous or non-ferrous material 3 coats shall be applied as follows;

- One-pack adequate primer, dry film thickness approximately 20 micron

- Intermediate coat, based on medium oil alkyd resin, dry film thickness minimum 40 microns
- Final coat based on medium oil alkyd resin (minimum 50% fatty acids), dry film thickness 40 microns.

#### Painting at Manufacturer's Premises

All metal surfaces such as for switchgear, cubicles and panels, structures and supports, casings, enclosures, frames and sub-frames, etc. i.e. all equipment or parts thereof incorporated in the work, shall be chemically pre-treated:

- Steel: zinc-phosphate
- Aluminium: chromating
- Other materials: adequately treated followed by a coating system (preferably powder coating)

The applied dry film thickness shall not be less than 100 microns, and shall be of an approved quality of anticorrosion paint.

Extra amounts of paint sufficient for all repairs shall be made available and shall be applied to all surfaces after erection and before commissioning of equipment, if so required.

The final coat shall preferably or as directed or approved otherwise by the Engineer.

In any case, at an early stage the Contractor shall explain in great detail all corrosion protection measures he intends to take, indicate the relevant standards for testing the applied measures, and apply for the Engineer's approval of the above-mentioned steps.

#### Asbestos cement sheet Ceiling

Plain asbestos cement sheets for ceiling shall comply with CS 9 and shall not be less than 5mm thick.

They shall be fixed with 25mm galvanised iron clout headed nails along all edges and joints, and with 25mm brass screws at intermediate cross joints. counter sunk and covered with lime putty. The joints shall be covered with plain ore moulded cove fillets of minimum section 31x10mm. Cove mouldings along all faces of walls shall have a minimum section of 50x50mm. The cover fillets and mouldings shall be fixed to the joists/hearers with 37mm brass screws driven not more than 600mm apart. Ceiling where laid flat shall be fixed to a system of 100x 50 mm joists at centres not exceeding 1200mm and 50x50 mm cross joists at centres not exceeding 600mm.

#### General

The rate for roofing shall include the covering materials (sheets), steel or precast concrete framing. In case of steel framework, the steel purling including all trusses, beams and posts steel hips and steel valley rafters.

#### Floor and trenches

Control building basement and cable trenches shall be waterproofed. A minimum of 1m width openings shall be provided in the falls bottom/cable basement etc. between Control & Protection Room, Battery Room, Communication Room, Auxiliary Room, Switchgear Room, etc. to facilitate the cable running inside the Control Building. In addition to this there should be sufficient space for cable entries (Power, Control & Protection & LVAC cables) between outdoor and Control Building depending on the cable sizes.

### Indoor cable trenches

Indoor concrete lined cable trenches shall have reinforced concrete beams to support panels with openings to pass cables.

### Checker Plate

Mild steel chequer plate (raised pattern) shall be fabricated from first grade mild steel with a minimum thickness over the plain portion of 6 mm. Weight of individual panels shall not exceed 60 kg. All mild steel chequer plate shall be galvanised after cutting to there required size.

### General

All floor finishes shall be protected from damage by following trades and other causes and any damage, howsoever caused, shall be made good by the Contractor at his own expense to the satisfaction of the Engineer.

Floor finishes will be rejected if they prove to be defective, due to cracking, crazing, curling, uneven surfaces, or lack of adhesion. Rejected floors shall be replaced at the Contractor's expense to the satisfaction of the Engineer.

### Screeded Beds

Concrete floors which are required to be surface with screed shall have a roughened surface, produced by hacking and wire brushing. The roughened concrete floor shall be clean, the surplus water shall be removing and: cement/sand grout shall be brush off. The screeded bed shall be 40 mm thick and shall be well compacted and levelled with a screeding board and steel towelled smooth. If the screed is the finished surface, it should be treated with an approved silicate of soda solution hardener to prevent dusting. The screed shall be mixed in the proportions of 1:2:4 (cement, sand, 10mm-pea shingle) by volume with the minimum quantity of water necessary to given a good hard smooth, steel trowelled finish. The section concerning concrete applies, but the sand shall satisfy the requirements of BS 1199.

Rigid screed battens shall be fixed on continuous beds of mortar to prevent movement when screed is being laid and compacted. The screed battens shall be fixed to true lines and levels.

The bay sizes shall not exceed 15 square meters and the length of any one bay shall be limited to 1.5 times the width. The bays shall be laid alternatively, i.e. in chequer board fashion, a minimum of 24 hours being allowed to elapse between the laying of adjacent bays.

The bays shall be separated by strips of hard plastic or other suitable material.

Screeded beds shall be cured for at least seven days, using polythene sheeting or other approved methods.

### Damp Proof Course (DPC)

A damp proof course shall be laid in walls, above ground levels so as to exclude rising moisture.

Damp-proof courses shall be from one of the following materials:

- (1) Lead and copper DPC complying with the requirements BS 6398.
- (2) Asbestos base bitumen DPC complying with the requirements of BS 6398.

- (3) Asbestos base lead cored bitumen DPC complying with the requirements of BS 743 Type F.

#### Damp-Proof Membrane

Approved bitumen PVC waterproof membrane shall be placed on the blinding under concrete floor slabs, to exclude rising moisture. The membrane shall be taken up walls and lapped with the wall DPC.

#### Indoor cable trenches

Indoor concrete lined cable trenches shall have reinforced concrete beam to support panels and with openings to pass cables.

#### Glazed Porcelain (Homogenous) Tiling

The glazed Porcelain (Homogenous) wall and floor tiles shall be of nominal size as required by the engineer. Colour and manufacturer shall be approved by the Engineer. The tile fixing and grouting materials shall be obtained from the same source.

The Contractor shall ensure that the rendering is accurately formed and has a true, plumb surface, which is free from all high spots and depressions.

The floated coat shall consist of a 13 mm thick rendering of 1:1:6 mix by volume of Portland cement, lime and sand: it shall be finished with a wood float. The Contractor shall ensure that the floated coat is plumb and free from all unevenness. Sufficient time for complete drying shrinkage shall be allowed to elapse between the completion of the floated coat and the start of tiling.

The work shall be properly wet out to the Engineer's satisfaction. The height of tile courses shall be set out properly by means of a tiling rod; all tiles and joints shall be accurately aligned both vertically

and horizontally. Joints between the tiles shall be 2 mm wide. Continuous expansion joints shall be made at all internal wall angles.

All tiles shall be dipped in water to ensure that they are completely clean prior to the application of the ceramic tile fix. All tiles shall be immersed in water in clean containers for at least half an hour before use. Tiles shall then be stacked lightly together on a clean surface to drain with the end tiles turned glaze outwards. They shall be fixed as soon as all surface water has gone - they must not be allowed to dry out more than this.

The rendering backing for tiling shall be clean and will be wetted (just enough to prevent it from absorbing water from the fixing bed) immediately prior to tiling. The tiles shall be bedded in ceramic tile fix which shall be trowelled on to the wall with a plaster's trowel having 6mm x 6mm notches at 25 mm centers: the tiles shall be tapped or pressed into position to a true plane.

Approximately two days after the fixing of the tiles, all joints shall be pointed with neat grouting cement: the finish shall be flush and free from all voids and irregularities.

All wall faces shall be finished plumb and flush throughout, free from unevenness and irregularities of plane: all angles shall be straight and true. The finished work shall be left clean and free from all materials; cleaning down must not be carried out with materials, which, will scratch or in any way impair the finished work. Final polishing shall be done with a dry cloth. The Contractor shall be responsible for the adequate protection of the tiling from all damage until the handing over. The Contractor at his own expense shall make any damage, which, occur, good. The whole of the work shall be left in a state satisfactory to the Engineer.



### Raised Modular Floors

Basement for raised modular floor shall be water proofed and should apply anti warming paint.

Full access raised modular floors shall be comprised of 600mmx600mm panels, each and any of which may be easily removed to provide access to the area beneath. The panels shall be supported on adjustable props at 600mm centers.

The props shall be of rust proof materials with a screw device to allow adjustment of level of not less than 119 mm.

The heads of the props shall be such that no gapping or staggering can occur in the panel joints.

The props shall fully support the floor panels without the necessity for intermediate members or stringers.

The panels shall be of galvanised steel with a core of special purpose high-density processed timber.

The surface covering of the panels shall be PVC tiles complying with BS EN 649, edged on all four sides with carbon loaded rigid PVC lipping. Flexible PVC tiles will be preferred.

The underside and edges of the panels shall be fire resistant and meeting the fire rating requirements of BS 6266.

Panel lifting devices form the same manufacturer, as the flooring system shall be provided.

The Complete system shall achieve a constant raised floor level within a tolerance 2.50mm in 12 m.

### Composite Foam Panels for Roofs

Roof and wall sheeting shall be a panel comprising of profiled galvanized steel sheeting in composite insulated panel form. The panel shall comprise an external fully protected galvanized steel weathering sheet, 50mm urethane foam core and an internal lining sheet with a finish to suit the final application.

The panels shall be a factory manufactured units produced on a continuous online injection facility with polyisocyanurate foam bonding the composite parts together in such a way to completely fill all spaces in its panel. The manufacturing process includes temperature control of the metal substrates, temperature control of the chemical dispensing area, temperature control of the online conveyor press to maximize uniformity of foam density and foam substrate adhesion. The panel shall provide effective cover width of 1000mm and shall be manufactured in precise lengths to suit the structure to minimize jointing.

The panels shall be formed with encapsulating side-tape ensuring maximum side lap joint uniformity.

The steel sheeting shall be of G90 (275 gms/m<sup>2</sup>) hot dipped galvanized steel conforming to ASTM A924 and ASTM A653 structural quality.

The outer skin shall be of galvanized steel sheet, 0.75mm gauge sheet with 45/250 trapezoidal profile, min. 45mm high, cover width 1000mm or equivalent, with an approved multi-layer coating system, consisting of:

#	Coat	Coat	Microns nominal thickness
1	Primer	: Epoxy primer coat - both sides	8
2	Base	:Urethane pigmented color coat - weather side	75
3	External Weather	:Epoxy barrier coat - both sides	70

### Insulation Core

The insulation core comprises a factory injected rigid closed cell fire retardant CFC free foam. The minimum depth of insulation shall be 50mm between the liner sheet and the outer sheet. The thermal 'U' value shall be 0.4 W/m<sup>2</sup> deg. C or less.

The insulation used in these panels shall be resistant to moisture, will not support fungal growth, nor rot or deteriorate with age. It is also resistant to moist oils, greases, adhesives, dilute acids and alkalis at normal temperature.

Further properties shall at least be:

Property	ISO	Limit
Density	845	<40 kg./m <sup>3</sup>
Compression Strength	844	C10 = 1.5 kg/cm <sup>2</sup>
Modulus of Compressibility	844	≥37 kg/cm <sup>2</sup>
Tensile Strength	1926	≥2.8 kg/cm <sup>2</sup>
Thermal Conductivity	2581	< 0.019 W/m*deg. K
Flame Resistance	3582	Foam only B2 rated minimum
Water Vapour Transmission	1663	72 gram/m <sup>2</sup> 24 hr. (at 38% to 90% Rel. Humidity).

### Finishes and fittings

#### Wall and ceiling finishes

##### Generally

All internal plastering shall be carried out in accordance with BS 5492 and external rendering with BS 5262.

All proprietary brands of plaster or rendering materials shall be selected and applied strictly in accordance with the manufacturer's instructions regarding the different purposes and backgrounds for which they are intended. Particular attention shall be paid to the manufacturer's instructions regarding the time allowed to elapse between mixing and using.

The plastering shall be carried out by persons experienced in this type of work and the whole of the work shall be finished to a true and even surface, free from all defects. Any cracks or other defects shall be cut out and made good.

## Workmanship

Backgrounds for plasterwork or rendering shall be prepared by carefully brushing to remove dust and other adherent particles of any other material likely to impair the bond of the undercoat with the structure. If undue suction occurs on the background surface, this shall be sprinkled with water to prevent drying the applied plaster.

Joints of block work, which is to be plastered or rendered, shall be raked out to a depth of 13 mm.

Joints shall be introduced in plastered and rendered surfaces over all movement joints.

Such joints shall be formed by inserting casing beds, plaster stops, etc., arranged one on each side of the joint, with the gap between them filled with a suitable mastic sealing material and covered with a metal astral strip.

Plaster/render stops and angle beads shall be expanded metal and provided at corners, movement joints doorways, lower edge of rendering etc., all in accordance with the manufacturer's instructions.

## Materials

Cement, sand, hydrated lime, gypsum plaster, galvanised expanded metal lathing, flat headed galvanised nails, galvanised staples and wires shall all comply with relevant British Standards and approved standards. Materials shall be carefully stored in a dry weatherproof store until required for use.

## Interaction of Materials

In no circumstances shall cement be used in the same mix as gypsum plaster, nor shall the two materials be allowed to contaminate each other. Any materials inadvertently contaminated shall be rejected from the site.

## Plasterwork

Care shall be taken in the selection of the type and strength of plaster mixes, to ensure that undercoats and finishing coats are compatible with each other and with the background, in order that bond failure, shrinkage and thermal cracking, etc. are minimised. Mixes may be based on cement or on gypsum. The first undercoat shall not be stronger than the background and each subsequent coat shall to be stronger than the previous coat. The total thickness of plasterwork shall not be less than 15 mm.

Non-hydraulic or semi-hydraulic limes conforming to BS 890 shall be used in these mixes.

Cement-based undercoats shall consist of Portland Cement, hydrated lime and sand to BS 1199, gauged in the proportions 1:1:6. The undercoats shall be keyed to take the subsequent coat and allowed to dry out completely before the latter is applied, but rapid drying must be avoided.

Finishing coats for use on cement-based undercoats shall be the same mix proportions as the undercoats and shall be finished to a smooth, true and even surface.

Gypsum based undercoats shall use retarded semi-hydrate gypsum plaster to BS 1191, Part 1, Class B, mixed in accordance with the manufacturer's instructions. Each undercoat shall be 6 mm thick. The second under coat shall be applied immediately the first coat has hardened and will produce adequate suction.

Gypsum finishing coats shall be gypsum to BS 1191, Part 1, Class B, mixed with clean water and used neat or mixed with up to 1/4 part lime and 1 part sand, all in strict accordance with the manufacturer's instructions, to thickness of 4 mm.

Other plaster mixes will be considered by the Engineer, but must be confirmed by the manufacturer as suitable for the background intended.

### External Rendering

Where walls are to be rendered externally, the concrete frame shall be proud of the block work panel walls.

External rendering shall be applied in two coats, with an approved waterproof agent added to the mixes. The walls shall be wetted before the application of the first coat, which shall be finished flat and vertical by straightedge, and scored to form a key. The second coat shall not be applied until the first coat has dried out completely. Immediately before application of the second coat, the surface of the first coat shall be wetted, and the second coat shall be applied by an approved method, to give a textured finish of uniform thickness. An approved plasticiser may be used in both coats. All external rendering shall be protected from rain and direct sunlight for a period of 7 days.

Where backgrounds for plastering or rendering are different material, the joint between them shall be covered where necessary with a strip of building paper under expanded metal lathing, overlapping the joint by a minimum of 150 mm. Where the lathing crosses concrete columns between block work panels, the complete column widths should be bridged by the building paper under the lathing, which should then be fixed to the block work only, on each side of the columns. Expanded metal lathing shall be cut, fixed and jointed in accordance with the manufacturers' instructions. Fixing shall be generally at intervals not exceeding 300 mm. Sheets of lathing shall overlap at least 25 mm at side and ends and wired together at 100mm intervals, using galvanised wire. After fixing, all cut edges and damaged nail heads etc. shall be painted with bitumen oil paint.

### Hand railing

Hand railing shall be a 50mm diameter steel pipe and uprights shall be 50 mm x 50 mm mild steel angles. Handrails and uprights shall be galvanised and painted.

### General

All work shall be properly cleaned and rubbed down between each coat in a way, and using materials, recommended by the manufacturers of the paint concerned. No coat shall be commenced until the Engineer has passed the previous coat as dry, hard and satisfactory.

Each coat shall be of the distinct colour from the proceeding one and all colours shall be approved by the Engineer. All paint shall be applied in accordance with the maker's recommendations and shall not contain more than a minimum quantity of thinners or disperses necessary to permit the satisfactory application of the paint. Spray painting will not be permitted except for internal faces of walls and ceiling. All other paint shall be thoroughly brushed into and completely cover the surface. Ironmongery shall be removed before painting and refixed when the paint is dry.

At the completion of all works, the Contractor shall clean down the premises; wash paving and steps; wash and leather down wall tiling, etc., clean all sanitary fittings; touch up paint work; examine all roofs and leave watertight; clean out all pipes and leave the whole of the premises in a clean, sound and perfect condition ready for immediate occupation.

### Paints and Other Materials

Paints for priming, undercoating and finishing shall be ready mixed paints of the best quality for the intended use and comply with BS 6150. All paints shall be obtained from an approved manufacturer who shall certify that the paint is suitable for the intended

purpose. Paint for use on concrete or block work shall be of a type specially prepared for this purpose. Linseed oil should be best quality refined raw or boiled linseed oil. Turpentine shall be best quality. No substitutes shall be used unless approved by the Engineer. Knotting shall be of the best quality to BS 1336, consisting of shellac dissolved in methylated spirits, and shall be free from resin and naphtha. Stopping shall be hard patent white lead stopping, composed of one part white lead and two parts linseed oil putty with the addition of a small quantity of gold size.

### Woodwork

given two priming coats and one under coat on the concealed surfaces.

All woodwork shall have knots treated with two coats of a knotting solution and then painted with aluminium priming paint prior to priming the complete surface. The wood shall then be primed, stopped and painted with two undercoats and one high gloss-finishing coat.

Hard wood which, is not required to be painted shall be made perfectly smooth, prepared and oiled twice with linseed oil. Alternatively, it shall be stained and wax polished, or treated with two coats of an approved varnish.

### Iron and Steel works (Except Structural Steelworks)

All surfaces shall be dry and thoroughly cleaned of all loose scale, rust and grease before painting is commenced.

Iron and steelworks which is to be built into or against block work masonry or concrete shall be painted with two coats of black Bitumastic paint.

All other iron or steelworks, except galvanised metal, shall be painted with two priming coats, two undercoats and one finishing coat. One coat of primer shall normally be applied at the manufacturer's works.

Galvanised metal which, is to be painted shall be treated with mordant. Solution and primed with one coat calcium plumbate primer, followed by one undercoat and one finishing coat of oleo-resinous paint.

### Bitumastic Painted Surfaces and Coated Pipes

Bitumastic painted surfaces and coated pipes shall be thoroughly cleaned to remove grease, dirt or there deleterious matter, and then painted with one coat of sealer, one coat of leafing aluminium, one coat of undercoating paint and one coat of high gloss finish.

### Copper Surfaces

Copper surfaces shall be thoroughly cleaned with white spirit and then painted with two coats of undercoat and one of high gloss finish.

All timber required to be built into, bedded or fixed against brickwork, masonry or concrete.

All the rooms shall be labelled. For emergency use Exit directions to be indicated.

Finishes of Control Building shall be as follows

Item	Description	Control	Protection, Auxiliary room	36kV G.I.S. room	Office room	Store room
1	Floor	Raised modular	Raised modular	Tiled	Tiled	Cement rendered painted with floor painted
2	Walls	Emulsion painted	Emulsion painted	Emulsion painted	Emulsion painted	Emulsion painted
3	Ceiling	Concrete	Concrete	Concrete	Concrete	Concrete
4	Roof	Zinc Aluminium coated roofing with insulation				
5	Doors	Fire proof steel with panic latches	Fire proof steel with panic latches	Fire proof steel with panic latches	Aluminium	Aluminium
6	Windows	Aluminium with 6mm clear wired glazed shutters with curtain and solar lamination	Aluminium with 6mm clear wired glazed shutters with curtain and solar lamination	Pressure relief walls	Aluminium with 6mm clear wired glass shutters with curtain solar lamination	Aluminium with 6mm clear wire glass shutters with curtain solar lamination
7	Furniture and fittings	Appropriate table, 4 chairs			1 table, 3 chairs, 1 cupboard	Racks
8	AC & Ventilation	AC	AC	AC	AC	Ceiling fans

Note: Furniture and fittings shall be provided as per the above table or as shown in the drawings.

Item	Description	Battery room	132/220 kV GIS room	Rest room	Toilet	Veranda
1	Floor	Tiled		Tiled	Tiled	Tiled
2	Walls	Anti acidic/alkaline painted	Emulsion painted	Emulsion painted	Tiled	Emulsion painted
3	Ceiling	Concrete	Concrete	Concrete	Concrete	Concrete
4	Roof	Zinc Aluminium coated roofing with insulation				
5	Doors	Fire proof steel with panic latches	Fire proof steel with panic latches	Aluminium	Aluminium/PVC	Aluminium
6	Windows	Aluminium with 6mm clear wired glass shutters with curtain solar lamination	Pressure relief walls	Aluminium with 6mm clear glass shutters with curtain solar lamination	Aluminium with glazed shutters	Aluminium with 6mm clear wired glass shutters with curtain
7	Furniture and fittings	Eye washer with shower tray Distilled water plant wash basing		With curtain dining table 4 chairs	Commode, cistern wash basin shower Mirror & all accessories (Imported fittings)	4 plants
8	AC & Ventilation	Exhaust ventilating system with ducting	AC	Ceiling fans	Exhaust fans	

Note: Furniture and fittings shall be provided as per the above table or as shown in the drawings.

### 13.1.12.1 Site office

All the work of site work shall comply with ICTAD Specifications for Building Works.

Site office shall be either temporary or permanent as requested in scope of work. Contractor shall provide all services, fittings and shall maintain up to the date of handing over the project.

This site office shall be erected immediately as the Contractor commences operations on the site in a position as directed by the Engineer outside the chain link fence.

The permanent site office shall be as per the given drawing. The office shall be provided all the services water, electricity, air conditioning and telephone facilities to the satisfaction of the Engineer. Toilets shall be draining to a suitably sized septic tank with overflow to an enclosed soak away. The office building shall have a damp-proof floor and

be provided a roof. It is to have opening windows fitted with sunblind. The office and toilet facilities and all services shall be provided and maintained to the Engineer's satisfaction. The services and maintenance shall be provided until the taking over date of the work., and all the equipment for pantry as requested by the Engineer.

Finishes shall be as follows

Item	Description	Office room	Conference Room	Pantry	Toilet	Veranda
1	Floor	Tiled	Tiled	Tiled	Tiled	Tiled
2	Walls	Emulsion painted	Emulsion painted	Emulsion painted Tiled	Tiled	Emulsion painted
3	Ceiling	As per the approval of Engineer				
4	Roof	Zinc Aluminium coated roofing with insulation				
5	Doors	Aluminium/ Glazed	Aluminium/ Glazed	Aluminium/ Glazed	Aluminium	Aluminium/ Glazed
6	Windows	Aluminium/ Glazed	Aluminium/ Glazed	Aluminium/ Glazed	Aluminium/ Glazed	Aluminium/ Glazed
7	Furniture & Fittings	Conference table 6 chairs	Conference table 6 chairs, two executive, two cupboards	Pantry cupboard with kitchen sink dining table 4 chairs and all necessary equipment's and appliances.	Commode, cistern wash basin shower mirror & other accessories	
8	AC & ventilation	AC & Ceiling fans	AC & Ceiling fans	Ceiling Fan		

Note: Furniture and fittings shall be provided as per the above table or as shown in the drawings.

The temporary site office shall comprise of one 15m<sup>2</sup> Office Room with a Table and Two Chairs, One file cupboard and one complete Toilet. The Contractor shall provide staff for cleaning and for general duties in the Engineer's site offices.



### 13.1.12.2 Temporary Works (Stores, access, contractors offices etc)

The Contractor's site office stores for all the substations shall be temporary structure locate outside the chain link fence area. The contractor should demolish it and clear the site as directed by the Engineer.

Any temporary approach or access roads, Drainages or any other temporary structure required by the contractor for the successful completion of the work shall include under this item,

#### 13.1.12.3 House for Diesel Generator

Shall be masonry permanent structure.

#### 13.1.12.4 Shed for car parking

Shall be Zinc Aluminium coated roof supported on permanent steel or concrete structural framework. Shall have space to park three vehicles.

#### 13.1.12.5 Guard room & watch towers

Finishes shall be as follows.

Item	Description	Office room	Rest room	Toilet	Verandas	Pantry
1	Floor	Tiled	Tiled	Tiled	Tiled	Tiled
2	Walls	Emulsion painted	Emulsion painted	Tiled	Emulsion painted	Emulsion painted
3	Ceiling	As per the approval of Engineer				
4	Roof	Zinc Aluminium coated roofing with insulation				
5	Doors	Aluminium/ Glazed	Aluminium/ Glazed	Aluminium	Aluminium/ Glazed	Aluminium/ Glazed
6	Windows	Aluminium with glazed shutters	Aluminium with glazed shutters	Aluminium with glazed shutters	Aluminium with glazed shutters	Aluminium with glazed shutters
7	Furniture & Fittings	1 table, 3 chairs, 2 cupboards	Bunk bed, 1 cupboard	Commode, cistern wash basin shower mirror & other accessories		Pantry cupboard with kitchen sink dining table 3 chairs and all necessary equipment's and appliances.

8	AC ventilation	& Ceiling fans	Ceiling fans			Ceiling fans
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## 13.2 BUILDING SERVICES

### 13.2.1 Air Conditioning and Ventilating Services

This Section of the Works covers the supply, delivery, installation, commissioning and setting to work of the air conditioning and ventilating systems for all the substation buildings.

#### 13.2.1.1 Contractors responsibilities

Drawings showing the proposals for all air conditioning and ventilating installations shall be submitted with Bids. These drawings shall be listed in the appropriate schedule.

Schedules giving technical details and particulars of all air conditioning and ventilating plant must be completed and submitted with Bid.

#### 13.2.1.2 Project requirement

Air Conditioners shall be in the form of direct expansion type air-cooled air-conditioners. The condensing units shall be remotely located outside the building. There shall be minimum of two set for each of the room. One set for duty and other set to stand by to ensure an uninterrupted service during 24 hours.

Individual extract fans with ducts shall be provided for the Battery Room. The Battery Room extract fan shall be corrosion resistant throughout, with a 2 mm PVC lining.

All civil works required associated with the air conditioning and ventilating installations shall be included within the supplying and installation of services.

#### 13.2.1.3 Design and liaison of work

##### External design conditions

The external conditions for the calculation of air conditioning duties and loads shall be: 34°C dB / 30.5°C WB

All items of plant and equipment shall operate without malfunction up to a maximum ambient condition of 45°C dB and a minimum ambient condition of 10°C dB with instances of 100% RH.

All plant and equipment installed externally, or which can be subjected to external conditions, shall be capable of withstanding without damage or deterioration the effects of solar radiation, rain, wind, dust, pollution from industrial plant, marine atmosphere, etc., appropriate to its location.

##### Internal design conditions

Air conditioning systems shall be in all air-conditioned areas within the following bands

Temperature 22 - 25°C

Humidity dB, 50-60 RH

Air conditioning systems shall be arranged to introduce a filtered fresh air quantity equivalent to 10% of the total air volume handled. Supply ventilation systems shall handle 100% fresh air. In all rooms, excluding battery rooms, systems shall maintain a positive pressure internally.

For mechanically ventilated areas air change rate shall be 10 m<sup>3</sup>/hour

All air conditioning and ventilation systems shall be designed for continuous operation. Plant shall be arranged to facilitate maintenance and future replacement of equipment. The Contractor shall calculate heat gains and losses under the specified conditions for each part of each building, taking into account solar radiation, thermal transmittance through roofs, walls, floors and windows, fresh air requirements, heat emission from installed electrical equipment and lighting, personnel, infiltration and any other sources. The Contractor shall be responsible for determining the heat transfer coefficients for all materials used in building construction. In the event of any change in materials, design or method of building construction, the Contractor shall at all times be responsible for rechecking the design of all systems to ensure that they are capable of meeting the specified design requirement.

### Internal Sound Levels

The maximum acceptable sound levels in all areas shall have a Noise Rating (NR) of 40 dB.

All plant and equipment shall be suitably selected and installed to ensure that the maximum sound levels stated are not exceeded and where necessary attenuating devices shall be incorporated.

### Vibration

All vibration producing equipment shall be isolated from the building by means of anti-vibration and noise isolators. The degree of isolation shall be such that noise criteria specified above are not exceeded and that no part of the building structure is subjected to vibration amplitudes in excess of the following values:

Frequency Vibration (Hertz)	2	5	10	20	50
Amplitude of Vibration (mm)					
(Mean to Peak)	0.2	0.07	0.02	0.008	0.002

### Standards

All air conditioning and ventilating equipment shall conform to British Standards 5720 and a certificate to prove such conformity shall be submitted.

### Design Calculations

The Contractor shall, submit to the Engineer copies of all his calculations forming the basis for the selection of all air conditioning and ventilating plant, plant selection details and full working drawings.

#### **13.2.1.4 Supplying and installation of services**

##### Manufacturers

Wherever possible all air conditioning and ventilating plants shall be selected from a single manufacturer's product range and origin. Where this is not possible, because of practical or technical constraints, then the number of different sources of origin shall be kept to minimum.

The Contractor shall provide, with his submission, comprehensive illustrated technical literature covering all plant and equipment offered. The air-conditioning sub contractor shall have a minimum of 5 years experience. Manufacturer shall have quality assurance certificate conforming to ISO 9001.

## Split System Air Conditioning Units

Air cooled condensing units shall have isolated electrical supply be of the fully packaged type requiring only site connection of refrigerant pipe work, isolated electrical supply and input from the control system. Casings shall be of heavy gauge galvanised steel, weatherproofed with special corrosion resistant primer and finished in durable baked on enamel paint of a light reflective colour. Compressors used in the air-cooled condensing units shall be fully hermetically sealed complete with suitable control and protective devices. Coils shall be suitable for direct expansion refrigerant, manufactured from seamless copper tube mechanically expanded on to copper or aluminium plate fins. Condenser fans shall be of the axial flow type with weatherproof permanently lubricated bearings.

Internal fan coil units shall consist of centrifugal supply fan, motor, cooling coil, electric heater battery, condensate drain pan assembly, filter and insulated cabinet with supply air head.

Refrigerant suction and liquid lines to be insulated as specified below. Condensate drain lines shall be supplied and shall be suitably insulated where they pass through the building interior areas. They shall be arranged to discharge into land drains.

### Thermal Insulation

All thermal insulation works shall be carried out in accordance with BS 5970 or equivalent international standard. Thermal insulation materials and finishes shall be proof against rotting, mould growth and vermin and shall be suitable for the ambient temperature and conditions prevailing. No insulation shall be applied to pipe work until hydraulic tests, approved by the Engineer, have been carried out. Vapour barrier finishes shall have permanence not exceeding 0.01 per ms and applied finishes shall comprise two coats of: one brush coat pigmented PVA solution meeting BS 476 Part 7, Class 1 fire resistance One layer of canvas wrapped around the glass fibber secured with PVA solution along a 50mm overlap. Two brushes applied coats of vinyl-based vapour barrier, which shall be of a suitable quality for weather proofing.

Alternatively a vapour barrier for pipe work may be applied in the form of a PVC sheet cladding system with moulded fittings for bends, tees, etc. PVC sheet shall be not less than 0.5 mm thick and of a light reflective colour.

Thermal insulation exposed to weather and solar effect shall be additionally protected against the weather by means of an external coating of aluminium sheet at least 0.8 mm thick pop-riveted into position and sealed at the joints with non-setting sealing compound. This aluminium shall be applied over the vapour barrier where applicable. Where insulated ducts or pipes enter a building through a roof or wall the insulation shall be included within the weathering flashing and sealed between the insulation and the flashing by means of non-setting sealing compound.

### Mechanical Ventilation

Supply air handling plants shall consist of a fresh air intake louver, insect screen, filter, fan and distribution duct work.

This Clause of the Specification deals with fans of all types as used in ventilation system of the packaged or site assembled type.

The performance of fans shall be determined by the manufacturer in accordance with the procedures specified in BS 848 Part 1 and Part 2 or equivalent for noise testing. Test certificates shall be submitted to the Engineer.

Fans shall be capable of the duties required to fulfil the specified design conditions. The Contractor shall calculate the system resistance using the frictional resistance of items of plant offered and/or duct runs as installed and shall be responsible for ensuring that the installed fan is capable of the required duty without exceeding the specified noise levels or driving capacity of the motor and drive.

#### Bifurcated fans

The exhaust air fans serving the battery room extract systems shall be axial flow, bifurcated type suitable for use in hazardous areas such as battery rooms, where corrosive fumes are expected.

The control equipment for the battery room fans shall provide means for electrically interlocking with the battery chargers referred to under another section of this specification to prevent the chargers from operating if the fans are not running. The control equipment shall be capable of providing a signal of "Fans running" by means of two sets of volt free changeover contacts.

Wiring between the fan control equipment and the point of interface with the battery chargers shall be provided.

#### Axial flow fans

Axial flow fans shall be of the single or multi-stage contra-rotating types. Axial fan casings shall be of continuously welded mild steel construction hot dip galvanised after manufacture. The lengths of the casing shall be sufficient to allow removal of the fan without disturbing the connected duct.

The motor/impeller assemblies shall be fixed to the casings by mild steel threaded rods shall be directly fixed to motor casings for motors up to 25 kW.

Axial flow fan impeller blades shall be of aerofoil section constructed from cast aluminium. The hub shall incorporate a cast iron blade fixing plate with keyed slots for the blades. The keyed slots shall permit the removal and readjustment of the blade pitch angle. The fan shall be clearly marked with the factory-set pitch angle and the maximum permissible pitch angle available with the motor fitted.

Axial fan casing of 150mm diameter and above shall be fitted with an airtight inspection door. The fan casings shall be fitted with galvanised mild steel mating flanges, bolted mounting feet, coned inlets and upstream guide vanes as necessary.

Electrical connections to the fan motor shall be taken to a terminal block enclosed in a terminal box welded to the fan casing. The terminal box lid shall be watertight.

#### Ceiling fans

Engineer's approval shall be obtained for the Make.

### **13.2.1.5 Control Equipment**

The Contractor shall provide full wiring diagrams of all control circuits giving terminal connection references.

The control system shall incorporate all necessary safety interlocks for the successful operation of the mechanical plant and systems. All the individual control elements shall be supplied by the same manufacturer.

Room sensors shall be enclosed in a robust high impact plastic housing not larger than 90mm x 90mm x 25mm. Control equipment for battery room fans shall be install in control room.

### **13.2.1.6 Electrical Control**

Each item of plant shall be provided with local isolation and/or emergency stop buttons to facilitate maintenance inspection and emergency operation.

In case of supply failure air conditioning plants shall be disconnected without switching directly after resuming power and shall be able to start manually.

### **13.2.1.7 Electrical Connections**

All electrical power, control cable and wiring associated with the ventilation system including all connections between control panels, valves, sensing probes and other like items shall be supplied, installed and connected up as a part of this Contract.

The cabling and wiring system shall comply with the requirements of the relevant clauses of this Specification and be either surface or flush installation appropriate.

Cables and wiring shall comprise either XLPE cables, laid in cleats or trenches, or PVC insulated wires drawn into galvanised conduits.

Final connections to electric motor and all other items of plant subject to movement and vibration shall comprise flexible cable in flexible conduit.

### **13.2.1.8 Maintenance**

The Contractor shall be responsible for the maintenance of all installations covered by this section of this Specification for the period stated in condition of contract

## **13.2.2 Fire Protection and Detection Facilities**

### **13.2.2.1 General**

Fire Safety Facilities shall be designed for maximum reliability and ease of maintenance. They shall be in accordance with IEEE 979 and the relevant codes for the National Fire Protection Association (NFPA).

The Bid shall be based upon the Standards named in this Specification. The Contractor may propose equipment in accordance with other relevant published standards, as optional alternatives. The Contractor shall submit copies of such alternative Standards with his proposal.

### **13.2.2.2 Design and liaison of the work**

Design proposed for fire protections shall be approved by the Sri Lanka fire Brigades.

#### **BULK HEADS FOR CABLES and PIPES**

Penetrations of electrical cables in fire resistant walls or ceilings shall be properly shut with an approved bulk head.

Only fire resistant, asbestos and mineral fibre free mortar shall be used as sealing material.

Except for cable penetrations which must be gas- and/or water-tight, approved cable transit systems may be proposed and installed.

During construction works and for temporary use only, cable penetrations may be shut with non-combustible, flexible and approved fire resistant pillows.

At penetrations of non-combustible pipes through fire resistant walls or ceilings, the remaining space between the pipes and the openings in the walls or ceilings shall be properly shut with an approved pipe seal.

Only fire resistant, asbestos and mineral fibre free mortar shall be used as sealing material.

At penetrations of combustible pipes in fire resistant walls or ceilings, approved bulk heads for pipes shall be installed.

The remaining space between the pipes and the openings in the walls or ceilings shall be smoke-tight shut with non-combustible material.

### **13.2.2.3 Fire Protection Coating for Cables**

Electrical cables located in floors and escape routes or in covered trenches, vertical shafts, raised floors, suspended ceilings or any other areas with a mass of electrical cables, such cables as well as their trays and supports shall be coated with an approved fire retardant coating.

Fire protection of the coating shall be performed by an intumescent action.

The coating shall be non-hygroscopic, non-aging and remaining flexible for easy removal of individual cables.

Tests regarding electrical de-rating, short circuit threshold, aging and termite resistivity shall be certified.

The coating shall be applied as wet material and the finish surface shall be dry and smooth.

### **13.2.2.4 Fire Detection and Fire Alarm System**

A centralised electronic fire detection and fire alarm system shall be designed, installed and commissioned with all necessary equipment, accessories and cabling in accordance with VDE 0833, DIN 14675 and V.d.S.-Form 2095 standards, latest edition.

A complete system shall be provided with all components required for automatic operation.

The main functions of the system shall be as follows:

- The actuation of any fire detection device shall be audible and visible displayed on a central fire alarm control panel and audible alarms shall be initiated throughout the building.
- The system shall differ whether the alarm was initiated by an automatic detection device or by a manual fire alarm station.
- Audible alarms may be silenced by pushing a silence button on the central fire alarm control panel. Any subsequent actuation of a detection device shall again sound the audible alarms.
- Fire doors, fire dampers, if any, air handling units or any other equipment or devices shall be released or shut down as required.
- Short circuit, wire break or any other system troubles shall be indicated on the central fire alarm control panel.

After restoration of the alarm detection device to its normal condition, the system shall be returned to normal stand-by condition.

Should the system require any separate workstation on PC basis for central system supervision, programming or configuration, it shall be installed on the control room floor level.

The scope shall also include complete installations with operator desk, printer, operator chair, etc. according to the manufacturers' standard.

The fire detection and fire alarm system shall mainly consist of the following equipment.

#### **13.2.2.5 Fire Alarm Panel**

A reliable central fire alarm control panel shall be supplied including all necessary electronic cards and equipment to receive, operate, supervise and display all detection and alarm installations and to release and initiate all other functions as described above.

Additional potential free contacts shall be provided for connections to other general alarm or event recorder and security or indication systems.

All detection devices shall be individually addressable and displayable.

Actuation of any detection and release device shall be displayed and/or printed by a data recorder.

The central fire alarm control panel shall be made of modular construction using solid state IC-components in a self-standing frame with openable glass front cover.

The central fire alarm control panel shall be designed for 230 V AC primary power and 24 V DC operating power for detection and alarm circuits.

Back-up batteries with an automatic charger and charging supervision shall be installed inside the panel frame.

The batteries shall be maintenance free, gas tight and dry fit types with power supply sized for 24-hours system operation and adequate reserve power for sounding audible and visible alarm devices at the end of this period for at least 5 (five) minutes.

The central fire alarm control panel shall be located in the entrance hall of the building.

In any case, common signals for fire alarm and system troubles shall be audible and visible displayed in the control room.

A visible alarm device outside the entrance hall shall be activated if an alarm occurs

#### **13.2.2.6 Manual Fire Alarm Stations**

Manual fire alarm stations shall be of the break glass push button operated type and individual addressable and displayable on the central fire alarm control panel if activated.

The boxes shall be painted red with white or black lettering in the local language and in English.

When operating the manual station, the pushed button shall remain down and the alarm contacts closed until the station is reset by opening the front, replacing the break-glass and closing the front again.

Inside the building, manual fire alarm stations shall be located on floors and at building exits following the normal exit paths.

#### **13.2.2.7 Automatic Fire Detectors**

Automatic detectors shall be of the fixed temperature and/or rate-of-rise heat detectors, optical smoke and/or ionization smoke detectors and ultraviolet and/or infrared flame detectors, subject to approval.

Rate-of-rise heat detectors shall be designed for a sensibility of 5°C/min temperature rise and a fixed initiation temperature of +57°C, +/-3°C.



For smoke detection, preferably only optical smoke detectors shall be installed instead of ionization type detectors.

Ionization smoke detectors, if any, shall be of the dual chamber type, with a radioactivity radiation of less than 1.0 micro-Curie.

Each automatic detector shall be addressable.

Actuation of any detector shall be displayed individually on the central fire alarm control panel.

Each automatic detector shall have a continuous condition supervision by using pulsing, trend evaluating or equivalent system techniques.

The detector spacing on smooth surfaces shall not exceed the distance recommended by the approving authorities.

In areas, where irregularities occur, the detector spacing shall be reduced in such a way as to obtain approved spacing.

Detectors generally shall be connected in groups to the central fire alarm control panel.

The number of detectors installed on any one signalling line shall be limited as recommended by the manufacturer.

Signalling lines shall be designed as loop connections, unless otherwise approved.

#### **13.2.2.8 Audible Alarms**

Sirens shall be installed inside the building.

They shall have a minimum noise level of 110 dB(A) at a distance of 1 m and shall be different in sound from other sirens, if any, installed in the area for other purposes.

The sirens must be audible throughout the entire building.

#### **13.2.2.9 Visible Alarms**

A red flash light shall be installed outside the building next to the main entrance.

The light shall have a frequency of 60 or 90 flashes per minute with an ample light energy.

#### **13.2.2.10 Cabling**

Signalling and release lines shall be marked as "fire alarm cable" and be laid in conduits.

Minimum wire size shall be 0.8 mm.

Further requirements for cabling and wiring as specified under the relevant chapters for Electrical Works shall be considered.

#### **13.2.2.11 Fire Protection Equipment**

All fire protection equipment shall be of types approved and listed by recognised approval authorities, or approved by the Engineer.

Acceptable approval authorities include national standard organisations, official testing laboratories, testing laboratories of the fire insurers, licensed private testing laboratories with specialised experience of fire protection, and recognised marine classification societies.

The appliances shall comply with BS EN 3 or equivalent standard.

All apparatus shall be suitable for operation by one person alone and shall be easily recharged. The discharge shall be non-corrosive and free of chemicals prone to give off toxic gases when heated.

The Contract shall include supply and installation of all wall brackets and fittings.

#### Portable wall mounted extinguishers

Portable, wall mounted, hand held extinguishers shall be 5.5 kg pressurised control discharge CO<sub>2</sub> units.

(a) Construction and operation

The body of the extinguisher shall be seamless, welded or brazed as appropriate.

The extinguisher shall be capable of being released by means of a lever-operated valve provided with a safety pin.

Extinguishers shall be capable of controlled partial discharge.

(b) Marking

All extinguishers shall be painted and marked in accordance with BS EN 3 or equivalent standard. In addition, they shall be marked in the English language with clear instructions for use.

(c) Housings for portable fire extinguishers

Where extinguishers are provided in external positions or other areas where they may be subjected to the weather they shall be hung inside protective cabinets.

The protective cabinets shall be red in color and marked with the words "FIRE EXTINGUISHERS" in English, in white. The cabinet shall provide protection for rain and wind blown dust and have a pull off front cover allowing ease of access to the extinguisher.

(d) Mounting

Where extinguishers are provided internally they shall be wall mounted and attached in a manner affording quick release from the supporting bracket. They shall be installed so that the top of the extinguisher is not more than 1.5 meters above the floor. In no case shall the clearance between the bottom of the extinguisher and the floor is less than 0.1 meter. The extinguishers shall be positioned so that the instructions for operation face outwards.

#### Mobile trolley extinguishers

##### Dry Powder type

The extinguisher shall consist of a powder container to which shall be attached a cylinder of compressed inert gas for use as the propellant of the extinguishant. The powder shall be fed from the container to the discharge nozzle through a flexible hose. This equipment shall be mounted on a metal frame with wheels and handle to make it mobile and manoeuvrable.

The dry powder container shall be of steel construction and shall have been pressure tested to at least twice its operating pressure. The container shall hold 45 kg of multi-purpose dry powder of ABC rating.

The pressurising cylinder shall be externally attached to the powder container. The hose conducting the powder to the discharge nozzle shall be 10 meters long and made of braided synthetic flexible hose. The hose shall be permanently connected to the dry

powder container. The hose shall be stored in a manner allowing easy removal for use. The unit shall have at least two wheels which shall have rubber or synthetic tyres and a minimum overall diameter of 300 mm. The overall width of the unit shall not exceed 800 mm.

A single easily accessible valve shall be used to release the pressurising gas into the powder container. The nozzle shall control the discharge of the dry powder and shall be designed for controlled partial delivery. The unit shall be capable of discharging all the dry powder in at most 60 seconds.

The extinguishers shall be painted and marked in the English language with clear instructions for use, which shall include the words "NOT FOR USE ON ELECTRICAL FIRES".

Mobile fire extinguishers shall be protected from the prevailing climatic conditions, and shall be clearly visible and accessible.

### Signs

Electrical hazard warning signs in English shall be positioned each entry door. Smoke detectors shall be provided in all the rooms.

## **13.2.3 Lighting and Small Power Supply Work**

### **13.2.3.1 General**

The completed installations shall comply in all relevant respects with the Regulations issued by the Institution of Electrical Engineers (IEE) with the Codes of Practice issued by the Chartered Institutions of Building Services, or International Electrical Committees Standards, or with such other

### **13.2.3.2 Contractors Responsibilities**

The Contractor shall submit to the Engineer for approval copies of all his calculations forming the basis for the designs of the lighting and small power installation which shall be shown on the working drawings, also to be submitted for approval.

Any approval shall not, however, relieve the Contractor of his contractual responsibilities.

The Contractor shall enter into the schedules, a fixed sum for the complete design work and construction works under this section of the Specification and no price variation will be considered.

### **13.2.3.3 Project Requirement**

This section of the Specification includes for the lighting and small power installations in new buildings and for extensions to the interior, exterior and emergency lighting and diesel generator small power installations where appropriate.

All civil works associated with this section of the works shall be deemed to be included either as part of the main civil engineering works or as part of the works in this section. No additional payments will be made for such requirements.

The requirements of this section of the works are subjected to the Conditions and Specifications laid down in other sections and volumes of the Bidding Documents.

regulation that may be in force in Sri Lanka.

The lighting installations shall be designed to give the standard service illuminations set out in the schedule appended to this section. Control and relay room and office room shall have

the service illumination measured at 850 mm above finished floor level. All other areas shall have the service illumination measured at floor level.

The installations shall also meet the limiting glare index requirements as set out in the specified codes of practice. The schedule gives proposals for the types of lighting fittings to be used in the area, type of control to be employed, number of socket outlets and the types of mounting expected to be suitable for the respective areas. When 3 phase lighting installations are to be used, contactor switching controlled by pushbuttons located in the areas to be illuminated are preferred.

In all rooms and corridors having two entrances the lighting installation shall have two way switching, the switches / push buttons being located in appropriate positions adjacent to the entrances.

Emergency lighting shall be arranged to illuminate all stairways, exits and entrance and provide some illumination in operational areas.

### **13.2.3.4 Design and liaison of work**

#### Coding System

The Contractor shall when preparing drawings showing the respective designs use a code to identify each lighting fittings and socket outlet.

The code shall comprise letters and figures so compiled that the following information can be readily identified;

- (1) The lighting distribution board to which the fitting or socket outlet is connected.
- (2) If connected to the normal supplies or to the emergency DC supplies.
- (3) The circuit numbers and phase of the distribution board to which the fitting is connected.
- (4) The sequence of the fitting in a particular circuit.

#### Schedule of Design Requirements

Key to Abbreviations:

L	Single pole local switches
S1, S2, etc.	Socket outlet or fused spur circuits
PB	Push-button for remote control
TS	Time switch control
C	Ceiling mounted
W	Wall mounted
P	Pole or earth mast mounted
M	Recessed modular mounting
D	Suspended
F	Flush installation
S	Surface installation
A	Automatic on mains failure
PEC	Photoelectric cell control

MAN

Manual control

### 13.2.3.5 Supplying and installation of service

#### AC Distribution boards

Distribution board for substation supplies shall be of the single busbar, air insulated multi-cubicle or multi-box factory built assembly type, incorporating air break, manually operated MCCB units, suitable for installation in the substation building on a 400-230 V, three-phase, four-wire, 50 Hz system, having the neutral earthed through earthing transformer.

Unless otherwise specified, distribution boards shall be in accordance with IEC 60439 and to IEC 60947 and the degree of protection shall be not less than IP 41 to BSEN IEC60529 or better equivalent of the concerned standards.

Incoming supplies to all distribution boards shall be protected at the point of supply by MCCB. All distribution boards should be suitably rated for a prospective short circuit breaking capacity of 25 kA at 600 V.

Distribution boards shall each include three-phase busbars, one neutral busbar and an earth bar; all of high conductivity copper supported to withstand the normal and fault condition stresses.

The neutral busbars shall have a rating not less than 50% of that of the associated phase busbars. Distribution boards shall have a busbar rating not less than 100 Amperes.

Each distribution board shall consist of a fabricated steel busbar chamber having MCCB, in distribution boards and attached and mounted at a height convenient for the operator. The distribution board shall be of a type, which is readily extensible and suitable for use in a hot humid climate. Each circuit shall be clearly labelled to show the destination of the associated cable, the "ON" and "OFF" positions of the switches being clearly indicated.

Cubicle type (metal-enclosed type) distribution boards shall be so arranged that the cubicles housing individual control units are grouped to form a multi-tier arrangement and a further part shall where possible constitute a cabling and wiring chamber of ample dimensions in which terminal boards, cable boxes and cable seal plates shall be located.

The distribution boards shall be finished to the approval of the Engineer and painted Munsell Colour 5Y7/1.

Each MCCB unit shall be mounted on a metal panel and provided with a hinged metal door and key locked. The board shall be sufficiently rigid to be capable of being lifted by either crane or forklift without damage.

The MCCB shall have a quick make and quick break action independent of the speed at which the switch handle is operated and shall be entirely suitable for switching the inductive loads associated with motor circuits.

Fuses shall be of the HRC cartridge type for operation at a prospective fault level of 25 kA and conforming to BS 88, where applicable. The mountings of the fuses shall be such that they can be readily withdrawn and replaced whilst the associated busbars and circuits are live.

Incoming circuits at distribution boards shall not be provided with fuses for prevention of lack of phase.

MCCBs shall be of the high speed fault limiting, thermal/magnetic type to IEC, or BS 3871 or equivalent standard, with quick make and quick break trip free mechanisms, which prevent the breaker being held in against overloads or faults.

Tripping arrangements shall be such as to ensure simultaneous opening of all phases. MCCBs on the incoming circuits shall have facilities for locking in the "off" position.

The rupturing capacity of the MCCB shall not be less than that of the switchboard itself.

ACBs or MCCBs shall be provided on the incoming circuits at the respective Substation Services, main distribution boards. These circuit breakers shall be equipped with thermal device shall have an adjustable IDMT characteristic and the magnetic device an adjustable short time delay.

Earth metal of distribution boards shall be bonded and earthed to the main station earthing system.

Approved MCCB or title labels shall be fitted externally on the front cover of each switch or distribution board giving the function of each circuit. A non-fading printed list of circuits shall be provided on each sub distribution boards, stating the location of the equipment served, rating of the protective unit and the circuit loading. The lists shall be mounted on the inside of the cover door and shall be protected by an acrylic sheet slid into a frame over the circuit list, the list and cover to be easily removable to permit circuit modifications.

The distribution boards for building services shall be manufactured and tested in accordance with the latest standard and be capable of withstanding without injury the mechanical and electrical stresses set up by a fault equivalent to 25 kA at 600V for twice the period required to disconnect such on any circuit.

Each distribution board shall have a dust proof metal case of sheet steel with either a galvanised or enamelled finish to IP 41 with adequate ventilation. Thickness of steel plate shall be not less than 2 mm for panels larger than 1 metre square. The colour of the enamel finish shall match the color of other switchgear. The metal casing shall be provided with a number of knockouts or other approved form of cable entries corresponding to the circuit capacity of the distribution board and a suitable earth busbar. All unused openings including panel base shall be blanked off.

Distribution boards shall also meet the requirements of the appropriate sections of this clause.

Distribution boards for exterior use shall be galvanized and weatherproof to IP 54.

Distribution boards for use on direct current system shall be double pole types equipped with adequately rated fuses.

Mixed capacity board shall be employed and all contactors and control switches associated with the respective outgoing circuits shall be accommodated within the distribution boards.

### Cables

Cables designated PVC shall be polyvinyl insulated or polyvinyl insulated and sheathed types manufactured and tested to the requirements of BS 6004, 600/1000V grade or equivalent. Sheathed types shall be equipped with an earth continuity conductor.

Cables designated XLPE shall be cross-linked polyethylene insulated filled and polyethylene sheathed or polyvinyl chloride sheathed overall and be manufactured and tested in accordance with the requirements of IEC60189, 600/1000 V grade or equivalent. The outer sheath to be coloured black. Jute fillings will not be permitted.

Flexible type cable for pendant cords and final connections to fixed apparatus shall be butyl or silicone rubber insulated and sheathed manufactured and tested in accordance with the requirements or BS 6500, 300/500V or 300/300 V grade as applicable.

The conductor shall comprise multi-strand of 0.25 mm or more. The number of strands shall be not less than 30 and in all cases of a number suitable for the protection rating of the respective circuits.

All cables used for lighting and small power shall have copper conductors.

The Contractor shall select conductor sizes for the respective final circuits to meet the following conditions;

- (1) That the minimum conductor size for lighting circuits shall be 1.5 sq. mm and for socket outlets 2.5mm.<sup>2</sup>
- (2) That the size shall be adequate for the current to be carried as set out in the cable manufacturers' specification.

That the size is sufficient to keep the voltage drop in the phase and neutral conductors to the farthest lighting or power point, under normal full load conditions, to within the final circuit limit specified in the IEE Wiring Regulations. Diversity will not be allowed.

#### Cable termination

Termination's for XLPE cables shall comprise compression type clamps and bonding clamps to meet the requirements of BS 6121 or equivalent and shall be designed to secure and to provide electrical continuity between the conductor and the threaded fixing component of the clamps.

Earth bond terminal attachments shall be provided.

Termination for PVC insulated and rubber insulated cables shall comprise compression type clamps as specified for the terminations for XLPE cables mentioned above.

#### Sealing and drumming

Drums and sealing and drumming of XLPE and PVC cables shall generally meet the requirements of the relevant clauses in Section 8.

#### Cable trays

All tray systems shall be built up from a matching range of straights, bends, reducers, tees, supports etc. They shall be fabricated 1.2 mm mild steel perforated to between 25 % and 50 % of the total area. After fabrication the trays shall be hot dip galvanised.

Trays shall have upturned edges and be of a width suitable for the number of cables to be supported and shall be supplied with purpose-made galvanized steel brackets at intervals not exceeding 1200 mm with 2 bolts to each bracket suitable for mounting from the building structure.

#### Cable jointing

The Contractor shall be responsible for the sealing and jointing of all cables supplied and installed as part of this Section of the Contract. All jointing and terminations shall comply with the relevant clauses of Section 8.

#### Contactors

Contactors shall comply with BS 5454, IEC 518/1, IEC 518/1A or equivalent and shall be of the electrically held-in types contained in heavy gauge sheet steel case suitable for panel mounting. Each contactor shall be continuously rated and suitable for thirty inductive switching operations per hour and a utilization category of AC2.

### Switches and Push buttons

Switches shall be rated for 16 or 20 amps. and shall be single pole types and be provided with an earth terminal.

Switches for use in areas designated for surface installation shall be quick-make-quick-break fixed grid industrial types mounted in galvanized malleable iron boxes with protected dolly and arranged where necessary for multigang switching.

Switches for use in areas designated for flush installation shall be micro-break types fixed to white plastic cover plates and mounted in galvanized steel flush type boxes.

Two way and multigang variations shall be provided as appropriate.

Push-button switches shall either be flush or surface types contained in galvanized steel boxes and are single pole rated for 5 Amps. or more. Push buttons shall be made of non-hygroscopic material be non-swelling and so fitted as to avoid possibility of sticking.

The terminals for all switches shall be adequate to accommodate 2 conductors each 1.5 sq. mm in area.

### Lighting Fittings

Illustrations and/or samples of all lighting fittings, which the Contractor proposes to purchase, shall be submitted to the Engineer for approval before issuing any sub-orders.

Lighting fittings for interior and exterior use shall be manufactured and tested in accordance with the appropriate sections of BS 4533 or equivalent and together with all components shall be suitable for service and operation in the climate stated.

Each fitting shall be complete with all lamp holders, control gear, internal wiring, fused terminal block, earth terminal and reflectors or diffusers as specified. The design of each fitting shall be such as to minimize the effect of glare and such that the ingress of dust, flies and insects is prevented. Where open type fittings are used it shall be impossible for insects to become lodged therein.

The control gear for use with fluorescent lamps shall incorporate power factor and interference suppression capacitors. Chokes shall be impregnated and solidly filled with polyester resin or other approved high melting compound and shall be manufactured to restrict the third harmonic content to less than 25% of the uncorrected current value and shall be silent in operation.

Control gear for discharge lamps shall incorporate power factor correction and interference suppression capacitors.

Internal connections shall comprise stranded conductors not less than 0.75 esq. covered with heat resistant insulation to the requirements of BS 6500 or equivalent. All internal wiring shall be adequately cleated to the fitting casing with an approved form of cleat. The finish of fittings for interior use shall be impervious to deterioration by atmospheric reaction. Fittings for exterior use shall have a vitreous enamel, natural aluminum or galvanized finish according to the manufacture's standard product.

Fittings for housing tungsten lamps exceeding 150 watts rating shall be provided with an approved method of dissipating heat from the lamp cap and terminal housing.

Lamp holders as applicable shall be suitable for the lamp specified and comply with BS 5042.

Flood lighting fittings suitable for 250W high-pressure sodium lamps are preferred.



Lighting fittings shall be of the type description as generally set out in the schedule appended to this Section of the Specification. The type references used shall be repeated in the Schedule and on the drawings.

### Lamps

The Contract includes the supply and erection of all lamps and tubes necessary to complete the installation and these shall be included in the prices quoted for the supply and erection of fittings.

Fluorescent lamps shall be manufactured and tested in accordance with British Standards 1853; IEC 81 or equivalent shall be bi-pin types and shall be warm white colour.

Tungsten lamps shall be manufactured and tested in accordance with BSEN 60064 or equivalent and shall be bayonet cap for lamps up to and including 100 watts. Lamps rated for 150 watts and higher shall have Edison screw caps. Low wattage lamps used in exit signs and emergency lighting units may be small or miniature Edison screw.

Discharge lamps shall be manufactured and tested in accordance with British Standard 3677 or equivalent. Mercury vapour lamps shall be fluorescent types having a 10% red ratio colour correction, whenever used.

### Socket Outlets and Fused Spur Outlets

The Contract shall include suitably located; heavy duty, weatherproof three phase and neutral interlocked switched socket outlets and plugs for supplying the transformer oil filtration units. Ample single phase outlets shall be located in convenient positions, and at least one three phase and neutral, light duty outlet with plug shall be located in each relay room.

Each socket outlet shall comply with the requirements of the British Standard 1363 or equivalent and shall be the interlocked shuttered and switched types arranged for surface or flush mounting in single or multi gang units as appropriate.

Each fused spur outlet shall be equipped with double pole isolator, a fuse to British Standard 1362 or equivalent and where required front entry for flexible connection.

Each socket outlet and fused spur outlet shall be equipped with a galvanized metal box with earth terminal.

Each group of five socket outlets shall be provided with matching fused plug top.

All socket outlets for exterior use shall be galvanized and weatherproof and be equipped with screwed dustproof cap attached to the socket by means of a chain.

### Conduit and Fittings

Steel conduits shall be manufactured in accordance with BS 4568, Part 1 or equivalent, heavy gauge screwed and welded Class B and shall be galvanized, or an alternative price can be quoted for high impact heavy gauge PVC of similar dimensions.

Fittings for steel conduits shall be manufactured of good quality malleable cast iron and of small circular pattern to BS 4568, Part 2 or equivalent, with internally tapped spouts minimum length 21 mm threaded to the correct length at inter-sections tees, draw through and stop ends. All conducting shall be run so as to enable cables to be drawn in after erection. Sufficiently accessible junction boxes shall be provided for this purpose.

Conduit fittings of PVC shall be of normal impact strength manufactured to Class A as defined in BS 4607 part 1 and plain bore pattern suitable for a push-on compression type

joint and shall be sealed with a hard setting vinyl cement to prevent ingress of vermin, water, dust, etc.

Rigid PVC conduit shall be securely fastened with approved saddles at a maximum spacing of 450 mm and where necessary additional saddles may be provided to avoid sagging in the conduit. Where any straight section of rigid PVC conduit not embedded in concrete exceeds 3000 mm in length an approved expansion joint shall be provided for each 3000 mm or part thereof along the entire length of the straight section.

### Poles

Lighting poles shall be of tubular or polygon shaped steel with a base of sufficient section to house an inspection trap, lockable door, cable entry and terminations suitable for the incoming cables and the secondary cables feeding the light sources, all of which shall be supplied with the pole. All poles shall be suitable for burying to a depth of 1.5 m, shall be suitable for embedding in concrete and shall be adequate to withstand the local wind forces with a factor of safety of 2.5.

Steel poles shall be galvanized and covered with a bituminous base preservative to cover both the inside and outside of the pole.

### Interior Installations

Wiring for the lighting and socket outlet installations shall comprise PVC cables drawn into conduits attached to walls, structural or roof steelwork or ceilings as appropriate. All wiring shall be fixed in a mechanically protected position and with a clearance of not less than 130 mm from all other services, unless suitable protection is provided.

All fixings shall be of a type approved by the Engineer and all metal work used shall be galvanized. Fixings to structural steelwork shall be with purpose made brackets or clamps, the drilling of structural steelwork will not be permitted.

Cleats with two screw fixings shall be used for supporting conduits at not greater than 2-m intervals.

All switch boxes, socket outlet boxes and items of a similar type shall be fixed with two screws or bolts. Switches and push buttons for lighting circuits shall be mounted at 1,300 mm above finished floor level. Socket outlets shall be mounted 500 mm above finished floor level but those for use with workshop benches shall be mounted 150 mm clear of the bench working surface.

Lighting fittings shall be attached to ceilings, walls, trunking or roof steelwork or suspended there from as appropriate. Where fittings are to be suspended, rod type suspension units shall be employed.

Final connections to all suspended lighting fittings shall be with heat resistant flexible cable terminated in porcelain clad connectors in the ceiling or junction box which shall also terminate the main circuit cable. The cable length shall be such that the suspension unit supports the full weight of the lighting fittings.

Where recessed type lighting fittings are to be installed suspension units shall be used to prevent the weight of the fittings being applied to the suspended ceiling. It shall be possible to carry out maintenance from the underside of the fitting without disturbing the false ceiling.

To facilitate this need the final connection to each fitting shall be with heat resistant flexible cable from a plug in type ceiling rose mounted above the false ceiling.

All cables not contained within conduit shall be terminated with a cable hole sealing to the requirements of Section 8.

Where lighting fittings are mounted direct on walls or ceilings the main circuit cables may be connected into the fitting terminal block and where the fittings are mounted flush with the ceiling the final connection shall be taken through ceiling roses. Where terminal blocks do not exist within the lighting fitting flexible heat resistant cable shall be used connected to a separate junction box.

Earth continuity shall be maintained throughout the entire wiring installation with separate insulated earth continuity conductors of adequate cross-section ultimately connected to a common earth terminal at the respective distribution board.

Each and every trunking route shall be bonded across all joints with external copper bonding links supplied for the purpose.

### Exterior Installation

Switchyard floodlighting shall preferably be mounted on earth mast structures at a height of 11 meters above ground level and suitable access ladders shall be provided on the masts for maintenance of the lighting fittings. Where this is not feasible the floodlight fittings shall be mounted on poles also at a height of 11 meters above ground.

Roadway lighting shall comprise roadway lanterns mounted on poles at 5.5 meters above the finished road level. All exterior lighting shall be controlled by photoelectric cell.

Cables to exterior lighting shall be XLPE cables laid in concrete trenches or cleated to building structures or into steel conduits galvanized as appropriate to the route requirement. The cables shall be terminated at a cut out located at the base of each support. Wiring between the cut-out and the control gear or lantern shall be with PVC or PE multi-core cables run within poles or drawn into galvanized steel conduit attached to the supporting structure.

This exterior lighting will be supplied by a diesel generator set during emergency.

### Earthing and Bonding

All equipment being supplied under this Section shall be effectively bonded to ensure earth continuity throughout the system. Continuity may be provided by means of steel conduits but a separate earth continuity conductor shall be included with all wiring in conduits. No reliance shall be placed on metal to metal joints in conduits for each continuity. The earth continuity conductors shall as far as possible be in one continuous length to the furthest part of the installation from the controlling switchboard. The earth conductor shall connect all metal cases housing electrical equipment. The branches shall be connected to the main conductor by permanent exothermic fusion welded joints or crimped joints approved by the Engineer.

### Emergency Lighting

Emergency lighting shall be installed in the modified/new substation buildings.

The emergency lighting shall be divided into two parts.

One part shall have fittings installed in strategic locations including control room, relay room, battery room and auxiliary supply room to ensure safe evacuation of the buildings, and shall switch on automatically following a power failure. This part shall not be connected to the substation DC system, but shall have dedicated batteries and chargers.

The other part shall be supplied from the substation DC system and the lighting in each room shall be controlled by a switch located in that room. The illumination level shall be sufficient to enable an operator to undertake emergency inspection and switching duties.

At least two rechargeable hand lamps shall be installed at each substation. They shall normally rest on wall mounted brackets incorporating the chargers. Each lamp shall incorporate a small red light to facilitate location following a lighting failure.

### Schedule of Lighting Fittings and Sockets Outlets

Lighting fittings described in this Schedule shall also meet the general requirements of Clause 15.16 of this Specification.

- TYPE F1 Shall indicate a basic channel complete with control gear and lamp holders for one 40-watt fluorescent lamp, equipped with open-ended metal reflector having upward light slots.
- TYPE F2 Shall indicate a fitting, which shall comply generally with the description for Type F1 but be equipped for use with two 40-watt lamps.
- TYPE F3 Shall indicate a basic channel complete with control gear and lamp holder for one 40 watt fluorescent lamp, equipped with an opal sided diffuser having clear reeded bottom.
- TYPE F4 Shall indicate a fitting, which shall comply generally with the description for Type F3 but be equipped or use with two 40 watt lamps.
- TYPE F5 Shall indicate a dust-tight weatherproof and vapour resistant fitting, having a grey polyester fibre glass reinforced chassis containing the control gear and having lamp holders for one 40-watt fluorescent lamp. The fitting shall be complete with a vacuum formed acrylic diffuser, which is secured to the body with injection-moulded toggles and sealed with a neoprene gasket.
- TYPE F6 Shall indicate a recessed modular fitting suitable for mounting in a suspended ceiling and equipped with an Aluminium louver with Matt mirrors. The material of fixture shall be coated steel. The fitting is to be equipped with a pre-wired removable gear tray and adjusting facilities to enable levelling relative to the ceiling to be carried out after erection. The assembly is to be complete with control gear and lamp holders for one 40-watt fluorescent lamp.
- TYPE F7 Shall indicate a fitting, which shall comply generally with the description for Type F6 but be equipped for use with two 40-watt lamps.
- TYPE F8 Shall indicate a surface mounted fitting suitable for mounting in a suspended ceiling and equipped with an Aluminium louver with Matt mirrors. The material of fixture shall be coated steel. The fitting is to be equipped with a pre-wired removable gear tray. The assembly is to be complete with control gear and lamp holders for one 40-watt fluorescent lamp.
- TYPE F9 Shall indicate a fitting, which shall comply generally with the description for Type F8 but be equipped for use with two 40-watt lamps.
- TYPE E1 Shall indicate a vitreous enamelled or spun aluminium over-lamp depressives type reflector with cover glass, cool wiring box and lamp

- holder all suitable for use with 60-watt tungsten lamp. Finished colour grey outside and white inside.
- TYPE E2 Shall indicate a non-sustained emergency lighting unit comprising an enamel metal base with flame retardant PVC mounted body equipped with white opalescent styrene moulded diffuser with the word "EXIT" in English added to the face in green characters.
- TYPE E3 Shall indicate a square shaped all insulated dust tight weatherproof fitting constructed of moulded polypropylene suitable for use with a 60-watt tungsten lamp.
- TYPE E4 Shall indicate a semi-recessed fitting housing a 100-watt lamp and equipped with crystallite glass diffuser.
- TYPE S1 Shall indicate 13 Amps one gang flush mounted switched socket outlet.
- TYPE S2 Shall indicate 13 Amps one gang surface mounted switched socket outlet.
- TYPE S3 Shall indicate a bench mounted 4-gang unit of 13 Amps switched socket outlets.
- TYPE S5 Shall indicate a one gang 13 Amps fused spur unit.
- TYPE T1 Shall indicate a bulkhead type fitting having a body cast from corrosion resistant aluminium alloy with light control by means of a prismatic glass held firmly in position in a hinged glazing ring, complete with lamp holder for 100 watt lamp, terminal block suitable for looping conductors and provision for cable entries. Mounting lugs are to be arranged such that fixing screws do not penetrate the fitting interior.
- TYPE T2 Shall indicate a light fitting having a body and diffuser of polycarbonate, complete with internal reflector and porcelain lamp holder suitable for use with a 60 watt 230 volt lamp.
- TYPE M1 Shall indicate forward throw floodlight fitting having a body moulded from glass reinforced plastic (GRP) with light control by means of a dimpled anodised aluminium reflector and 4 mm toughened soda lime flat glass secured in GRP frame hinged and secured to the main body by four stainless steel bolts, complete with lamp holder for 250 watt lamp and mounting bracket stirrup type.
- TYPE J1 Shall indicate a street lighting fitting of the post top pattern comprising an opal prosper bowl with special spigot cap for mounting directly to the top of the pole and having a spun aluminium canopy held on to the bowl by means of stainless steel spring clips and neoprene sealing ring. The fitting shall be finished vitreous enamel white and suitable for one 250watt lamp with the control gear preferably mounted in the fitting.

## Lighting and Small Power Supply Works

### Schedule of Requirements

Location	Service Illumination		Type of fittings		Type of fixing	Type of control & switch	Socket outlet	Type of installation
	Lux	Index	Main	Emer				
Switchgear, Room	500	19	F6/F7	E4	C	L/A	S1,	F
Battery room	150	-	F5	E4	C	L	S1,	F
Office room All buildings	500	16	F6/F7	E4	C	L/A	S1	F
Auxiliary room	300	16	F8/F9	E4	C	L/A	S1	F
Control, Protection and relay room	300	16	F8/F9	E4	C	L/A	S1	F
Store all buildings	150	-	F1	-	C	L	S2,	S
Corridors all buildings	200	-	F6/F7	E4	C	L/A	S1	F
Exits	-	-	-	E2	W	A	-	F
Switchyard area (covered by Chain link fence)	10	-	M1	-	P	PEC/ MAN	-	-
Road ways	10	-	J1	-	P	PEC/ MAN	-	-
Buildings exterior	10	-	T1	-	W	PEC/ MAN	-	-
Rest room	300	16	F8/F9	-	C	L	S1, 2	F
Toilet all buildings	150	-	T2	-	C	L	-	F
Guard room	300		F6/F7	E4	C	L/A	S1	F
Watchtowers	150		F3		C	PEC/M AN	S1	
Security lighting	10		J1/M1		P	PEC/M AN		

Note:

1) The above small power outlets are those required over and above the requirements for fans, air conditioners, water heaters etc. specified here in.

### Clocks

Dry battery cell type clocks shall be installed in the control and protection room in new control building. The clock shall be 600 mm in diameter or digital type approved by the Engineer.

### Maintenance

The Contractor shall be responsible for maintenance of the installations comprising this section of the Specification for the agreed period as set out in this Specification.

## **13.2.4 Gantry Crane**

### **13.2.4.1 General**

This article covers the supply and installation of the crane to be installed inside the 220 KV SWG Hall, including all operating machinery, structural steel, runway rails and all other parts and accessories required for their safe and efficient operation.

The crane shall be used for erection work and for normal maintenance, repair and overhaul purposes of the installed equipment.

The cranes shall be of the overhead travel ling type, of all welded, box-girder or I-beam construction, electrically operated through pendant type control switches as well as infrared remote control switches from anywhere in the operation area. All parts of the crane shall be in accordance with DIN, VDE, BS, EN, IWS, FEM, or other Standards and/or accident prevention rules approved by CEB.

Each crane must include facilities for inspection and repair.

Structural steel to be used for manufacturing the crane and its steel structures shall be at least grade S 275JO, according to BS/DIN EN 10027-1.

### **13.2.4.2 Crane**

A permanent service platform (designed for a live load of 3000 N/m<sup>2</sup> and 600/920 mm wide) running the full length of the bridge shall be fitted to provide access to all the crane equipment, as well as to all high bay lights, detectors, AC ducts, diffusers, etc. The clearance between the platform and any overhead structure or roof beam shall be 2.0 meters. The platform shall be fitted with a safety rail, but shall not obstruct the access to the hoist travel mechanism or crane lift. Local control facilities and access to the platform shall also be provided.

Access to the platform shall be provided through a movable structure (scaffolding) made from aluminium or other approved materials and shall include a safe/caged side ladder, stabilizers, castors, bridge beams, horizontal braces, diagonal braces, etc. and a platform with handrail and toe boards (min. 1.2 x 2.0 m) with a safe working load of 1500 N/m<sup>2</sup>.

The Bidder/Contractor shall define the height and the span of the crane in accordance with the building and equipment design. The crane shall be capable of lifting the maximum erection/maintenance weight, however, at least five tons. A safety factor of 1.5 shall be applied to the maximum working load in all stress calculations and also shock loading in case the design and construction of the crane is performed different from DIN. The lifting equipment shall be classified as "Class 2 m" according to DIN 15020 for lifting capacities up to 15 tons, representing an average daily working time of 2 to 4 hours and an equal share of small, medium and heavy loads (normal duty).

Sufficient guards shall be provided to protect personnel from accidents caused by moving mechanism etc. The guards shall be removable for inspection and maintenance.

Each crane shall have a crab with one hoist and an auxiliary hoist of one (1) ton capacity.

The bridge girder shall be securely jointed to the end carriages, to prevent cross racking. It shall not under any circumstances be possible for the crane to fall from the gantry in the event of derailment. The rails shall be fitted with steel stops. The end carriages shall be equipped with flexible rubber/plastic bumpers on each side of the bridge girder and gantry girder.

The holding of hoist load shall be affected by means of an automatic spring-set, electrically or electro-hydraulically released double shoe type brake. The brake capacity shall not be less than 200% of the torque caused by the maximum nominal load of the crane. The brake must prevent the load from descending until the hoist motor is energized for operation in lowering sense.

Bridge and trolley drives shall be equipped with a spring-set, electrically (solenoid or electro-hydraulic) released shoe or disc brake, whose capacity shall be at least 1.5 times the full operating torque of the drive. The brake shall be applied when the motor control switch or main power switch is in the "off" position and/or when the current fails on any one phase. The braking action shall be gradual and the brake shall become fully effective after a certain time lag.

The gears and bevel wheels shall be completely covered with oil-tight gearboxes made of cast steel or welded steel plates. All gearing shall be made of steel and shall be machine cut.

The driving wheels shall be interconnected to avoid cross-racking in any case.

Double-flanged, spherical cast iron travelling wheels of suitable diameter and width for running on the runway rail profile shall be fitted, and it must be possible to readily withdraw the wheels for inspection or repair. The wheel bearings shall easily be renewable.

The crane including the girders, bridge, trolley, platform and railing etc. shall be protected against corrosion subject to the approval of CEB. The final coat shall be painted "yellow".

All the equipment, materials, accessories, calculation for steel structure, as well as arrangement drawings and wiring diagrams etc. shall be submitted for approval. Warning light/horn for crane movement and floodlights shall also be included in the submittal. The submittal shall also include all clearances, height, span, motor, quality/grade of steel, etc.

The crane motor shall be provided with class F insulation, 50°C ambient temperature rating and step less (electronic) speed control and the speed shall preferably be in the following range:

- Long travel: 5 m/min to 25 m/min
- Cross travel: 4 m/min to 20 m/min
- Hoist : 1 m/min to 05 m/min.

All the cables shall be clearly identified by suitable tags or durable markings to facilitate the installation and maintenance.

The crane shall be equipped with following enclosed limit switches of the closed-circuit type:

- Block-actuated switch to limit upward travel of the load blocks



- Double switches to limit travel of bridge in both directions; first switch to reduce the speed before the end position is reached, second switch to stop at the end position
- Double switches to limit travel of trolleys in both directions; first switch to reduce the speed before the end position is reached, second switch to stop at the end position
- Lower hoist limit switch
- Over Load limit switch
- Warning horn and warning lights to indicate crane movement
- Limit switches shall be arranged to reset by reversing the associated controller. Only the motion being limited shall be affected by tripping the limit switch
- Light fittings providing an illumination level below the crane hook of at least 300 lux at floor level. These fittings shall be adequately ventilated to prevent overheating and shall be accessible from the crane platform. Wire guards or wired glass visors with safety chains shall be provided as protection.

The complete crane, including the hoist, trolley, bridge, cross girder, platform etc. shall be manufactured, fabricated, assembled and tested at the manufacturer's work place by CEB, Engineer and/or an approved independent inspection authority according to the approved factory test procedures.

Design, structural calculation, drawings, detailing and welding details, etc. of longitudinal/gantry girder and rails shall be done by the manufacturer of crane. However, an approved local Agent may fabricate and install the longitudinal/ gantry girder and rail and carry out the testing and commissioning of the crane.

The Bidder/Contractor shall supply suitable load plates on both sides giving details of the lifting capacity of the cranes. These nameplates shall be clearly visible and shall be written in English.

The Bidder/Contractor shall provide the following certificates:

- Factory test certificate of the crane
- Material test certificate for the hook
- Basic crack examination/test certificate for the hook
- Ultrasonic test certificate for the hook
- Material/mill certificates for the main beam, rail, girder
- Welding test certificate
- Material and load test certificate for the wire rope.

The following accessories shall be supplied with the crane:

- 2 nos. steel wire rope sling (50% of SWL)
- 2 nos. polyester/nylon sling (50% of SWL)
- 2 nos. polyester/nylon sling (75% of SWL)
- 3 nos. screw pin "D" shackle (25, 50, 100% SWL)
- 1 no. hook safety catch
- 1 no. safety harness

- 1 no. lockable storage cabinet for above

### **13.2.4.3 Testing and inspection**

#### **Site Tests**

After erection at site, functional and load tests shall be carried out according to approved site test procedures in the presence of CEB, as well as the approved Independent Inspection Authority. The test load at approved speeds shall be 120% of the nominal load and 150% of the nominal load under static conditions.

The Crane Test shall include the levelling and alignment of crane equipment, girders and rail, paint thickness check, load test, over load test, deflection test, limit switch test, movement check, speed measurement, ampere measurement, Insulation resistant measurement, visual inspection dimensional check, operation of controllers, warning light, flood light, horn, certificates and documents.

The levelling and alignment check of longitudinal/gantry girder and rail shall be done at site only, before the installation of crane at site. The longitudinal movement/measurement of Crane shall be done at site only.

### **13.2.5 Closed Circuit Television Equipment**

#### **13.2.5.1 General**

The Closed Circuit TV system is intended to monitoring indoor/outdoor equipments/panels and surveillance to the substation from the local site or from a central control center. At the main control center, control console with all required monitoring/control equipment shall be used to perform the monitoring task by the control engineers.

The video/control signals shall use the fiber optical transmission system for transmitting the signal up to the main control center.

The CCTV shall mainly comprise but not limited to:

- Cameras at specified rooms/areas of the substation.
- Control/monitoring equipment at the control room of substation.
- Speech facility between the control unit, various cameras with in the site and the main control center.
- Control and Monitoring Equipment at the main control center, guard room and control room of the site location.
- Night vision capability of the cameras.
- Motion sensing facility for the cameras used for surveillance purpose.

The interface between the CCTV system and the communication media shall be added in the general description.

The required equipment shall have been already working successfully in industrial environment such as power utilities. Therefore it shall be suitable for reliable operation in harsh environment with electromagnetic interference. Domestic-type CCTV equipment will not be accepted. Open communication protocol shall be provided for camera and DVR of the CCTV system in order to use similar components of different manufacturers.

The equipment provider should have an agent to support for maintenance.

### 13.2.5.2 Closed Circuit Television Equipment/System Design

The CCTV equipment shall be of solid state technique and of a proven design. Special attention shall be paid to high reliability of the system under the severe electromagnetic interference as well as to easy maintenance.

The system shall include a master station, which will be responsible for the primary control of the CCTV system, besides at least two local control units at each individual site. The CCTV system shall provide the capability of concurrent and independent control of camera stations from both the master and the local control. Access from the master station shall have priority over access locally from a site.

The master station shall have the following capabilities

- Control of the pan, tilt and zoom function of all camera stations within the CCTV system. The master station shall be equipped with one camera controller module for all sites.
- Control of the video signal presented to the backbone transmission system at any site. This will require selection of a minimum between a video signals combined images from all cameras at the site or a video signal from a selected single camera.
- At least two video monitors (minimum 17 inch) shall be provided, both allowing single and multiple camera images.
- A digital recorder, with Ethernet LAN interface shall be provided, equipped with sufficient storage capacity to allow at least 72 hours recording of the camera images received from all stations.
- The recorder shall allow simultaneous encoding, recording and multi-screen viewing. Play back shall support 4, 9 and 16 multi-screen modes. Facilities for menu driven search and retrieval shall be provided.
- Additional recording capability shall be provided for archiving recorded video information, from the digital recorder to a permanent storage media (optical disk).
- Multiplexer and controller equipment to provide all the above mentioned functions, locally as well as remotely.
- Hardware and software shall be provided at the master station for a graphical user interface management system to allow configuration of the CCTV system.
- The CCTV control and monitoring equipment at the main control center shall be provided such as to enable operation on network basis, i.e., the control facility shall be expandable to cater for a large number of the remote sites. The number of remote sites to be monitored shall be agreed by the CEB. Any software/administration programs to achieve this task shall be provided. The system shall provide all relevant management and configuration tools.
- A laptop computer shall be provided, complete with all required interface equipment, suitable applications and operating system, to allow local configuration of CCTV surveillance system equipment at other stations.

The CCTV system at remote stations shall have the following capabilities

- Multiplexer and controller equipment to provide;

- ✓ Control of all individual camera functions (both automatic & manual) like pan, tilt and zoom should be capable remotely.
  - ✓ Ability to combine the images derived from the local cameras in to a single video signal and to interface with the SDH (Synchronous Digital Hierarchy) equipment, to allow transmission via the backbone network.
  - ✓ An interface port and required hardware to allow system configuration.
  - ✓ Should be able to give the priority sequence among slave control centers equipment to access cameras.
- The camera (PTZ video camera) controllers shall be of keyboard style with an integrated joystick.
  - Colored video monitors should be at least 17 inch size.
  - The video cameras shall be switched by means of selector pushbuttons from the control panel. The selected camera shall be indicated by illumination of the respective pushbutton, and the pictures shall simultaneously appear on the monitor screen. All cameras shall be kept in stand-by operation to avoid time delay when switched to any monitor.
  - The controller unit shall have a minimum capacity of 16 preset sequences for each camera to be stored and initiated. It shall be possible to input and store these sequences both locally and remotely from the control center.
  - The CCTV system controller shall be fed by the 230 V AC mains and shall be able to control all cameras under the scope of this specification and two more future cameras.
  - The node multiplexer shall multiplex input signals from multiple cameras to a single output video signal for local monitoring and/or for remote transmission. Multiplexed camera images shall include the camera station identification and time stamp.
  - A duplex audio facility between the controller and each of the cameras shall be provided.
  - Video and audio interface cabling between the controllers and cameras, and associated power supply arrangements shall be provided.
  - The coaxial cable carrying the video/audio and control signals should be of very low attenuation and shall be connected to the camera, monitors and other electronic equipment by means of plugs and sockets. In addition, if applicable, using of fiber optic cables, as transmission media for video and audio signals, instead of coaxial cable may also be considered.
  - Cable correction amplifiers (if deemed necessary) are to be installed near to the monitor. These amplifiers have to be installed if the distance between camera and monitor is too long for good reception of the picture. The exact position of the cameras in the respective buildings shall be decided upon later, depending on the equipment installed to give the best overall view for supervision purposes.
  - Cameras and zoom lens assembly including housing, sun shield and integrated facilities for cleaning suited to the operating environments.

## Cameras

Cameras shall include:

- 1/2" format interline transfer CCD;
- 480 line horizontal resolution;
- video output signal shall be 1V p-p PAL-B;
- video signal to noise ratio (luminance) shall be not less than 50 dB;
- backlight compensation;
- automatic gain control;
- automatic white balance tracking over the range of light conditions between bright daylight and night-time lighting;
- electronic light control (CCD iris) from 0.1 to 20 ms;
- operation to provide a clear image under minimum illumination of 5 lux;

Lenses

Camera lenses shall meet the following minimum requirements:

- variable focal length lenses shall be an electrically controlled motorised zoom configuration;
- lenses shall be compatible with the cameras, that is 1/2" format or larger;
- magnification factor of the lenses shall be sufficient such that a 1.8 m object located at the most distant point within the surveillance range of the camera station shall occupy at least 30% of the vertical height of the monitor;
- the zoom function shall be compatible with the controller;

Camera Housing

The camera and lens at each camera station shall be enclosed within an outdoor camera housing which shall meet the following requirements.

- suitable for outdoor all-weather operation with a protection rating of IP65 or better;
- fully compatible with pan/tilt assembly;
- equipped with sunshield;
- equipped with cleaning facilities (e.g. blower, etc). Glass surfaces of camera housings shall be provided with a polyester film protective coating and the housing assembly shall include mounting for accommodation of cleaning materials;
- provide suitable access to allow for camera adjustment and service by authorised personnel equipped with appropriate equipment to override security facilities;
- rugged design including suitable protective and security measures to prevent tampering, malicious damage or theft.

Pan Tilt Assembly

Pan and tilt assemblies shall meet the following requirements.

- suitable for outdoor all-weather operation with a protection rating of IP65 or better;
- panning range shall not be less than 340°;

- tilt range shall be suitable to meet video surveillance area requirements and shall provide for elevation range not less than +10° to -90° referred to the horizontal plane;
- panning speed shall be variable with a maximum speed not less than 45° degrees per second, and shall be sufficient to ensure that lenses (at minimum focal length) are capable of traversing the complete azimuth range of the camera station surveillance zone within 5 seconds;
- tilt speed shall be variable with a maximum speed not less than 10° per second, and shall be sufficient to ensure that lenses are capable of traversing the maximum elevation range within the surveillance zone of the camera station within 5 seconds;
- provide independent limit switches for pan and tilt which shall be externally hand adjustable;
- the rated duty cycle shall not be less than 50% over a 30 minute period at ambient temperatures up to 60°C;
- robust heavy duty construction designed for a long service life with minimum maintenance, including:
  - all shafts shall be stainless steel;
  - all metal gear construction;
  - bearings shall be heavy duty;
  - life-time lubrication for bearings and gear trains;
  - gear backlash and drift shall be less than 0.25°;
  - Braking operation shall be virtually instantaneous such that pan and tile motion ceases immediately the control function ceases with no discernible overrun.

The pan/tilt assembly, mount and the supporting structure shall be sufficiently rigid to ensure that the lateral and vertical image movement, with camera lenses at maximum focal length, does not exceed 10% of the field of view under any conditions that may reasonably be expected at the site.

### 13.2.5.3 Testing and Inspection

The tests for the CCTV equipment/system shall be mainly on visual and functional basis and shall include Factory and Site tests:

#### Factory Tests

##### Type Tests

Evidence shall be given to prove that the proposed CCTV equipment under this specification has been subjected to all insulation and EMC type tests at an internationally recognized testing station.

The Bidder/Contractor shall supply certified copies of type test certificates covering the proposed CCTV equipment. If required at the discretion of CEB, the manufacturer shall arrange further type test to be carried out in his premises or other places subject to the approval of CEB. The type test certificate shall be issued by an internationally recognized laboratory.

Type Tests shall be performed comprising as a minimum the following tests:

- a) Mechanical/Material Characteristics:

- Insulation of wires (2 kV AC)
- Image Quality/storage capacity.

#### Sample Tests

Sample Tests shall be performed, comprising as a minimum the following tests:

- Visual checks
- Wiring and labeling

#### Routine Tests

Routine Tests shall be performed on the complete equipment, comprising as a minimum the following tests:

- Visual checks
- Functional checks
- Measurement of video SNR
- Verification of image quality/storage capacity
- Checking other features, which are inherited by the system.

#### Site Tests

Site tests shall be performed, comprising as a minimum the following tests:

- Installation Checks.
- Wiring, Termination and Earthing.
- Checking of the System Functions.
- Checking of the communication links via the Main and Standby routes.

The Bidder / Contractor shall carry out and supply the test equipment for the above tests. The supplier shall ensure that their equipment is suitable for these tests and advise whether any further site tests are considered necessary prior to commissioning.

**CHAPTER 14 –OTHER SERVICES AND TRAINING**

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## CHAPTER 14- OTHER SERVICES AND TRAINING

### 14.1 OTHER SERVICES

#### 14.1.1 Transport

The Contractor shall provide, maintain, and keep available at all times, the transport for the exclusive use of the Engineer and the Employer's officers engaged in the project. In the event of unavoidably due repairs or overhaul, the contractor shall provide equivalent substitute.

The specification for the vehicles shall be as follows for the contract.

- a) Cars with engine capacity of 1500 cc petrol engine, four door, 4 passenger capacity with air conditioning, CD/radio and all other standard fittings and safety facilities such as seat belts, head rests, SRS air bags for front passenger/driver, height adjustable seat for driver, power mirrors, and ABS brakes with EBD.
- b) Off Road four wheel drive (double cab) with engine capacity of 2800cc or less (not less than 2400cc) diesel engine, four door, 4 passenger capacity with air conditioning, CD/radio and all other standard fittings and safety facilities such as seat belts, head rests, SRS air bags for front passenger/driver, height adjustable seat for driver, power mirrors, and ABS brakes with EBD.
- c) Two wheel drive (double cab/van) with engine capacity of 2500cc or less (not less than 2300cc) diesel engine, four door, 4 passenger capacity with air conditioning, CD/radio and all other standard fittings and safety facilities such as seat belts, head rests, SRS air bags for front passenger/driver, height adjustable seat for driver, power mirrors, and ABS brakes with EBD.

All vehicles should be new when supplied and shall be registered under the Employers name.

One month after the taking over certificate is issued the vehicles shall be handed over to the employer. They shall be in sound technical condition with new tires, including spares and complete set of tools. All damages shall be repaired and full technical service performed all to the satisfaction of the Engineer.

The contract rates for transport of the Engineer's personnel shall include for each vehicle the fixed cost of the vehicle; comprehensive all inclusive, insurance, registration, license plates, fuel oils, lubricants, repairs, maintenance and the provision of one full time competent driver and all other costs and charges not specifically mentioned but which may be incurred during running and keeping of the vehicles throughout the contract.

The employer shall have an option to request more vehicles against the same rate if it becomes necessary.

The contractor not later than two months from the contract commencement date shall provide the vehicles as above.

The vehicle shall be made available full use during the period of contract working hours are 7.00 to 18.00 hours from Monday to Saturday. The vehicle should be available on Sundays or after 18.00 hour if necessary.

#### **14.1.2 Engineers Living Accommodation**

The Contractor shall provide and maintain living accommodation for the Engineers and Employers supervision staff at the locations as requested in the Scope of Works. The location of housing shall be to the approval of the Employer/ Engineer.

The accommodation may be provided in rented houses/flats. Where the Contractor proposes to rent accommodation, the location, furnishing, fittings and other facilities shall be subject to inspection and approval by the Engineer. It shall have separate bed rooms with attached bathrooms and each bed room will accommodate maximum number of two persons. The accommodation should have sufficient parking space with driver's accommodation.

Contractor shall provide staff for cleaning and for general duties in the Engineer's living accommodation.

All accommodation shall be weather proof, equipped with electricity, land line telephone facility, water, and connected to sewerage system and supplied at no additional cost.

### **14.2 TRAINING**

The Employer may request to provide training under single module or multiple modules as stated in the scope of works.

The Contractor shall arrange product training on new switchgear, substation automation system, protection relays, and communication equipments. The training shall take place during the factory assembling of the switchgear and other equipment ordered.

The training shall contain the theoretical and practical (hands-on-training is preferred) sessions. During the training the trainees shall be able to view/ work-on at least the assembling, final adjustments and factory testing/inspection.

The Employer's Representative shall approve the contractor's proposal for the training program. The duration of the training program shall be manufactures standard training module duration for the particular training module.

The full cost of the above training including course fee, foreign accommodation and food, air fare, transport and etc. shall be borne by the contractor

The content of each training module should be as follows.

#### **14.2.1 Training Module No 1: Outdoor 220kV Switchgears**

- Erection and installation procedure of all offered HV switchgear
- Testing and commissioning of Circuit Breakers
- Maintenance practices of above equipment recommended by the manufactures (Adjustments to performed after new replacement of circuit breaker, disconnecter and earth switch)
- Hands on training on periodic adjustment required, and parts replacement procedure in circuit breaker mechanism
- Inspection and parts replacement procedure in the arcing chamber of SF6 circuit breaker

#### **14.2.2 Training Module No 2: Outdoor 132kV Switchgears**

- Erection and installation procedure of all offered HV switchgear

- Testing and commissioning of Circuit Breakers
- Maintenance practices of above equipment recommended by the manufactures (Adjustments to performed after new replacement of circuit breaker, disconnecter and earth switch)
- Hands on training on periodic adjustment required, and parts replacement procedure in circuit breaker mechanism
- Inspection and parts replacement procedure in the arcing chamber of SF6 circuit breaker

#### **14.2.3 Training Module No 3: 245 kV GIS Indoor Switchgear**

- Erection, installation, testing and commissioning of the GIS switchgear
- Hands on training on recommended gassing and degassing procedures
- Hands on training on periodic adjustment required and parts replacement procedures in Circuit Breaker, Earth Switch and disconnecter mechanisms. ( The complete O&M manuals of the offered GIS are to be provided during the program)
- Replacement procedure of entire circuit breaker mechanism in case of failures
- Procedure of access of cable conductors in case of HV cable testing
- Procedure of extension of switchgear bay to existing installation

#### **14.2.4 Training Module No 4: 145 kV GIS Indoor Switchgear**

- Erection, installation, testing and commissioning of the GIS switchgear
- Hands on training on recommended gassing and degassing procedures
- Hands on training on periodic adjustment required and parts replacement procedures in Circuit Breaker, Earth Switch and disconnecter mechanisms. ( The complete O&M manuals of the offered GIS are to be provided during the program)
- Replacement procedure of entire circuit breaker mechanism in case of failures
- Procedure of access of cable conductors in case of HV cable testing
- Procedure of extension of switchgear bay to existing installation

#### **14.2.5 Training Module No 5: 33 kV and 11kV GIS Indoor Switchgear**

- Erection, installation, testing and commissioning of the GIS switchgear
- Hands on training on recommended gassing and degassing procedures
- Hands on training on periodic adjustment required and parts replacement procedures in Circuit Breaker, Earth Switch and disconnecter mechanisms. ( The complete O&M manuals of the offered GIS are to be provided during the program)
- Replacement procedure of entire circuit breaker mechanism in case of failures
- Procedure of access of cable conductors in case of HV cable testing
- Procedure of extension of switchgear bay to existing installation

### 14.2.6 Training Module No 6: Substation Automation

Training for SAS should be conducted at the original manufacturing factory only for at least 15 days. Trainings organized at the factories of System Integrator partners in other countries will not be accepted. During training period following modules shall be covered with both theoretical lectures and hand on practical sessions. Printed and soft version of Training Manual which is covering following modules shall be given to each participants.

- IEC 61850 Substation Automation Systems Fundamentals
  - The basic functions for data acquisition, process supervision and process control
  - The approach of IEC 61850 with the split between data model and communication and the reason for this approach
  - The hierarchical, object oriented data model
  - All communication services
  - The mapping of the abstract data model on the stack both for non-time critical and time critical services.
  - The use of industrial Ethernet including the redundancies defined by IEC 61850.
  - The basic structure of the standard family IEC 61850.
  - Aware of the system configuration language (SCL) and the engineering process.
- Substation Automation System Software Operation
  - The main features and characteristics of the system software
  - The process used for SAS Software Human Machine Interface
  - Alarm signals and event lists
- Substation Automation System Software Maintenance
  - Troubleshooting the system, using the operation and maintenance manual
  - Replacement of defective IEDs and other components (station computer, gateway, switch, GPS clock) in the substation automation system
  - The safety rules and instructions to be observed when working on the equipment
  - Configure the replaced units by appropriate tools and downloading the relevant product and system configuration files
  - Identify possible cyber security features
  - Backup the whole system
  - Restoration of application software in the event of failures
- Substation Automation System Software Configuration
  - The system software and hardware concepts and the system basic configuration principles
  - Change parameters such as database objects, signal texts, measurement scaling and others
  - Create graphic displays e.g. single line diagrams, overview pictures, system overview picture
  - Create reports e.g. daily energy reports
  - Create specific command routines

- Setting up an IEC 61850 OPC server and its Data Acquisition client for sending the signals to the software database based on predefined scd-file and database
- Modify existing application programs
- IEC 61850 System Integration & Testing
  - Explain the IEC 61850 integration process using the system integration tool
  - Identify all important features of product integration into an SAS or 3rd party SA system
  - Perform the system integration task for a sample system by using Integrated Engineering Tool
  - Set the integrated and engineered system into operation (commissioning)
  - Troubleshoot IEC61850 communication by usage of the tool suite for system testing and debugging

#### 14.2.7 Training Module No 7: Protection

##### Training Module No 7A: Protection for Transmission Lines – Application & Design

The course shall be designed so that the participants acquire in-depth application knowledge for transmission lines that enable them to design protection application solutions in practice.

##### **Following objectives to be met,**

- Gain an overview about the general requirements and objectives of transmission line protection
- Explain the measurement principles and behaviours of the protection functions
- Study protection principles and evaluate the appropriate protection concepts
- Coordinate different protection functions and establish selective and graded schemes
- Calculate the settings of several protection functions
- Introduce different application scenarios.
- Specify and verify the suitability of instrument transformers for different line protection applications

##### **Lectures, designs, applications and calculation exercises shall be formulated to cover following modules**

- Introduction  
*Positioning of power devices in the power system, faults and disturbances, line parameters, protection functions overview etc.*
- Line protection functions  
*Line-distance, line-differential, Directional earth fault to detect high-resistance earth faults, autoreclosure, synchrocheck, telecommunications, power swing etc.*
- Calculation examples of protection settings
- Instrument transformer requirements
- Current transformer calculation example
- Conceptual solutions for different applications in transmission line protection  
*Short lines, medium lines, long lines, teed-lines, high-voltage cables, multi-terminal lines ...*

- Protection philosophies, protection principles, typical application arrangements, tripping methodology, autoreclosing
- IED selection for different applications (Double breaker schemes with two line CTs etc.)

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## **Training Module No 7B: Protection for Busbars, Circuit Breakers and Power Transformers – Application & Design**

The course shall be designed so that the participants acquire in-depth application knowledge for busbars, circuit breakers and transformers that enable them to design protection application solutions in practice.

### **Following objectives to be met,**

- Understand the internal busbar, breaker failure and end fault protection function
- Learn the development steps and implementation of a protection concept
- Understand how to prepare customer requirement into standard specifications
- Study protection principles and evaluate the appropriate protection concepts
- Design protection schemes for busbars, circuit breakers and transformers and select important protection functions
- Coordinate different protection and establish selective and graded schemes
- Calculate the settings of different protection functions
- Specify and verify instrument transformers
- Particular application cases

### **Lectures, designs, applications and calculation exercises shall be formulated to cover following modules**

- Introduction
  - Positioning of power devices in the power system, faults and disturbances, transformer and system parameters, protection functions overview etc.
- Busbar, breaker failure and end fault protection application and functions
- Transformer protection application and functions
  - Differential, thermal overload, restricted earth fault etc.
- Calculation examples of protection settings and CT parameters
- Current transformer requirements
- IED selection for different applications

## **Training Module No 7C: Demonstrations and Hands-On Training on Protection**

Demonstrations and hands on training shall be provided for the participants for a selected IED for each module discussed under chapters 14.2.7A and 14.2.7B. Those shall contain following modules. Each participant should be given a separate workstation equipped with IEDs and secondary injection test kits

### **- Hardware Configuration**

Hardware configuration including analog input modules, binary input modules and binary output modules. This shall include assigning analog modules for different protection functions considering following different applications.

- Line Protection with a double busbar scheme
- Line protection with an one and half scheme
- Transformer protection for 2 winding transformer with two REF functions
- Transformer protection for a 3 winding transformer with two REF functions
- Busbar Protection for double busbar scheme
- Busbar Protection for one and half breaker scheme

In addition, changing threshold values of binary inputs, changing properties of LEDs shall also be discussed.

- Parameter Setting  
Parameter setting for following all protection functions discussed in chapters 14.2.7A and 14.2.7B shall be demonstrated.
- Configuration of a single line diagram for bay controlling function
- Assigning Interlocking Logics
- Assigning Logics between Protection and Control Functions; Eg: Configuring synchronism check release for autoreclosing function
- Assigning Binary Inputs and Outputs to different protection and logical functions
- IEC 61850 Configuration
  - o Configuration of data sets
  - o Configuration of report control blocks
  - o Demonstration and hands-on training for participants with a IEC 61850 client
  - o Configuration of goose control blocks
  - o Demonstration and hands-on experience for participants of a GOOSE application with several IEDs
- Testing of different protection functions using a secondary injection test kit

#### **14.2.8 Training Module No 8: PLC Equipment**

- Functions of PLC equipment, coupling devices, line traps, PLC equipment architecture, analogue services, digital services, tele-protection applications, configuration software, equipment test and maintenance, equipment set up and programming.
- On the job training on trouble shooting, programming, operation and maintenance

#### **14.2.9 Training Module No 9: PABX Telephone System**

- PABX features and applications, understanding of Analogue and Digital subscriber lines and trunk lines and conference facility, programming & configuration with software, numbering systems
- On the job training on trouble shooting, programming, operation and maintenance

#### **14.2.10 Training Module No 10: Fiber Optic Multiplexer**

- Understanding of system interfaces/equipment, equipment configuration, digital cross connection, SDH/PDH applications, voice applications, data applications, LAN/WAN applications, IP applications, tele-protection applications, Synchronization, interface additions, downloading of embedded software management communication
- On the job training on trouble shooting, programming, operation and maintenance



#### 14.2.11 Training Module No 11: RTUs

- Understanding of RTU architecture and its functionality, hardware components, interfaces, configuration tools, adding analogue and digital signals and configurations of the RTU testing and trouble shooting
- Understanding communication protocols and testing of the system using protocol tester
- On the job training on trouble shooting, programming, operation and maintenance

#### 14.2.12 Training Module No 12: Gateway/SAS Interfacing for SCADA Transmission

- Understanding of the system architecture, Hardware and software concept, configuration of communication interface, implementation and modification of signals and commands, testing, trouble shooting and maintenance of the system
- Testing of the system using protocol tester
- On the job training on trouble shooting, programming, operation and maintenance

#### 14.2.13 Training Module No 13: Breaker Switched Capacitor Banks

- Methodology of selecting the correct reactor and design appropriate reactive power compensation to suit the specified network node.
- Familiarization on simulation studies to understand the interaction between capacitor banks and the network and designing of detuned or tuned harmonic filters/ capacitor banks based on above study.
- Familiarization workshop for all primary and secondary equipment supplied under Capacitor bay installation.
- The training period shall be 2 weeks and it shall be scheduled before submitting the Capacitor bank design for approval.

#### 14.2.14 Operators Training

- From commencement of erection until the taking over of the Work, the Contractor shall instruct those employees designated by CEB, who will subsequently be responsible for operation and maintenance of the equipment.
- An effective training program including proper classroom training for each equipment to cover equipment introduction shall be presented to ensure that, by the time any section of works is taken over, CEB personnel have been trained to operate the equipment and carry out maintenance of the works efficiently and safely.
- The training programme shall be carried out during erection, commissioning and warranty period, as follows:
  1. During Erection  
Training of CEB personnel for the erection, dismantling and adjustment of the equipment to be carried out during maintenance of the plant.
  2. During Commissioning  
Training of CEB personnel to operate the equipment.

### 3. During Warranty Period

Training of CEB personnel how to carry out maintenance of the plant with all necessary checking, adjustment and the use of testing results for the same. Training and Instructions shall be given in English and there shall be no constraints on the number of personnel taking part in on-site training programme. The full cost of the above training shall be borne by the Contractor.

#### 14.2.15 Training on Grid Substation Primary Equipment Handling

The training shall be carried out before commencement of construction works for Electrical Engineers and Electrical Superintendents for a period of 1 week including following modules;

- Erection and Installation of primary equipment including description of method statement for each primary equipment installation.
- Critical adjustment setting for each offered primary equipment.
- Gas filling procedure with required measuring instrument handling.
- Earthing arrangement for each HV equipment.
- Recommended pre commissioning tests, analysis, and acceptance of test results and usage of testing equipment's for each HV equipment.

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