# CEYLON ELECTRICITY BOARD
# SRI LANKA

INTERNATIONAL COMPETITIVE BIDDING (ICB)

# BID DOCUMENT

# FOR

# KELANITISSA GAS TURBINE PROJECT



## BID NO.: CEB/KGTP/PROC/01/Re

# VOLUME 3 of 5

April 2021

# BID DOCUMENT
# FOR
# KELANITISSA GAS TURBINE PROJECT

CEYLON ELECTRICITY BOARD



# Volume 3

# TECHNICAL SPECIFICATION

FOR

KELANITISSA GAS TURBINE PROJECT

BID NO: CEB/KGTP/PROC/01/Re

# Contents – Summary Description

# Volume 03

## TECHNICAL SPECIFICATION

**Section 1 – General Specification**

**Section 2 – Mechanical Specification**

**Section 3 – Electrical Specification**

**Section 4 – Control, Instrumentation and Communication System Requirements**

**Section 5 – Civil Requirements**

**Section 6 – Power Station Fire Detection and Protection System**

**Section 7 – Water Treatment Plant**

## Appendices

Appendix A: Colombo Metrological Data & Weather Parameters for Design

Appendix B: Diesel Characteristics (Fuel Specification)

Appendix D: Approval and Terms & Conditions imposed by CEA

Appendix E: Electrical and Control Drawings

Appendix F: Soil Investigation Reports

Appendix G: Site plan

Appendix H: 132kV Feeder energization sequence and cable/line network details

Appendix J: Proof of Ability

Appendix K: Signal list to SCADA system of NSCC

## Abbreviations

| | |
|---|---|
| ACB | Air circuit breaker |
| AGC | Automatic Governor Control |
| AIS | Air Insulated Switchgear |
| ANSI | American National Standards Institute |
| API | American petroleum Institute |
| ASME | American Society of Mechanical Engineers |
| ASTM | American Society for Testing and Materials |
| AVR | Automatic Voltage Regulation |
| BDS | Bid Data Sheet |
| BFP | Boiler feed water pump |
| BOP | Balance of plant |
| C&I | Control & Instrumentation |
| CAPEX | Capital operating expenditure |
| CCR | Central Control Room |
| CCTV | Closed Circuit Television |
| CD | Compact Disc |
| CEA | Central Environment Authority of Sri Lanka |
| CEB | Ceylon Electricity Board |
| CEMP | Construction Environmental Management plan |
| CEMS | Continuous emissions monitoring system |
| CFC | Chlorofluorocarbons |
| CI | Combine Inspection of Turbine |
| CIF | Cost, Insurance and Freight |
| CMMS | Computer maintenance management system |
| CNC | Computer Numerical Control |
| COD | Commercial Operation Date |
| CPM | Critical Path Method |
| CPM | Capacity price mechanism |
| CT | Current Transformer |
| CV | Calorific Value |
| CV | Curriculum Vitae |
| CW | Cooling or circulating water |
| dBA | Decibels |
| DC | Direct current |
| DCS | Distributed Control System |
| DFO | Distillate fuel oil |
| DGA | Dissolved gas analysis |
| DIN | Deutsches Institut für Normung |
| EAF | Equivalent Availability Factor |
| ECP | Electro-chlorination plant |

| | |
|---|---|
| ECR | Economic Continuous Rating |
| EDI | Electronic Data Interchange |
| EIA | Environmental Impact Assessment |
| EMP | Environmental Management Programme |
| EPC | Engineering, Procurement and Construction |
| EPZA | Export Processing Zone Authority |
| ESB | Electricity Supply Board |
| ESD | Emergency Shutdown |
| ESP | Electrostatic precipitators |
| FCA | Free Carrier |
| FIDIC | Fédération Internationale des Ingénieurs Conseils (International Federation of Consulting Engineers) |
| FOB | Free on Board |
| FSNL | Full Speed No-load |
| GCC | General Conditions of Contract |
| GIS | Gas Insulated Switchgear |
| GPS | Global positioning System |
| HAZOP | Hazard and Operability |
| FO | Heavy fuel oil |
| HGPI | Hot Gas Path Inspection of Turbine |
| HHV | Higher heating value |
| HMI | Human Machine Interface |
| HP | High pressure |
| HR | Heat rate |
| HU | Hazen Units |
| HV | High voltage |
| HVAC | Heating Ventilation Air Conditioning |
| Hz | Hertz |
| I/O | Input / Output |
| ICC | International Chamber of Commerce |
| I & C | Instrumentation and Control |
| ID | Induced draft |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| IFB | Invitation for Bids |
| IFO | Intermediate fuel oil |
| IP | Intermediate pressure |
| IPP | Independent Power Producer |
| IRR | Internal rate of return |
| ISDN | Integrated Services Digital Network |
| ISO | International standards organisation |
| ITB | Instructions to Bidders |
| KKS | Kraftwerk Kennzeichnungs System |
| LAD | Lanka Auto Diesel |
| LAN | Local Area network |

| | |
|---|---|
| LED | Light Emitting Diode |
| LLC | Lifetime Levelized Cost |
| LP | Low pressure |
| LSD | Low speed diesel |
| LV | Low voltage |
| MI | Major Inspection of Turbine |
| MCB | Miniature circuit breaker |
| MCC | Motor Control Centre |
| MCR | Maximum continuous rating |
| MOU | Memorandum of understanding |
| MSD | Medium speed diesel |
| MSG | Minimum stable generation |
| MVA | Mega volt ampere |
| MVAR | Mega volt ampere reactive |
| MW | Megawatt |
| NDT | Nondestructive testing |
| NOx | Nitrous Oxide |
| NSCC | National System Control Center |
| NTP | Notice to Proceed |
| O&M | Operations and maintenance |
| OCB | Oil circuit breaker |
| OEM | Original equipment manufacturer |
| OFAF | Oil forced air forced |
| ONAF | Oil natural air forced |
| ONAN | Oil natural air natural |
| OPC | OLE for Process Control (OLE - Object Linking and Embedding) |
| OPEX | Operating expenditure |
| OS | Operating System |
| P&ID | Piping and Instrumentation Diagram |
| PA | Public Address |
| PDF | Adobe Acrobat software file type. |
| PFD | Process Flow Diagram |
| PHA | Preliminary Hazard Analysis |
| PLC | Programmable Logic Controller |
| PPA | Power purchase agreement |
| ppm | parts per million |
| PS | Power station |
| RH | Relative Humidity |
| RHS | Rectangular Hollow Section |
| ROM | Read Only Memory |
| RTD | Resistance Temperature Detectors |
| RTU | Remote Terminal Unit |
| SBD | Standard Bidding Document |
| SCADA | Supervisory Control and Data Acquisition |

| | |
|---|---|
| SEM | Single electricity market |
| SF6 | Sulphur hexafluoride |
| SI | Systeme International d'Unites |
| SIL | Safety Integrity level |
| SIS | Safety Instrumented System |
| SLD | Single Line Diagram |
| SMP | System marginal price |
| SO2 | Sulphur Dioxide |
| SOE | Sequence of Events |
| SOx | Sulphur oxide |
| SR | Starting Reliability |
| Sub | Substation |
| SWG | Switchgear |
| SWMP | Soil and Water management Plan |
| TC | Thermo Couple |
| ToR | Terms of Reference |
| TS | Technical Specifications and Drawings |
| Tx | Transformer |
| UHF | Ultra-High Frequency |
| UPS | Uninterruptible power supply |
| US$ | American dollar |
| USB | Universal Serial Bus |
| VCV | Vertical Continuous Vulcanization |
| VDU | Visual Display Unit |
| VIGV | Variable Inlet Guide Vane |
| VoIP | Voice over Internet protocol |
| VT | Voltage transformers |
| WHO | World Health Organization |
| WTP | Water Treatment Plant |
| XLPE | Cross-Link Polyethylene |
| YTD | Year-to-date |

## Units

| Units | | Symbols | |
|---|---|---|---|
| bar | 1 bar = $10^5$ Pa (pressure) | CO | Carbon monoxide |
| BTU | British thermal unit (energy) | $CO_2$ | Carbon dioxide |
| cal | Calorie (energy) | N | Nitrogen |
| $^oC$ | Degree Centigrade (temperature) | NOx | Nitrogen oxides |
| h | Hour (time) | $O_2$ | Oxygen |
| Hz | Hertz (frequency) | pH | Scale of relative acidity |
| K | Kelvin (temperature) | $SO_2$ | Sulphur dioxide |
| kg | kilogram (mass) | SOx | Sulphur oxides |
| J | Joule (energy) | | |
| m | Meter (length) | | |
| $m^3$ | Cubic meters (volume) | | |
| $m^3/h$ | Cubic meters per hours (Flow rate) | | |
| MW | Active power | | |
| MWh | Active power energy | | |
| MVar | Reactive power | | |
| MVarh | Reactive power energy | | |
| N | Newton (force) | | |
| Pa | Pascal (pressure) | | |
| s | Second (time) | | |
| t | ton (weight) | | |
| V | Volt (electrical) | | |
| VA | Volt Ampere (Apparent power) | | |
| Var | Reactive Power | | |
| W | Watt (power) | | |
| Wh | Watt hour (energy) | | |
| y | Year (time) | | |
| µS/cm | Conductivity | | |

# TABLE OF CONTENTS

# 1 General Specification

## 1.1 General requirements

All equipment supplied shall meet the Specification and shall conform to current prudent industry power plant practice. Notwithstanding any requirement specified herein with regard to material, design or other matters, it shall be the Contractor's responsibility to supply equipment which shall be fit for the purpose and entirely satisfactory for all operating conditions.

The Plant shall be capable of withstanding without damage, undue heat, strain, vibration, noise, corrosion or other operating difficulties, all stresses which may be experienced during normal operation, cyclic load operation, part loading, over speed, sudden load swings and under all specified test conditions.

All materials, plant and other supplies to be incorporated in the works shall be new and of a standard proven design. The Contractor shall not propose nor provide equipment from any manufacturer, which the manufacturer proposes, for the duration of this Contract, to be superseded or outdated by a later generation of equipment. The Contractor shall not propose to provide equipment which is not in regular commercial use and service in installations of scope and magnitude similar to this contract or for which local support and/or services in Sri Lanka are not currently available.

The Works shall be designed so that no single fault of auxiliary plant shall cause the failure of any duty equipment. Bypasses shall be installed wherever possible so that instrumentation, equipment and critical control valves can be repaired on-line. All trip functions shall have redundancy.

All equipment and systems shall have sufficient margin to cater for equipment and system wear and tear and deterioration. The Contractor shall identify and justify all margins during engineering submission including margins for sizing/design of cooling water pumps, heat exchangers, cranes, Air conditioning & ventilation system, fire protection systems, transformer capacity, safety features, isolated phase bus capacity, generator breaker capacity, battery and UPS systems and the emergency/black start diesel generator.

All electrical and control & instrumentation (C&I) equipment (e.g., the 400V power center, motor control center, UPS and DC systems, DCS Controllers & Input / Output units, HMI & other engineering and workstations, and other PLCs etc.) shall be housed in dual air-conditioned rooms or cubicles.

The Works shall be designed so that, in the event of a Gas Turbine tripping, GT and its associated systems shall shutdown in a safe manner without damage to equipment. All equipment shall be designed to permit safe shutdown on loss of electrical power supply or on loss of control system. The detailed design of all buildings shall include consideration of energy efficiency. The architectural treatment shall be consistent with the overall site landscape plan.

### 1.1.1 Language

The English language shall be used in all documents and in all correspondence between the Contractor and the Employer, whenever anything is required under the terms of the Contract to be written, marked, printed or engraved. The English language shall be used except where otherwise provided in this Specification.

### 1.1.2 Departures from specification

No departures from the specification, except those shown in the Schedule of Departures approved by the Employer or subsequently approved in writing by the Employer shall be made. Further, this implies that the Contractor deemed to have agree to all the terms and condition of the bid except those mentioned in the Schedule of Departures.

## 1.2 Hardware and software

All hardware, software and firmware supplied including any embedded systems shall be insensitive to any date change such that no value for current date shall cause any interruption in operation. The Contractor shall certify that the complete Works are compliant. The Contractor shall provide any standard software, firmware, and operating system developed for and applicable to the control and monitoring systems being provided by the Contractor on this project. Such software shall be provided without any reservations as to its use by the Employer, except, if applicable that it be used in systems provided for this project.

The Contractor shall provide two sets of software backup, as applicable, in the form of CDs, ROM modules or other means of replacing or repairing damaged software. The software shall be completely documented by the Contractor.

The Contractor shall develop and provide any custom software needed to adapt or customize the control and monitoring systems being provided by the Contractor to perform the various tasks and provide the various functions required by this Specification. It is the intent of this Specification that such software development utilizes routines developed by the systems manufacturers to serve as a framework for such custom software development. Customized software shall be menu driven with multi-window capabilities to the maximum extent possible and shall utilize other guidance, routines to permit personnel not trained as programmers to conveniently alter or supplement the contents of the various routines. The reservations as to the use of custom software, and the backup and documentation for such software shall be as described for standard software.

Software licenses for unrestricted use by the Employer shall be provided for all systems supplied as part of the Works and shall apply to all software required for the operation, diagnostics and reconfiguration of these systems.

## 1.3 Dynamic Simulation Modelling

The system provided under the scope of work in combination with Turbine-Governor, Generator and Excitation system should be capable of simulating through the PSSE (Power System Simulator for Engineering) software tool in steady-state conditions as well as over timescales of a few second for its dynamic stability simulation and studies carried out by Transmission Division of CEB. An accurate Dynamic Simulation Model of each Gas Turbine unit delivered shall be provided and any other important considerations and parameters shall be presented with the model suggested by Contractor to comply the CEB future requirements.

It shall be the responsibility of the Contractor to validate the dynamic simulation models provided for each Gas Turbine unit at the testing and commissioning.

## 1.4 Access and maintenance

The Works shall be designed with provision for good maintenance access and for ease of operation and maintenance. All routine operation and maintenance activities shall be achievable from permanent work platforms with suitable access and safety devices (such as handrails, thermal insulation from hot parts, protection against electrical shocks, covers or guards for moving & rotating parts etc.).

It shall be possible to complete maintenance of redundant plant items or items not essential for maintaining continuous operation of the plant, (e.g., pumps & fans, RTD, thermocouples, sensors) without reducing output from full load. All such maintenance activities must be planned by the Contractor to be in accordance with safety requirements and applicable Laws and Standards and described in the maintenance manuals.

Access ways, walkways etc. shall be free from cable ways, conduits, pipework etc. which could cause tripping hazards or impede the normal progress of operations and maintenance staff around the Works.

## 1.5 Mechanical and Structural Works

### 1.5.1 General

All materials shall be new, the best of their respective kinds and of such as are usual and suitable for work of like character. All materials shall comply with the latest American Society for Testing and Materials (ASTM), unless otherwise specified or approved by the Employer.

All workmanship shall be of the highest class throughout to ensure smooth and vibration free operation under all possible operating conditions, and the design, dimensions and materials of all parts shall be such that the stresses to which they may be subjected shall not render them liable to distortion, undue wear, or damage under the most severe conditions encountered in service.

All parts shall conform to the dimensions shown on and shall be built in accordance with the approved drawings. All joints, datum surfaces, and matching components shall be machined and all castings shall be spot faced for nuts. All machined finish shall be shown on the approved drawings. All screws, bolts, studs and nuts and threads for pipes shall conform to the latest standards of the International Organization for Standardization (ISO) covering these components and shall conform to the standards for metric size. The Contractor shall use exclusively the standards and size system presented in his Bid Proposal and accepted and incorporated in the Contract.

### 1.5.2 Castings

All castings weighing 226.8 kg (500 pounds) or more shall have test coupons attached from which test specimens may be prepared. The number, size and location of the test coupons shall be to the approval of the Employer. Faulty material or materials found to be inferior to that specified shall be rejected and removed at once and shall not be used in any part of the Plant.

All castings shall be dense, sound and true to pattern, of workmanlike finish and of uniform quality and condition, free from blowholes, porosity, hard spots, shrinkage defects, cracks or other injurious defects, and shall be satisfactorily cleaned for their intended purpose.

All castings shall be checked for defects before final machining. Casting shall not be repaired, plugged, or welded without permission of the Employer. Such permission will be given only when the defects are small and do not adversely affect the strength, use or machinability of the castings. Excessive segregation of impurities or alloys at critical points in a casting will be cause for its rejection. The largest fillets compatible with the design shall be incorporated wherever a change in section occurs.

Surfaces which do not undergo machining and are exposed in the final installation shall be dressed to provide a satisfactory appearance so that they will not require surface smoothing at site prior to painting.

### 1.5.3 Forgings

The ingots from which the forgings are made shall be cast in metal molds, the workmanship shall be first class in every respect and the forgings shall be free from all defects affecting their strength and durability, including seams, pipes, flaws, cracks, scales, fins, porosity, hard spots, excessive nonmetallic inclusions and segregations.

The largest fillets compatible with the design shall be incorporated wherever a change in section occurs. All finished surfaces or forgings shall be smooth and free from tool marks.

The forging shall be clearly stamped with the heat number in such location as to be readily observed when the forging is assembled in a completed unit.

### 1.5.4 Walkways, Floor Plates, Ladders and Handrails

Adequate walkway, floor plates, ladders, and safety handrails and guards shall be provided on and around each unit, where necessary, to afford access to and protection from all moving and electrical parts. Such items shall be designed to facilitate easy removal to permit free access to the various parts of the Plant. Ladders whose height is more than 2 m shall be covered with the back guard.

Floor plate shall be of checkered or expanded metal type with an approved raised pattern and shall not be less than 4.5 mm in thickness. All edges of plate shall be planed and joints shall be cut so as to maintain continuity of pattern.

### 1.5.5 Machine Work

- **General**

All tolerances, allowances and gauges for metal fits between plain cylindrical parts shall conform to ANSI B4.1 (ISO 286) or other approved equivalent standards for the class of fit as shown or otherwise required. Sufficient machining stock shall be allowed on locating pads to ensure true surfaces of solid material. Bearing surfaces shall be true and exact to secure full contact. Journal and sliding surfaces shall be polished and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. Parts entering any machine shall be carefully and accurately machined. All drilled holes for bolts shall be accurately located and drilled from templates.

- **Finished Surfaces**

Surface finished shall be indicated on the Contractor's drawings and shall be in accordance with ANSI B46.1 or other approved equivalent. Compliance with specified surface will be determined by sense or feel and by visual inspection of the work compared to standard roughness specimens, in accordance with the provisions of the above stated standards.

- **Unfinished Surfaces**

So far as is practicable, all works shall be arranged to obtain proper machining of adjoining unfinished surfaces. When there is a large discrepancy between adjoining unfinished surfaces, they shall be chipped and ground smooth, or machined, to secure proper alignment. Unfinished surfaces shall be true to the lines and dimensions shown on the drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in an approved manner.

### 1.5.6 Pins and Pin Holes

Pin holes shall be bored to gauge, smooth and straight, and at right angles to the axis of the member. The boring shall be done after the member is securely fastened in position. Pins shall be of hardened and ground steel and positively held in position. Wheels or rollers for use in enclosures shall be mounted on removal pins and have self-lubricating bushings or self-aligning roller bearings and brass washers.

### 1.5.7 Balancing

All revolving parts shall be truly balanced both statically and dynamically so that when running at normal speeds and at any load up to the maximum, there shall be no excessive vibration due to lack of such balance and the Plant shall operate with the least possible amount of noise.

### 1.5.8 Small Bore Piping

Seamless stainless-steel pipes shall be used for all fuel oil and lube oil lines. Galvanized steel pipe or copper pipe shall be used for all air or gas lines. Stainless steel pipe shall be used for water lines.

All necessary studs, bolts, screws, nuts, washers, gaskets, packing, supports, etc., required in connection with the field assembly of the piping system, shall be supplied by the Contractor. All gaskets and packing shall be of approved material and of a type that has proved satisfactory for the service conditions, to which they will be subject.

All lines shall be sloped to allow drainage at the low point. Where a branch cannot be drained through fixtures, a drain valve shall be provided on an accessible location.

All piping shall be fitted and assembled to introduce the minimum of stress to the pipe, fittings and relevant structures, and the assembly shall conform to the best piping practice.

Pipe unions, flexible joints and dismantling flanges shall be fitted where necessary to facilitate installation or maintenance of equipment, as directed and approved by the Employer.

The Contractor shall supply and install all pipe hangers, brackets and supports required for support of piping, including drilling and caulking for expansion anchors and any work incidental to the setting of such embedded anchors or inserts in concrete.

Unless otherwise specified, pipe supports shall be spaced at 2-meter centers maximum for steel and 1-meter centers for copper. Piping hangers for copper pipe shall be copper-plated and of an approved type. Vertical runs shall be supported by means of pipe clamps or collars at each floor. Hangers and supports shall be painted. Pipe supports to be embedded in concrete shall be made of material, which will not deteriorate, weaken or cause damage to the pipe.

Pipes shall be uniformly painted and be provided with colour bands in the colour given for the marking of pipes according to DIN 2403 or equivalent. The flow direction shall be marked by black arrows.

### 1.5.9 Joint of Structural Members

All joints between each structural member shall be made by means of bolting or welding and designed in such a manner that all forces are transmitted by one of such method of connection as bolting or welding. No sharing of specific load by these types of connection shall be accepted.

When bearing type bolts are used, they shall be so proportioned that the unthreaded part of the bolts shall resist the load at the reamed holes of the materials together with washers having a minimum of 5 millimeters thick. For all sloping surfaces, beveled washers shall be provided. For high strength tensile bolt connections, lock nut and washers shall be provided.

All edges of plates to be welded shall have the edge prepared by machine or other approved methods so as to be suitable for the type of weld employed. Sheared edges of all stress carrying plates shall be flattened to at least 3 mm.

**1.5.10 Embedded Steelwork, Opening, etc.**

Unless otherwise specified, blockouts in the primary concrete, any foundation, wall and roof opening and covering, concrete floor filling in the foundations and walls, trench with floor plates for cables, and the second stage filling concrete into the blockouts, etc. shall be provided by the contractor.

The Contractor shall supply and install all anchors, fasteners Anchor bars, anchor pad plates, U-shaped hooks, embedded steelwork, covering where required, piping, conduits and sleeves associated with and required for the Plant being provided and installed under this Contract, except as otherwise provided in the Specifications and Drawings for Bids.

The foundation bolts, embedded steel parts, anchors, braces, post, supports, shims, etc., and all steel work as may be required for temporary or final support of anchorage of the Plant, shall be provided and installed by the Contractor as part of this Contract.

Structural steel supports and facilities for anchors shall be supplied and installed by the Contractor to prevent displacement or uplift of the embedded component due to buoyancy or external forces that may occur during placing concrete.

Any steel work which is to be set into the concrete foundations shall not be painted nor coated unless otherwise approved.

During installation of and concrete placement to all embedded steel pipes, the openings of each pipe shall be plugged by suitable covers which shall be removed after completion.

**1.5.11 Welding**

**1.5.12 General**

All welding shall be done either manually by the shielded metallic arc process or automatically by the shielded arc or submerged arc method. All welding shall conform to the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, with the specifications taking precedence.

The Contractor shall develop and submit a Welding Procedure Specification (WPS) for approval of the Employer. After the welding procedure has been approved, the Contractor shall record it on a special drawing which shall thereupon become one of the drawings of the Contract. Weld sizes and types shall be shown on all Contractor's drawings where welding is employed.

Non-Destructive Examination / Testing (NDT) such as radiographic or ultrasonic, or magna-flux or dye-penetrated inspection shall be carried out by the Contractor when required by the standards, these Specifications or the design criteria employed. All important welds which, in the opinion of the Employer, may be subject to the full stress induced in the adjacent plate, or which, in the opinion of the Employer, do not appear to conform to the welding standards, shall be non-destructively tested.

Suitable meters shall be provided to show the welding current and the arc voltage at all times during the welding operations, so as to control the designed welding heat input, etc. Unless otherwise specifically stated, welded parts requiring machine finished shall be completely welded before being finished.

All welds shall be made continuous. The minimum throat dimension of fillet welds shall be 4.5 mm.

Plates to be joined by welding shall be accurately cut to size and rolled by pressure to the proper curvature which shall be continuous from the edge. Flattening in the curvature along the edges with correction by blows will not be allowed. The dimensions and shape of the edges to be joined shall be such as to allow thorough fusion and complete penetration and the edges of plates shall be properly formed to accommodate the various welding conditions.

The surfaces of the plates for a distance of 25 mm from the edge to be welded shall be thoroughly cleaned of all rust, grease and scale, to bright metal.

The Contractor shall submit for approval a detailed Quality Plan for Welding and Fabrication which complies with the applicable Clauses and Elements of BS 5750/ISO 9000 series. It shall define the structure, welding and fabrication responsibilities, authority levels and internal/external interface arrangements of personnel.

The Contractor shall be responsible for ensuring that the final documentation and records

provide the necessary objective evidence that the quality required has been achieved. This shall include the results of inspections, tests, monitoring of work performance, material and welding identification and related data such as qualification of procedures and personnel. The Contractor shall appoint only qualified personnel with the necessary level of authority to ensure compliance with the requirements of this Specification.

### 1.5.13 Qualification of Welding Procedure

The technique of welding employed, the appearance and quality of the welds made and the methods used in correcting defective work, shall conform to the latest requirements of the Structural Welding Code-Steel ANSI / AWS D1.1, or other standard as proposed in the Bid Proposal and subsequently incorporated into the Contract.

The Contractor shall conduct the tests required to qualify the procedures and these shall be witnessed by Employer. Welding Procedure Specification (WPS) shall be submitted and approved and welding shall not commence until the appropriate procedure tests, WPS have been approved by the Employer. Existing pre-qualified procedures may be considered, subject to the submission to the Employer of full documents verified by an acceptable third party. If pre-qualified procedures are acceptable, the Employer reserves the option to re- qualify a representative number of them.

### 1.5.14 Qualification of Welders and Welding Operators

All welders and welding operators assigned to the Facilities shall have passed a qualification test within the preceding six (6) months, for welders and welding operators, in accordance with ANSI / AWS D1.1 or other approved equivalent standard. The Contractor shall furnish the Employer with certified copies of reports of the results of physical tests of specimens welded in the qualification tests. If, in the opinion of the Employer, the work of any welder at any time appears questionable, he shall be required to pass the appropriate re-qualification test. All costs of such qualification tests shall be borne by the Contractor.

All welding operators to be assigned to the work shall pass the qualification test for welding operators as specified in Section VIII, paragraph UW-29 and Section IX of the ASME, Boiler and Pressure Vessel Code.

### 1.5.15 Welding Electrodes

The welding electrodes shall conform to ANSI / AWS D1.1/D1-A5.3 low hydrogen type covering or another approved equivalent.

Stainless type weld metal, where used in the water passages for protection against pitting, etc., shall be of chromium nickel steel. The type, chemical composition and AWS number of welding rods for this purpose shall be approved by the Employer.

For daily requirement, all the welding electrodes shall be kept in bulk storage in a room or cupboard in which the temperature is maintained continuously between 350-400 $^0$C or higher if recommended by the manufacturer and it is necessary to maintain list of remaining stock at the oven. The Contractor shall have a drying oven for heating electrodes to highest temperature prior to use if required by the electrode manufacturer and also for drying of electrodes which have been returned for drying. The Employer may require the Contractor to provide smaller drying cabinets for intermediate storage for site work. Individual moisture proof canisters, preferably electrically heated, shall be provided for each welder.

The Contractor shall submit for the Employer's approval, a complete proposal of the method of storage and distribution of electrodes at the site. The proposal shall indicate a system of documentation which will ensure that proper discipline is maintained in the storage, issue and usage of electrodes.

### 1.5.16 Repair

If the workmanship is not satisfactory to the Employer, the welding shall be chipped out to sound metal, tested and repair welded, subject to approval of the Employer. The welding work contained such defect shall be inspected and tested all along the line by the same method used first as instructed by the Employer to his satisfaction.

### 1.5.17 Lubrication

Provision shall be made for lubricating all bearings, including ball and roller bearings, by a pressure gun system. All lubrication nipples shall be readily accessible.

Where accessibility to a bearing for lubricating purpose is difficult, in the opinion of the Employer, provision shall be made for remote lubrication or safe access to the lubrication point. Ball and roller bearing shall be packed with grease during initial assembly.

All bearings and gear cases shall be made grease and oil-tight and drip pans shall be provided where necessary to prevent excess oil or grease dripping to the floor or deck.

The oil and grease shall be of a type available in Sri Lanka as approved by the Employer and the specifications shall be mentioned in the Operating and Maintenance Instructions. The type available in Sri Lanka shall be investigated by the Contractor himself.

## 1.6 Protection, Cleaning and Painting

### 1.6.1 General

The painting of the Plant shall be executed a manner to satisfy the expected atmospheric conditions in the environs of the Project Site. The painting of the Plant shall include the preparation of the metal surfaces, paint application, protection and drying of the paint coatings, as well as the supplying of all tools, laborers and materials necessary for the entire painting work.

The Finish Color of all Plant shall be approved by the Employer. The Contractor shall Propose a Color Scheme for the Plant and shall submit the Painted Samples or Color Chips. A color chip shall be included with the approved painting specification for each type of finish. The color of all undercoats shall match the color of the finish coat.

Paint shall be marine grade paint manufactured by an internationally reputed manufacturer and shall be delivered in the manufacturer's sealed tins, stored under cover and used within the guaranteed term of validity and in accordance with the method recommended by the said paint manufacturer. Contractor shall propose the methodology for disposing expired paint at the site.

Upon making interfaces between the member firms forming the Contractor, inclusive of all subcontractor(s) and supplier(s) approved in advance, the experienced specialist designer of the Contractor shall prepare and submit the Unified Painting Specifications for approval of the Employer. The Unified Painting Specifications shall describe all Plant to be supplied under the Contract, and cover paint schedule, manufacturer's statement of the physical and performance characteristics for paint materials to be selected, and manufacturer's recommended procedures for the surface preparation, application, handling instructions, equipment, ambient conditions, mixing instructions, safety and storage instructions, etc. The procedures shall also include special requirements for in-situ treatment such as field repairs to the damaged coating and for the coating of field joints.

All parts which will ultimately be buried in concrete shall be cleaned and protected, before leaving the manufacturer's shop, by wash primer, zinc rich primer or other approved method by the Employer. Before being installed they shall be thoroughly de-scaled and cleaned of all rust and adherent matter.

All the paintings shall stand for ISO 12944 C5-I environmental conditions including galvanized items.

### 1.6.2 Surface Preparation

All oil, paraffin, grease and dirt shall be removed from the surfaces to be painted, by wiping the surfaces with a clean cloth dipped in mineral solvent. Following solvent cleaning, all weld spatter, slag, burrs, loose rust and mill scale and other foreign substances shall be removed preferably by shot or grit (or sand, if available at site)-blasting to "ISO 8501-1 Sa 2 1/2" or "Sa 2 1/2" of Swedish Standard SIS 055900 or SSPC-SP10 of Steel Structures Painting Council Manual Volume 2 (near white blast cleaning). Those mechanical components shall be to "ISO 8501-1 St 2 or St 3" or to equal grade. Special attention shall be given to cleaning of corners and converging angles. Blast cleaned surfaces showing plate surface defects such as scabs or sharp gouges shall be repaired in an approved manner prior to painting.

After cleaning, the surface shall be dusted off or blown off with compressed air free of detrimental oil and water. All surfaces to be painted shall be completed dry, clean and free from moisture just prior to and during painting. If rust forms or the surface become contaminated in the interval between cleaning and painting, re-cleaning to the same degree shall be required.

Proceed with blast cleaning only when the following time and relative humidity schedule for application of the first coat can be achieved and maintained:

| Relative Humidity | Time |
|---|---|
| 85% or above | Do Not Blast |
| 80 – 84% | 2 Hours |
| 70 – 79% | 4 Hours |
| 60 – 69% | 10 Hours |
| 50 – 59% | 12 Hours |
| 30 – 49% | 24 Hours |
| Under 30% | 1 Week |

### 1.6.3 Application Procedure

The application of protective coating shall be carried out at the Contractor's shop and/or a field shop at site, whenever possible. Painting work at installation / erection site is to be limited to touch-up coatings for the damaged areas and coatings for field welding portions.

If primer for the sake of in-situ painting after field welding with pre-heating procedure, is applied, primer shall be kept back more than 200 mm each from the field weld joint. Primer shall be finished immediately after NDT be completed.

All paint, when applied, shall provide a satisfactory film and a smooth even surface. Paint shall be thoroughly stirred, strained, and kept at the uniform consistency during application. Paint shall not be applied when the temperature of the metal or surrounding air is below 10°C and that of the metal is above 50°C, or when the humidity is above 85 percent, or when it threatens to rain before the painted coat gets dry. Each coat shall be protected during the initial curing period against the possibility of moisture condensation or contamination with foreign matter. All painting works shall be performed by airless spraying.

When the coating material is applied by spraying, suitable means shall be provided to prevent segregation during the coating operation. Free oil and moisture shall be removed from the air supply lines of all spraying equipment. Each coat shall be uniform and free from runs, sags and other imperfections. The time between successive coats shall be not less than the minimum nor more than the maximum re-coating time recommended by the paint manufacturer.

The paint shall be applied so that the thickness at any point is not less than that stipulated in the approved painting specification. Surfaces not required to be coated, but adjacent to surfaces which are to be cleaned and coated, shall be adequately protected during cleaning and coating. Repairs to damaged areas of the coating shall be carried out strictly in accordance with the approved painting specifications.

Because of the flammable and toxic nature of the coating materials, the Contractor shall take precautions to eliminate any health or safety hazard that may arise during the application of the coating. Smoking and welding shall be prohibited in the vicinity of the place whenever painting is in progress at open area.

Where steelwork is to be welded, only the primer shall continue over the weld area. Subsequent coats shall end not closer than 200 mm from the weld and completed after welding. The primer shall be such that no toxic fumes are given off during welding. Alternatively, approved temporary protection such as taping may be provided as an alternative to priming the weld areas. The edges of shop coats exposed on removal of the tape shall be treated in accordance with the manufacturer's instructions to ensure adhesion to coats applied at Site.

Painting shall be stopped off 75 mm from the edges of interface areas for high strength friction-grip bolts. Painting over and around such bolts shall be completed as specified after assembly.

All painted structures to be cut by torch or blade for fitting and welding purpose and all field – welds shall be prepared as specified in Swedish Standard SIS 055900.

### 1.6.4 Surfaces not to be Painted

Bronze, brass, machined parts surfaces of gear teeth, finished ferrous surfaces, surfaces in rolling or sliding contact after field assembly and hoist ropes, and manufactures' name plates shall not be painted. All corrosion resisting steel surfaces for bearings and machinery parts shall not be painted.

On completion of cleaning, the surfaces not to be painted shall be coated with an approved rust preventive coating material or an adhesive plastic film to protect the surfaces from minor mechanical damage and corrosion during shipment and storage at the Site. The coating material shall be stripped off after field erection of the Plant.

Unassembled fittings, pins, bolts and nuts shall be oiled and wrapped with moisture-resistant paper or protected by other approved means.

### 1.6.5 Paint Schedule

Painting schedules for all plant and equipment shall be in accordance with paint manufactures specifications applicable to Contract and shall be subjected to Employer's approval.

### 1.6.6 Galvanizing

The steel structure exposed in outdoor shall be completely galvanized, except for part which shall be embedded in concrete foundation. All ferrous materials shall be galvanized to meet the requirements of ASTM A123.All component members shall be galvanized after all necessary cuttings, drillings and other works are completed. The galvanizing shall be applied by the hot-dip process.

Galvanizing for bolts, nuts, washers, lock nuts, step bolts, ladders and similar hardware shall meet the requirements of ASTM A153. Excess zinc on bolts, nuts, washers, lock nuts, step bolts, ladders and similar hardware shall be removed by appropriate means acceptable to the Employer. The threads of bolts shall not be re-tapped after galvanizing.

- Cleaning

After fabricating has been completed, all materials shall be cleaned of rust, dirt, oil, grease and other foreign substances.

- Coating Weight of Galvanizing

The zinc coating shall be uniform clean and of a standard thickness on the entire surface of all materials. The galvanizing coating shall meet the values as shown in the following table.

**Galvanizing Coating Weight**

| Description | Thickness | Coating Weight (g/m$^2$) | | Uniformity Time |
|---|---|---|---|---|
| | | Average Value | Minimum Value | 1 min/1 time |
| Shaped steel | over 6 mm | more than 700 | 610 | more than 5 |
| Steel plates | under 6 mm | more than 610 | 550 | more than 5 |
| Bolts, nuts, washers, etc. | - | more than 470 | 400 | more than 4 |

Galvanizing routine tests for uniformity of all galvanized materials shall be performed by the Contractor in accordance with the applicable designations given in the ASTM.

- Repair of Galvanized Member

Materials on which galvanizing has been damaged or non-galvanized at the factory shall be re-dipped or re-galvanized. Damage due to local transportation or erection may be repaired by applying a coating of galvanizing repair paint such as zinc paint "Roval" or equivalent if approved by the Employer. Where, such repair is authorized, the damaged area shall be cleaned with wire brush and wiped with clean rag saturated solvent to remove residues before a heavy brush coat of galvanizing repair paint is applied.

### 1.6.7 Inspection

All Works shall be inspected by the Contractor in accordance with the approved Test Procedure by the Employer.

Following the visual inspection on surfaces that have been coated, the dry film thickness of coating shall be checked at as many spots of the coated areas as possible to prove the specified minimum thickness by the electromagnetic thickness meter.

The thicknesses shall be measured at least 10 points per each square meter area in the Unified

Painting Specifications and approved by the Employer in advance, and they shall be more than the minimum thickness specified above. If one (1) point among minimum 10 points measured per each square meter shows less than lower level of the specified range above, it shall be kept at least more than 80 % of lower level of the specified range.

Further, for the purpose of measuring the continuity of coatings, the coated areas shall be examined by the pin hole detector ("Holiday" detector). The peeling inspection shall also be performed for the coated areas.

All test equipment to be provided by the Contractor.

## 1.7 Oils, chemicals and consumables

All oil, chemicals and other consumables such as parts, gases, lubricants, packing, paper, etc., used by the plant up to Handover shall be provided by the Contractor. All chemical tanks, lube oil tanks etc. to be full at Handover and all other consumables shall be replaced by the Contractor before the works are taken over.

## 1.8 Corrosion protection

All materials shall be selected to minimize the potential for corrosion under their service conditions.

Where dissimilar metals are in contact or close proximity and corrosion may occur through electrolytic action or differences in electric potential, protection shall be afforded by electroplating, suitable gaskets, cathodic protection or other means.

All surfaces shall be adequately protected in transit and any damage shall be renovated immediately on off-loading and on completion of erection.

Materials subject to corrosion, including all exterior equipment surfaces and structural steelwork, shall be protected with suitable coatings systems. Protection systems shall generally be to the most stringent international standards, with exposure classed as "high" and a design guide of 10 years to first maintenance.

### 1.9 Heat Insulation

Thermal insulation shall be applied to:

- Any heated surface having a surface temperature exceeding 60ºC not requiring insulation for energy conservation purposes which is accessible to plant personnel and is within 2 meters of any floor or access way, and/or;
- All normally exposed sections of the plant including drains, pipes, valves, ducts and casings having a surface temperature exceeding 60°C during operation.

The surfaces shall be insulated with an agreed material covered by Aluminum cladding or provided with "stand-off" protection so that the temperature of the outside of the cladding or protection does not exceed 60°C when the ambient temperature is 28°C and assuming a wind speed of no more than 0.25m/s and the surface in question is not in direct sunlight.

Where regular inspection of the equipment is required, the insulation and/or protection shall be durable and readily removable. Where access across pipework or insulation is required, the insulation shall be protected by checker-plating or other suitable protection.

All thermal insulation shall meet the requirements of one or more of the following Standards or its international equivalent if agreed by the Employer.

- BS 3708 - Thermal Insulating Materials between 230°C - 650°C;
- BS 3958 - Thermal Insulating Materials
  - Part 2 - Calcium Silicate Preformed Insulation
  - Part 3 - Metal Mesh Faced Mineral Wool Mats and Mattresses
  - Part 4 - Bonded Preformed mineral Wool Pipe Sections
  - Part 5 - Bonded Mineral Wool Slabs (for use above 50°C)
- BS 5422 - Thermal Insulation in the Range 95°C - 230°C

No insulation containing asbestos shall be used.

Cladding shall be not less than 0.7mm (22 SWG) in thickness and shall be adequately supported to prevent sagging or excessive deflection. In the case of exterior surfaces, it shall be designed to resist wind loadings. Due allowance shall be made in the design and fixing of the cladding for thermal expansion of the lagged surface. Where necessary, expansion joints shall be provided in insulating materials. All joints in cladding shall be waterproof.

Insulation of large flat or curved surfaces shall be by means of blankets or preformed slabs retained by pins and wired into position as necessary. The insulation for piping systems shall be of the moulded pre-formed type.

Pipework insulation shall be terminated at a distance equal to the length of the flange bolts from the flange in the case of flanged joints or at point which permits preparation of the pipe end for welding without disturbing the insulation in the case of welded-in valves. The joint or valve shall be insulated independently of the pipe by preformed blocks or blanket type material of thickness at least equal to that of the adjacent pipe insulation. Valves shall be insulated up to and including the bonnet but not the bonnet joints.

Insulation and lagging over all flanges and valves shall be easily removable and replaceable without disturbing the surrounding insulation. The separate portion of the lagging shall extend sufficiently far along the pipe to allow the joint bolts and nuts to be withdrawn without disturbing the lagging on the pipe. The casing over flanges shall have a drain hole to indicate the presence of a leak.

Insulation shall be continuous through floors, walls, pipe supports, anchors, guides and hangers. The insulation shall be sealed at all interruptions due to hangers etc. and the cladding shall be flashed and sealed to make it weather tight.

Insulation shall be installed only after the completion of any hydrostatic testing of the pipework system or equipment has been completed.

### 1.10 Buildings

If the Gas turbine is not supplied with a factory fitted enclosure, the gas turbines, generators and associated auxiliary equipment shall be located indoors and shall include an overhead crane (Capacity shall be enough to lift at least one heaviest part of the gas turbine and generator, pendent control and step less movements). The arrangement of the major equipment within the building shall allow free access for the overhead crane for maintenance.

### 1.11 Signage

Wall mounted signs shall be provided at all floors, platforms, etc. to indicate reduced headroom clearance, hazardous areas, warning signs and others as required by the design review, HAZOP, Codes and Standards.

### 1.12 Degree of automation

The plant shall be automated and require minimum operator intervention for normal operation. It shall be possible to start the plant and bring it to full capacity after the whole plant has been out of service for one day (i.e., "cold" condition) without operator intervention outside the control room. Local control facilities (start, stop, emergency trip and etc.) shall be provided for each gas turbine unit and associated auxiliary equipment at their local control cubicle.

All motors, valves etc. which must be operated during start-up, shutdown, normal, emergency or special operations of the plant and auxiliaries shall be automatically operable by the control system, with the sequences initiated either from the central control room or dedicated local control cubicle. Notwithstanding this, it shall also be possible for the operator to interrupt the automatic, programmed sequences and control the plant manually from the central control room wherever there is no risk to the plant and equipment.

If the control mode is set to start the units automatically on 132kV voltage failure, units shall start automatically without operator intervention and reach the full speed no load state in addition to the manual black start facility of the units.

The degree of automation provided shall ensure the plant can be safely and reliably started, shut down, controlled and monitored from a remote-control room location.

### 1.13 Laydown areas

The Gas turbine building design shall provide the necessary access and laydown area to operate and maintain the Works. A truck access aisle into the area shall provide free passage of a tractor trailer loaded with the largest component subassembly to be handled.

The laydown areas shall be large enough to accommodate the full disassembly of a power train at one time. Space shall also be provided for free access to components by maintenance personnel, in order to perform required service operations and accommodate use of appropriate tools.

The laydown areas shall be arranged and located to permit X and Y horizontal movement, in addition to vertical access by the overhead crane hooks. The need to pass major components over operating units shall be minimized.

### 1.14 Protection of Plant

The contractor shall provide and maintain fencing of his own office/ workshop / storage areas and any security lighting and guards where considered necessary or as required by the Employer.

The Contractor shall arrange for the protection of all material against corrosion and mechanical damage during transport, storage and erection at the Site to the satisfaction of the Employer. The packing or protection used shall remain serviceable for at least six months at Site. The Contractor shall take particular care in the storage of combustible materials.

### 1.15 Storage facilities

The contractor shall store material at site or suitable storing facility. But the cost of any temporary covered storage accommodation and handling of material that may be required shall be borne by the contractor and be deemed to be included in the contract price. The contractor shall provide any necessary protection and watchmen to safeguard material in the areas used for storing. The handling and storage of any plant at the site shall be at the risk of the contractor and without responsibility to the employer.

### 1.16 Design and Standardization

The Contractor and Subcontractors shall make every effort to standardize mechanical and electrical equipment as well as instrumentation & Controls. The essence of design shall be simplicity and reliability and all similar parts of the plant shall be readily interchangeable. Equipment shall be suitable for the particular environment and shall be designed to prevent ingress of all vermin, accidental contact with live parts and to minimize ingress of dust and dirt.

Consumable items such as indicating lamps, storage media, printer papers, ink cartridges and ribbons etc. shall be standardized so as to maintain minimum stocks of different types and sizes.

The Works shall be designed to permit interchange ability of parts and ease of access during inspection, maintenance and repair.

A KKS (Kraftwerk Kennzeichnungs System) or agreed equivalent Plant Identification System comprising of alphanumerical characters shall be used to identify all equipment and components of the Works. The Plant Identification System shall be integrated into the DCS, main plant and all auxiliaries.

The Contractor shall provide detailed training sessions and full documentation for the supplied Plant Identification System prior to commissioning work. The Contractor shall supply soft and hard copies of the KKS (or equivalent) component list for the plant and for all components on which maintenance must be carried out. The list shall include: KKS, Plant Item, Reference Drawings, O&M Manual Reference and Spares Reference.

The Contractor shall provide details of the proposed Plant Identification System in its bid.

### 1.16.1 Compliance with standards

Unless another standard is specifically mentioned in this Specification all materials used and provided under the Contract, and all design calculations and tests shall, where such standard exists, be in accordance with such authoritative Standards appropriate to the country of manufacture as in the opinion of Employer ensures an equivalent or higher quality than International Standards Organization (ISO) for mechanical equipment and International Electro technical Commission (IEC) recommendations for electrical equipment.

Where required by the Employer for approval purposes, the Contractor shall supply without charge duplicate copies of the proposed standards with English translations.

The Contractor shall have available in his place of business (or in his supplier's works) and on Site, the relevant copies of standards or codes used, for the use of the Employer. One set shall be provided to the Employer at Site, for his exclusive use.

### 1.16.2 Statutory Regulations

The Works and all plant, equipment and materials forming part of this Contract shall comply in all respects with any relevant statutory regulations by-laws or orders currently in force in the country where the plant is to be erected.

### 1.17 Prohibited materials

The Works shall not incorporate:

- Asbestos or asbestos-containing materials;
- Naturally occurring aggregates for use in reinforced concrete and/or naturally occurring aggregates for use in concrete which do not comply with the appropriate Standards;
- Cast iron for any oil service;
- PCBs (Polychlorinated biphenyls);
- CFC's or other ozone depleting substances except (with Employer's consent in writing) in applications where their use cannot reasonably be avoided, and is generally accepted for the specific application;
- Carcinogenic materials; and
- Any other materials generally known in the construction industry at the time of use to be deleterious to health if used or incorporated in such Works.

### 1.18Classification of hazardous areas

The Contractor shall carry out a thorough, comprehensive plant-wide assessment of all areas which could be deemed hazardous in accordance with IEC or international standards and shall complete the Works to meet all the requirements of the Codes and Standards.

The assessment shall consider the fuel supply systems, power house building and any other area where an explosion risk may occur.

The Contractor shall take all practical steps to eliminate, by design, all potential leak points and all gas traps and this shall be supplemented by adequate and appropriate ventilation.

Notwithstanding the above, the internal volume encompassed by the Gas turbine building and any potential gas compartment shall be considered to be Class 1, Zone 2 hazardous areas due to the future conversion of the gas turbines to dual fuel, as defined in IEC 60079, that is an area:

In which an explosive gas atmosphere is not expected to occur in normal operation and if it occurs is likely to be present only infrequently and for short duration unless a Zone 0 or Zone 1 rating is found to be applicable.

The Contractor shall submit the relevant information to show that the ventilation system design and gas detection system meets the above requirements.

The Contractor shall ensure that potential sources of ignition within the above areas are eliminated or suitably protected to the relevant International Standard.

Notwithstanding any of the above, the Contractor shall be ultimately responsible for ensuring the zoning classifications as defined by the requirements of IEC 60079 are met and that the final installation complies with all personal safety and plant protection requirements.

The Contractor shall prepare a dossier providing complete installation, operations and maintenance information for all equipment installed in hazardous areas and any circuitry designed to provide protection to that equipment. The dossier shall incorporate a test and maintenance plan to ensure the integrity of the installed protective systems can be monitored, recorded and maintained over the life of the plant. It shall also include details of the certification of all equipment supplied.

### 1.19 Hazardous substances and dangerous goods

The Contractor shall minimize wherever possible the use of:

- Hazardous substances; and
- Dangerous Goods

The Works shall incorporate all safety precautions such that the transport, storage, care and use of these hazardous substances or dangerous goods shall comply with any relevant Acts and Regulations.

### 1.20 Drawings and documentation

The Bidder shall submit with his bid general arrangement drawings and typical details of the essential items of plant offered.

When the Contract is let, the successful Bidder will be required to supply any additional copies of such tender drawings as may be selected by the Employer which will be bound in the Contract Document.

Between the date of award of the Contract and the commencement of manufacture, the Contractor shall submit to the Employer for approval three hard copies of all drawings, soft copies in Auto CAD and PDF formats and information relevant to the plant included in the Contract supply. These shall include, but not be limited to:

i. A drawing register listing all drawings supplied under the Contract indicating dates of submission and approval status of each contract drawing. An update issue of this shall be submitted monthly.
ii. A list of all the equipment to be installed, together with principal operating characteristics.
iii. Civil work and building plans.
iv. General arrangement drawings, assembly drawings, plant layouts for each building and room, pipework layouts, terminal point details, foundation drawings and erection instructions.
v. Wiring and pipe work diagrams, interconnection diagrams and schematic diagrams for equipment modules and systems.
vi. Single line for main electrical system
vii. Logic diagram for all control systems
viii. Cable route drawings, cable schedules and termination schedules.

In addition to the above hard/soft copies the Contractor has to maintain a cloud base document and drawing management system on behalf the Employer. All the Employer's engineers and supervisors shall have the access to the cloud-based documents and drawings. The contractor shall supply 06 nos. of mobile computer devices (Tablets of 10-inch screen sized) of reputed brand to be used by the employer's project engineers with required software to access and review the drawings and documents.

All symbols used on drawings or diagrams shall comply with the appropriate sections of BS 3939.

All legends and notes on drawings provided by the Contractor shall be in English. All drawings shall be dimensioned in millimeters (or meters) and drawn to one of the preferred scales quoted in ISO 5457 and on paper of the appropriate size from the International series of A sizes.

The Contractor shall submit any additional drawings and/or documentation necessary to meet the requirements of the Specification. Also, the Contractor shall provide a copy of any documentation submitted to third parties to satisfy any regulatory or legal requirements.

Drawings showing the physical location of all devices and a plot plan showing the location of all equipment shall be provided. Plans shall be oriented so that North is at the top of the page. The drawings shall be adequate to demonstrate compliance with the Contract requirements

and provide a complete understanding and accurate record of the equipment supplied.

Where necessary, copies of the appropriate calculations and data shall be submitted with the drawings. The sequence of submission shall be such that all information necessary for checking is available for checking each item as it is received. In all cases, the drawings shall be submitted in sufficient time to permit modifications to be made if such are deemed necessary by the Employer without delaying the delivery of the Contract Works.

As soon as practicable, and normally not later than one month after receipt, the Employer will advise whether the drawing is "Approved", "Approved Subject to Comments" or "Not Approved", as may be appropriate.

The notations "Approved" and "Approved Subject to Comments" authorize the Contractor to proceed with manufacture of the equipment covered by such drawings subject to any corrections or amendments required by the "Comments". Where drawings have been "Approved Subject to Comments" or "Not Approved" the Contractor shall make the necessary revisions on the drawings and submit further copies for approval in the same procedure as for the original submission of drawings.

It is to be understood, however, that approval of the drawings will not exonerate the Contractor from any responsibility in connection with the work.

Amended drawings which are submitted for approval shall incorporate a revision number to show that the drawing has been changed and the alterations shall be clearly indicated to draw the Employer's project engineers' attention to the full extent of the proposed amendments.

Any approval which is given to revised drawings will only apply to amendments which have been clearly indicated in this way.

All drawings submitted by the Contractor or by any Sub-Contractor shall have the following particulars in the lower right-hand corner:

- Employer's Name
- Contract Title
- Drawing Title
- Contract Number
- Contractor's Drawing Number
- Employer's Drawing Number
- Drawing Revision Number

The Employer's drawing number shall be included in all cross references between drawings submitted under the contract.

The Contractor shall allocate Employer's Drawing numbers to each drawing submitted from a series of numbers advised by the Employer.

All drawings and lists, schedules etc., generated in conjunction with the plant, e.g., instrument lists, measurement list, circuit lists, alarm lists, valve schedules etc., shall be provided in electronic as well as hard copy format.

Drawings shall not be "typical" but shall actually represent the equipment provided. All drawings shall be corrected to "As built". Proprietary drawings shall be provided in PDF if they are not available in AutoCAD. However, dedicated schematic drawings for each Gas Turbine unit and their auxiliary systems shall be provided. The scope of potential drawings not in AutoCAD shall be limited to general arrangements, proprietary drawings and some standard drawings from sub-suppliers and shall be subject to the acceptance of the Employer.

Notwithstanding this, all submittals shall include a PDF copy of each drawing, report or document.

A logic diagram and a detailed list of all switches, contacts, and relays used in a normal start-up shall be provided. The logic diagram shall show the sequence of operation and typical allowance windows in which a device shall operate.

Before Handover, the Contractor shall provide a complete set of hand marked "As built" drawings including all P&IDs, wiring diagrams, lists of set points and calibration data.

On completion of the Works the Contractor shall furnish to the Employer for record purposes, two sets of "As built" drawings and documentation on CD Rom (one set in AutoCAD latest version and one set as PDF) and six sets of "As built" drawings and documentation in hard copy format. As-built application software shall be backed up on to a suitable medium and shall be supplied in duplicate.

The Taking Over Certificate will not be issued until an approved set of prints or reproducible of "As built" drawings along with a schedule of all drawings, produced specifically for this

Contract, whether or not previously submitted for approval, have been provided for the purchasers use on site. The balance of the “As built” drawing requirement shall be submitted within three months of the issue of the Taking Over Certificate.

### 1.21 Labels, Rating plates, Name plates and Packing

Each item of plant including, field devices and drives shall be durably and legibly labelled, indicating the purpose, plant identification number and where necessary any operating position functions. Each shall have its unique plant identification system number. Equipment descriptions shall be agreed with the Employer.

Each main and auxiliary item of plant shall have permanently attached to it in a conspicuous position a rating plate of in-corrodible material upon which shall be engraved any identifying name, type or serial number, together with details of the loading conditions under which item of plant in question has been designed to operate, and such diagram plates as may be required by the Employer.

The description and number of each item of plant shall be consistently applied throughout all drawings, manuals, documents and labels. The labels shall facilitate effective operation and maintenance of equipment.

Labels shall be conspicuous without being obtrusive and shall be capable of being read by the user when viewed from a normal working position.

All labels shall be firmly fixed by means of suitable attachments to non-detachable parts of equipment using not less than two fastenings. Label fixings shall be such as to allow ready replacement without damage to the label or the fixing.

All interconnecting pipes including those in trenches and all pipes carrying potentially hazardous substances shall be colour coded and have pipe markings on the outer surfaces.

Where pipe work and/or cables are installed underground the Contractor shall supply and install reinforced concrete marker posts at each change of direction point and at intervals of no greater than 30m along the route. These marker posts shall indicate the directions and functions of the services involved.

Labels shall be provided on front and rear access doors of all cubicles. Labels shall also be provided inside cubicles to assist the identification of apparatus and terminals.

Labels in outdoor areas shall be metallic and corrosion resistant.

### 1.19 Packing

Each crate or package shall contain a packing list in a waterproof envelope and copies in triplicate shall be forwarded to the Employer prior to dispatch. All items of material shall 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 them to the appropriate shipping documents including the following shipping mark:

Additional General Manager (Generation),
Generation Headquarters,
Ceylon Electricity Board,
New Kelani Bridge Road,
Kolonnawa 10600
Sri Lanka.

Kelanitissa Gas Turbine Project
No: CEB/KGTP/PROC/01/Re

The Employer may require inspecting and approving the packing before the items are dispatched. Such inspecting will not exonerate the contractor from any loss or damage due to faulty packing.

Packaging shall comply with BS 1133 and 4672 or equivalent standard.

All packing material, excepting standard shipping containers, shall become the property of the Employer.



## 1.20 Documentation - manuals

### 1.20.1 General

Plant manuals shall be in the form of A4 sized books with loose leafed pages to permit the insertion of additional information or revised pages as necessary. Drawings and diagrams shall, where practicable, be reduced to no greater than A3 size to be bound into the manual as "fold-out" sheets. However, in the reduced size they must be completely legible and suitable for reproduction. Where a drawing cannot be reduced to a suitable size for the manual, it shall be folded to A4 size and inserted into a "pocket" which is to be bound into the rear of the relevant section of the manual.

It is a condition of the Contract that the Employer shall be free to reproduce any part of the manuals without restriction for the purposes of the business.

### 1.20.2 Operating and maintenance manuals

The Contractor shall supply six copies of the Operating and Maintenance manuals as required by the Contract, all in English.

The Contractor shall provide complete and detailed instruction manuals covering the description, operation and maintenance of the plant including all ancillary equipment. Manufacturer's standard brochures may be appended to the text provided they are specific to the as installed equipment and free of matter applicable to other equipment or operating circumstances.

Two copies of the manuals in draft form shall be submitted to the Employer for agreement.
The manuals shall have the following format:

**(i). Index**

The index shall provide rapid and easy access to particular subjects, drawings and illustrations. It shall consist of a master index plus a sub-index to each section.

**(ii). Description**

The manual shall provide descriptive information on both the major plant systems and on the components of those systems. It shall include:

- Drawings sufficient for understanding the descriptive information;
- Flow sheets or single line block diagrams which explain the function or logic of the system;
- Schedules such as valve schedules, materials schedules, operational limits schedules, pares catalogues etc.;
- List of Original equipment suppliers

  Data sheets which provide in a concise format all relevant technical details of a plant system or an individual item. (The purpose of a data sheet is to provide a quick reference to the essential details, omitting all general descriptive information.)

**(iii). Operation**

This section shall include basic step by step instructions on how to operate the plant, beginning with the plant system and then proceeding to the individual items of equipment within that system. The instructions shall include references to relevant safe operating procedures and operational limits for that system or item.

Details of appropriate shut-down and plant preservation procedures for extended outage periods shall also be provided.

**(iv). Maintenance**

This section shall include all information necessary for the safe and effective maintenance of the plant. It shall include:

- A schedule of routine maintenance requirements including details of limited-life components;
- Details of plant checking procedures, including the allowable tolerances;
- Step by step maintenance procedures for the equipment, including details of the spares and special tools required to carry out the work;
- Fault diagnosis guidelines;
- Drawings sufficient to illustrate the maintenance procedures;
- Schedule of lubricants with details of approved suppliers and trade names;
- Schedule of ball and roller bearings
- List of special tools (Cost shall be included in Schedule 3, Special tools of Volume 5)

**(v). Spare Parts**

This section shall provide information about the spare parts required for the plant including details of their dimensions, manufacturing standards and materials as well as ordering details for both OEM and Vendor-supplied items. It shall consist of:

- A spare part list together with referenced sectional drawings from which the descriptive name and part number can be identified for ordering purposes;
- Contact details for spare parts suppliers including address; e-mail address; telephone and fax numbers. (In this context, spare parts suppliers are to be the original component or equipment manufacturer. It shall not be acceptable for the Contractor to nominate himself as the supplier of "bought in" items unless they are manufactured by a third party in accordance with the Contractor's own manufacturing drawings.);
- A list of spare/replacement parts required for each type of inspection/overhaul nominated in the Maintenance Section of the manual.
- All descriptive information and part numbers given in the Manual shall be consistent with the corresponding information provided in the spare parts recommendations submitted with the Bid.

### 1.20.3 Instrumentation and control system documentation

The Contractor shall provide detailed instruction manuals covering all instruments and other hardware together with copies of all software to enable the Employer to maintain the plant instrumentation and control systems and in particular to:

- Identify faults
- Make adjustments
- Reconfigure
- Reprogram
- Alter control programming, logic, algorithms or settings
- Retrieve plant historical data from system storage media
- Back up and Restoration of HMI and other engineering stations

The documentation which are of "As Built" shall be included, but not be limited to:

- A Plant Operating Philosophy
- Process and Instrumentation Diagrams (P&ID)
- Process descriptions
- Control System Architecture Diagrams
- Control System Arrangement Drawings
- Control System Interface Description
- Cubicle/Panel General Arrangement and Schematic drawings
- C&I power supply distribution and loading
- Control room and electronic room layout
- Explanation of Overall Plant nomenclature instrumentation and signal tagging system
- Functional Descriptions for all control systems including;
- Logic Block Diagrams

- Logic Flow Diagrams
- I/O signal lists covering hardwired and serial data signals
- SAMA or latest format of Drawings for Modulating Control Configuration
- Written Text description of control functions, including algorithms
- Cause and effect diagrams
- Event lists
- Trip set points (Commissioning values) lists
- List of alarms and set points (commissioning values)

- Field Instrument location drawings and tapping point details
- Instrument Arrangement Drawings
- Instrument calibration certificates
- Safety Shutdown Systems Documentation
- Instrumentation and wiring system database
- List of measurements
- List of signalizations including:
    - Serial number
    - KKS or plant identification number
    - Application (e.g., lube oil system)
    - Status e.g., HH
    - Location
    - Instrument range from / to
    - Instrument span from /to
    - Kind (range) of output signal
    - Installation details
    - Sensor type
    - Medium normal/maximum pressure
    - Line nominal diameter
    - Tapping arrangement
    - Cable type and index number
    - Terminal numbers
    - All set point data
    - References to other documents, e.g., P & ID, logic and loop diagrams, wiring diagrams, instrument data sheets, circuit diagrams, etc.
- List of control valves and actuators
- Instrument data sheets
- Wiring diagrams
- Interface points to other systems
- I & C cable schedule including:
    - Cable no
    - Termination points (at both ends)
    - Cable route
    - Cable type

  - Cross section
  - Length
  - Standard ampacity
  - Ampacity under site conditions
  - Estimated load current
  - Voltage drops
  - DCS Software Register
- DCS Hardware Register
- Spares List

The contractor shall give following draft documentation with the system and these documents shall be reviewed after the commissioning to prepare the final as built documentation.

The contractor shall also provide all the documentation in pdf format.

The schematic drawings and mechanical drawings shall be in AUTOCAD 2017 or latest version and in pdf format. All other literature shall be in PDF form.

The documentation shall consist of at least following items;

The operation and maintenance manuals shall contain following information to enable the client to maintain, dismantle, reassemble, adjust, test, commission and operate the system.

- Table of content
- List of illustration
- Introduction
- Operating principle and characteristics
- Operating instructions
- Testing and adjustments /commissioning parameters
- Maintenance instructions
- As built drawings

Detailed description which shall contain a complete and accurate description of the offered system including:

- Range of features provided as standard.
- Range of optional features.
- Details of the operating characteristics of the system.
- Statement of performance under the reference conditions.
- Variation of performance on deviation from reference conditions.
- Effects from interruption of control circuit auxiliary power supply.

# 2. Mechanical Technical Specification

This Specification covers the mechanical specifications other than the specification for power station fire detection and protection system that shall be complied by the bidder under the contract. The specifications are detailed as mentioned below under each subsection.

## 2.1 Gas Turbine

### 2.1.1 Unit Identification

#### 2.1.1.1 Type

The offered power plant shall consist of Three (03) identical, simple cycle Gas turbines.

#### 2.1.1.2 Power

The total output of the plant shall be in the range of 105MW – 130MW at maximum site ambient temperature and conditions specified in Clause 3.4 of Volume 2.

The minimum acceptable thermal efficiency of each gas turbine shall be 36% under ISO conditions considering LHV of LAD. Offered gas turbines with efficiencies lower than 36% under ISO conditions will be rejected.

No External power augmentation technologies except inlet air chilling, is allowed to achieve the net power output of the gas turbine. The technology used for inlet air chilling shall be based on a proven technology which has been established in gas turbines at least for five years. A list of gas turbines operated with this technology shall be provided in the proof of ability section. In proposed inlet air chilling system in this contract shall be comprised of all the necessary safety devices to protect the gas turbine compressor from forming of ice, carry over water and etc.

#### 2.1.1.3 Offered Units

**a.** The units shall be complied with the specifications given in this bid document. If any proposal violates any of the specifications which affects the life and performance of the plant shall be rejected.

**b.** The offered Gas Turbines shall not have any lockout feature after tripping, unless a fault exists in the gas turbine. If the gas turbine manufacturer proposes any corrective measures for the thermal lockout, the corrective measures shall be proven and well established in the industry.

**c.** It shall be part of the Contractor's obligations to present supplementary recommendations directed towards rendering the pre-designed general plant as reliable as possible in operation and as simple as possible in maintenance, offering simultaneously a high standard of economy.

**d.** Only new Gas Turbine Generator units (unused- except limited number of hours only for test running only at manufacturer's facility) shall be accepted for this Contract.

**e.** There shall not be any premature failure in main components of Gas Turbine and Compressor which causes for Combustion Inspection, Hot Gas Path Inspection, Major Inspection and Overhauling of the offered unit, before due scheduled time (Due schedule maintenance with specified operational hours) with normal operation, throughout the life cycle of the Gas Turbine. Offered gas turbine models with reported premature failures for RLNG or Liquid fuel shall not be considered for evaluation and will be rejected. If any such a failure is reported, bidder is required to provide sufficient evidence to prove that such failures are not design related premature failures.

**f.** The offered GT-Units shall be identical and accessories too shall be identical and interchangeable., e.g., rotors, rotating and stationery hot paths, bearings and other components etc.

### 2.1.2 Design Consideration

Design shall be based on systems, equipment and components which have undergone not less than three (03) continuous years of proven successful operation. The contractor shall take special precautions in the selection and protection of materials & equipment against deterioration due to the effect high humidity and temperature, dust & slightly salt laden atmosphere. Attention must also be paid to selection and protection of electronic components, protection relays, instrumentation and temperature and humidity sensitive equipment. It is the contractor's responsibility to determine and select the correct material/protection specified for the environmental and service conditions involved.

Prototype GTs shall not be considered. A GT is assumed to be a prototype if it has less than 12,000 running hours per single unit on liquid fuel as prime fuel fired in the GT is liquid fuel. The model offered should have more than 60,000 aggregate actual running hours and at least three (03) units of the offered model shall have reached 12,000 actual running hours each, only in continuous running on liquid fuel.

When the RLNG fuel is available in Sri Lanka, GT shall be capable of RLNG operation and therefore offered GT model shall have demonstrated minimum of 12,000 actual running hours each on RLNG for at least three (03) units.

The manufacturer of offered Gas turbine shall have supplied to international customers at least ten (10) units of offered design with in last five (05) years.

The offered Gas Turbine model and the technology used for the offered units shall not be a discontinued from the manufacturing process. The offered model shall be incorporated with the all proven and optimized systems and components.

The design philosophy shall follow proven, modern utility practice, modified to suit the specific site requirements and the anticipated operating regime. It shall follow International safety standards specified for handling RLNG and LAD. (NFPA Class I, Division – 2, Group – D, Explosion proofing or Equivalent)

Details of any modifications incorporated on the Gas turbine model offered, since its commercial introduction shall be provided by the bidder.

The performance guarantee for GTs shall be for Diesel fuel (LAD) firing.

**2.1.2.1 Emission & Noise Regulations**

Emission Regulations

Stack emission from the Gas Turbines shall be complied with the following interim standards for stationary source emission control in RLNG and LAD operation.

| Type of Pollutant | Emission Limits (At Standard Conditions) |
|---|---|
| Sulfur Dioxide ($SO_2$) | 1. 850 mg/$Nm^3$ for new power plants with maximum 28kg $SO_2$, per day per MW subject to maximum 14 metric tons of $SO_2$/day for first 500MW plus 10kg $SO_2$ per day per MW for additional MW<br>2. Shall be controlled by fuel quality for existing power plants. |
| Nitrogen Oxides ($NO_x$) | Max. 450mg/$Nm^3$ for gas turbine (At 3% Reference Oxygen) |
| Particulate Matter | Max. 150mg/$Nm^3$ |
| Smoke | Max. 20% Opacity |

a. No smoke shall be visible from the chimney at any stage of operation.

Noise Regulations

Construction Stage - Noise level at the boundary of the land during the construction stage shall be maintained at or below 75 dB (A) during day time. (from 6.00 am to 9.00 pm)

- No noise generation activities shall be carried out from 9.00 pm to 6.00 am

Operation Stage - Noise levels at the boundary of the premises during the operation shall be maintained at or below 63 dB(A) during day time (from 6.00 am to 6.00 pm) and at or below 50 dB(A) during night time (6.00 pm to 6.00 am).

(Noise pollution in Gas turbines shall be measured according to the international standard– ISO 10494:1993 or equivalent)

#### 2.1.2.2 Fuel Flexibility

(a) The proposed Gas Turbine units shall have the dual fuel capability, to operate on Lanka Auto Diesel (LAD) and Re-Gasified Liquid Natural Gas (RLNG).

(b) The plant shall be capable of operating on Lanka Auto Diesel specified in Annex B during first few years until RLNG is available.

(c) The starting and stopping of the GT units shall be done by both RLNG and LAD.

(d) The dual fuel system shall provide smooth, bi-directional fuel transfer without shutdown or interruption of load carrying ability.

(e) When operating on gas fuel, the liquid fuel lines, nozzles, manifolds etc. shall be automatically purged continuously to prevent plugging and coking.

(f) On base fuel system HP filters shall be Duplex type and shall be able to change without unit tripping at base load running. The system shall include differential pressure gauges to indicate level of clogging of filters and alarm system connected to GT control system.

(g) The design of fuel injectors shall be optimized for both fuels specified.

#### 2.1.2.3 Turbine

(a) The casings of the gas turbine generator shall be of sufficient strength to ensure complete, containment in the event of a compressor or turbine rotor blade failure at the maximum allowable operating speed.

(b) All turbine blading and casings shall be designed to withstand the maximum temperature scatter which may occur in service under adverse combustion conditions, with the machine running at the design maximum mean turbine inlet temperature. The casing, blading and ducts shall withstand, without premature failure, the thermal shock associated with repeated starting and loading and any other stresses due to cyclic effects.

(c) The combination of maximum mean turbine inlet temperature and turbine blade materials offered shall have been fully proven over extensive periods of successful commercial service. The materials selected for all high temperature components shall have a well-established high resistance to formation of sulfides and other corrosion phenomena at the maximum operating temperatures, taking into account the fuel analysis given in the Specification Appendices (for LAD and RLNG) and the atmospheric conditions prevailing at site.

(d) Nozzle shall be capable of sufficient atomizing of fuel at any load for colorless exhaust under any fuel mentioned above to achieve mentioned emission regulations.

(e) The combustion liner, transition piece or combustion chamber which ever applicable shall be of robust, long life design with thermal barrier coating. Combustion efficiency and fuel atomizing shall be sufficiently high to ensure a colorless exhaust, when burning the LAD or RLNG under any condition of load, startup and shutdown.

(f) A flame supervisory system shall be installed based upon redundancy principles to ensure high reliability.

(g) Installed Barring gear/slow turning device for Cool down system in order to avoid any thermal deformation of the shaft, is to be entirely automatic in operation and is to engage and disengage as necessary during the start-up and shutdown sequences. If any gas turbine model does not require such barring gear, adequate document proof shall be submitted with the Bid.

I. Interlocks shall prevent barring in the absence of adequate lubricating oil pressure unless the design is such that barring under such conditions is not detrimental to the bearings of the machine.

II. The barring gear shall also be capable of engagement and disengagement manually.

III. Facilities for entirely manual barring shall be provided by installing pneumatically powered equipment or any other suitable means.

(h) All the surfaces at the gas turbine unit which exceed 60 °C in operation are to be provided with insulation covered by water and heat resistant fabric and secondary covered with aluminum sheet cladding. The surface temperature of the installed insulation shall not exceed 50 °C. Hot parts of the components which exceed this temperature shall also have precautions to avoid direct contact. The insulation covers shall be easily removable and re-fixable. Insulation material shall not contain any Asbestos material or any other hazardous material.

(i) All external thermal insulation with the possible exception of the exhaust ducting shall be of the blanket type with Stainless steel covers and fitting clamps and be capable of removal and replacement for overhaul purposes without damage. Thermal insulation (Environmentally friendly material) shall be provided, where appropriate, to prevent adjacent concrete or any other surfaces from reaching excessive temperatures.

Thermal Insulating shall be complied with particular British Standard or equivalent.

(j) The gas turbine generator unit and/or associated equipment shall be enclosed in integral sound insulated housing(s) which shall be arranged for easy access of equipment and maintenance. The housing(s) may enclose the compartment for turbine auxiliaries, gas turbine, generator and generator auxiliaries.

Generally, the following design criteria shall be observed:

I. The enclosure(s) shall be of the rigid frame type with removable roof and side wall of sectional construction. The roof shall be slightly pitched to prevent accumulation of water, the same is applicable for the bottom.

II. Full rigid frames shall be provided at each end of the enclosure(s). High strength bolts shall be used for rigid frame, splices, struts and end columns. Standard machine bolts may be used for all other connections.

III. The roof and side wall sections shall be designed for thermal and acoustical adequacy in addition to the structural strength.

IV. Removable sections, lift-out sections, swing-up sections, as well as removable side wall sections shall be provided, where access required for normal maintenance, observation and operational adjustment. Louvered openings for ventilation shall be provided together with the connection ducts to the building outside.

V. The enclosures shall as far as required be provided with space heaters capable of maintaining suitable start-up temperatures and protection against humidity during shutdown and standby periods.

VI. All enclosures shall be provided with ventilators to ensure adequate air circulation.

VII. The heated cooling air shall be ducted to the outside of the machine enclosure.

VIII. All compartments shall be furnished with adequate, lighting fixtures and industrial type socket outlets for normal operation and maintenance and with a separate lighting system for emergency cases.

IX. For maintenance, cleaning and other purposes service air facility shall be provided inside the compartment

X. All doors shall have panic proof design.

XI. The outside of the enclosures shall be of sea water resistant aluminum.

### 2.1.2.4 Compressor

The air compressor shall be of a multi stage axial flow design with a split casing. The operating range of the compressor shall allow all operation modes without any surge or unsuitable flow at specified maximum ambient temperature and frequency control operations.

The compressor of the gas turbine shall be sufficiently flexible aerodynamically to permit satisfactory operation of the turbine generator unit to be maintained when reasonable amount (5% of total mass flow drop) of compressor blade fouling are present. There shall be a measuring instrument to measure the fouling status in terms of pressure drop of the compressor.

The method of providing cooling air for the turbine cooling shall ensure the little or no potential for leakages which may lead for turbine disc creeping.

Compressor blades shall have the sufficient strength to operate the Gas turbine generator in frequency control mode with VIGV partially closed positions.

If blow-off valves, variable angle stator blades or any other special equipment shall be provided to avoid any undesirable conditions (surging and stalling) at low compressor speeds and during the shutdown and any other emergency situations of the unit, full details of such equipment shall be given in the bid.

Automatic control of VIGVs shall allow closing during start-up and opening at full speeds, as well as adjustment of these guide vanes for optimum part load efficiency and exhaust gas temperature control during any mode of operation.

Provision shall be made in the design of the compressor to measure mean compressor delivery temperature and pressure accurately with test instruments.

The air path including rotor, blades and casing shall be protected by a special coating to avoid corrosion and erosion or shall be of corrosion free materials to withstand the site conditions belong to C 5-I category of ISO 12944.

**2.1.2.5 Performance and Degradation of the gas turbine generator**

(a) Maximum allowable Heat Rate shall not be exceeded by 1% of the declared value given in the bid.

(b) Maximum allowable power output shall not be lower than the guaranteed value given in the bid.

(c) Correction Curves for output power and heat rate with ambient temperature and humidity variations for each machine for both fuels shall be provided.

(d) Degradation charts of the turbine and compressor for its proposed life cycle shall be provided.

(e) Accurate charts illustrating design limitations and the performance limitations shall be provided. - Operational Envelop

(f) Vibration (With reference to ISO 10816, ISO 20816, ISO 7919)

**2.1.2.6 Critical Speed & Vibration**

- Any critical speed of the rotor shall be at least 20% above or 20% below the nominal speed.
- The plant shall be (comprehensively) designed and constructed to operate with allowable vibration limits as per the internationally acceptable standards (ISO 10816/ ISO 7919) which do not affect the total life cycle of the plants or output capacity.
- The Bidder shall state in his bid the normal running vibration levels, experienced on the gas turbine machinery.
- Vibration monitoring system shall be capable of communicating data transmission online with modern condition monitoring equipment and software.
- Authorization of all configuration software related to operational and maintenance activities of monitoring instruments shall be handed over to the Employer.
- Natural frequency concerns considered during the design stage shall be declared to employer.

#### 2.1.2.7 Gas Leakage Detection System

Flexibility of installing relevant gas leakage detection systems for RLNG operation in future, to detect any gas leak inside the gas turbine enclosure and possible risk areas, shall be available.

#### 2.1.2.8 Foundation

The GT-Unit shall be installed on a concrete foundation block. This concrete block shall be erected vibration isolated from the remaining building structures and designed according to the civil requirements of such foundations.

The GT-Unit/ Generator foundation and the generator supports shall be designed for the loads and forces resulting from a torque, corresponding to ten (10) times the full load short circuit torque of the generator.

### 2.1.3 Operation Flexibility

The plant shall be required to operate satisfactorily either continuously or intermittently, at any load up to the maximum peak load rating synchronized with the national grid or isochronous operation under design ambient or climatic conditions as specified in Section 3.4 of Volume 2which may occur.

The gas turbine shall be able to start again after a shutdown without any operational limitations at any given time. Gas turbine shall not have any thermal lockout limitation after shutting down or tripping unless a fault exists in the gas turbine. If the gas turbine manufacturer proposes any corrective measure for the thermal lockout, the corrective measure shall be proven. Gas turbine units without proven corrective measures for their thermal lock out shall be rejected.

#### 2.1.3.1 Load Control Capability

The unit shall be able to operate in applicable droop setting range 2% to 10% as per the Grid code of Sri Lanka in synchronous and island modes. And the droop setting should be able to change while the GT in operation.

The units shall have the capability to operate for limited periods of time at a peak load rating equal to at least 105% of the base load rating.

#### 2.1.3.2 Frequency Control Capability

The Gas Turbine Generator units shall be operated on frequency control mode as when required without any adverse effect on compressor and turbine life cycle.

Plant shall be able to perform the primary/secondary frequency control with a droop setting range of 2% to 8%. Governor droop setting shall be able to set to preset values while turbine is in operation.

### 2.1.3.3 Self-Sustaining Capability

The design of the units and its associated control system shall be such as to permit full load rejection, disconnection from 132 kV connection, without tripping and shall continue operating with the auxiliary equipment without any adverse effect to the plant and equipment.

In the event of total grid failure GT shall operate without tripping. In case of grid-failure GT units shall be remain full speed, no load state and shall be available for subsequent synchronization. This feature shall be required to be demonstrated at site.

### 2.1.3.4 Island mode (Isochronous) running

All gas turbine units shall be able to operate in island mode in parallel to restore Colombo city electricity supply. Proposed plant shall be mandatory to have the capability of quick restoration of Colombo power supply in the event of total power failure. There shall be a control mechanism to maintain the load sharing, system frequency and voltage within values specified in the Grid Code of Sri Lanka.

The plant shall be fully adhered to meet the following critical concerns of the Plant which intends to serve for specially Colombo system restoration.

1. Ability to black start. It shall be capable of commencing the island wide system restoration from Colombo in the event of a total system failure.
2. Ability to withstand the momentarily high inrush currents following the initial closing of line circuit breakers and energizing the hitherto de-energized 132kV underground cable network. Details of the 132kV underground cable network to be energized is given in Appendix H
3. Ability to operate and maintain stability at sufficiently leading power factors to absorb reactive power expected to be generated along the standard total failure restoration route consisting of UG cables.
4. Ability to operate at low loads for extended times such as 2-5MW for a period up to 30 minutes without losing the stability.
5. Ability to withstand high load fluctuations that is expected during a total failure restoration when feeder breakers are closed. As the generator would be lightly loaded at the time, the per unit load variation is high and hence significant rate of change of frequencies (df/dt) could be experienced unless the generator has sufficient inertia or other control interventions.
6. Ability to regulate frequency when operated in isolation and upon gradually synchronizing other generators to the system.

### 2.1.3.5 Functional Requirements

a. Total plant design shall have service life not less than 30 years.
b. Operating availability shall be over 95% on base load operation related to 8,760 hours per year.

c. 250 starts per year
d. Minimum rate of load change shall be 10% of maximum continuous rating per minute. The rate shall be adjustable.
e. Continuous operation of frequency ranges 47- 52 Hz while carrying load.
f. All motor driven auxiliaries shall be capable of running without physical damage during emergency conditions at frequencies between 47 – 52 Hz together with voltage as low as 85% of nominal voltage.
g. All installations shall be suitable and available for continuous operation without major overhauls per minimum period of twelve (12) months.
h. Minimum stable load for GT unit operation shall be 12% of GT unit base load.
i. The gas turbine control system shall perform the startup sequence and ensure that all sub systems of the gas turbine perform satisfactorily, and the turbine rotor temperature does not increase too rapidly or overheat during startup.
j. The gas turbine control system shall support combine load control of all turbine units of the plant while the plant operates on grid frequency control mode by setting a joint load reference set point.
k. Continuous operation shall be possible within the entire load range between 100% base load and minimum load.
l. There shall be no limitation of time for no load operation at nominal speed.

### 2.1.4 Maintenance Flexibility

a. Mounting of the gas turbine generator on its support frame shall be arranged so that removal of the complete machine and installation of a replacement can be carried out as conveniently and quickly as possible.
b. It shall be possible, when the gas turbine is shutdown, to carry out a visual inspection of the stator and rotor blades in turbine and compressor using optical instruments or special equipment if necessary. Sufficient access points for the visual inspection of turbine and compressor using optical instruments (Borescope etc.) shall be provided.
c. If rotor balancing at site is required by the design, provision shall be available in the plant for correcting any out-of-balance of the rotor at site without having to remove the rotor from the bearings.
d. Replacement of rotor blades must be possible without additional balancing of the rotor.

### 2.1.5 Fuel Supply System

#### 2.1.5.1 General

The fuel supply system shall form the interconnection between the fuel supply terminal points and the GT units on base fuel systems. The fuel supply system shall be designed to handle separately the different fuels (LAD & RLNG) as required for the operation of the GT units. To meet the fuel inlet requirement of each GT unit off-base fuel forwarding unit with discharge pipe work shall be provided.

The supply shall include all equipment auxiliaries and piping required for safe and reliable operation. The selected equipment shall be in all respects, well within the range of manufacturer's proven experience and shall not involve the use for application of any prototype design or components. The contractor shall choose prefabricated standard equipment which shall be approved by the Employer. The final flow design capabilities shall be adopted to the Gas turbine type chosen.

Attention shall be paid to the safe handling of fuel in general and specially to RLNG. The fuel forwarding skids for both fuels shall be provided with adequate ventilation and drain provisions in order to avoid hazardous explosion mixture. All vents and drains shall be led to safe areas.

Any accumulation of fuels and fuel fumes exposed to air shall be avoided within enclosures as well as within the complete power station. Specified safety instructions and design regulations shall be observed and all components for handling fuels shall be designed accordingly. The GTs shall be able to start with LAD or RLNG. The fuel system shall be able to handle the two different fuels LAD and RLNG as required which allows the changeover at any load above minimum stable load defined in Sub-Clause 2.1.3.5 from one type of fuel to the other and vice versa including a fuel oil management system which shall allow the automatic switch over from one fuel to the other manually and remotely. Gas turbine control system shall provide the facility for safe change over from RLNG to LAD and vice versa by monitoring relevant parameters.

The contractor shall familiarize himself about required connection to the existing installations of LAD fuel system at Kelanitissa Power Station. All necessary modifications and works such as emptying and cutting, welding, electric welding, heat tracing, insulation, removal of blinds included in his scope and shall be responsible for any damage. The contractor shall arrange interconnections to the existing Diesel fuel ring circuit by a method such as "Hot tapping" without draining Diesel fuel in lines.

RLNG will be available at the site boundary at Kelanitissa to operate the Plant in near future. Therefore, it is required to provide all the equipment necessary to operate the plant on RLNG when RLNG supply is available at the site boundary (location is indicated in Appendix G).

The RLNG supply pressure at the site boundary will be 45-65 bar and the minimum temperature will be 100C.



### 2.1.5.2 Diesel System

This system covers fuel supply pipe work and connected equipment from Diesel ring circuit terminal point to off-base forwarding skids and from off-base forwarding skids to terminating points of on-base systems. This system shall include but not be limited to

- **a.** Fuel oil treatment plant with sufficient capacity
- **b.** Daily fuel storage tanks
- **c.** Fuel forwarding pumps
- **d.** Fuel Strainers at pump suction and any other protective locations
- **e.** Isolating flanges

f. Isolating valve, isolating blind and bleed valve
g. Drains and vents
h. Underground pipeline, coated and wrapped
i. Fuel supply pipe from ring circuit to forwarding skid
j. Fuel pressure pipe work from forwarding pumps to the on base fuel system
k. Fuel return pipe work from forwarding skid to ring circuit
l. Fuel flow meters
m. Pressure gauges at suction and discharge points of the pumps

#### 2.1.5.2.1 Fuel oil treatment plant (FOTP) - Centrifuge type for Gas turbine generators

Fuel oil treatment plant supplied by the contractor shall be brand new and with sufficient filtering rate to operate all the gas turbine generators simultaneously at rated capacity. The minimum capacity of the FOTP shall be at least 150% of the normal plant requirement when all Gas Turbines run at their base load continuously.
The proposed location inlet for the FOTP is marked on Appendix G. An additional flange outlet shall be provided for a future connection to the existing purified fuel storage tanks in addition to the connections to the day tanks of the proposed plant.

The manufacturer of fuel oil treatment plant shall be an internationally reputed manufacturer who is having experience in manufacturing fuel oil treatment plants for a period not less than 15 years. The manufacturer shall have supplied at least 10 units of fuel oil treatment plants with same or higher capacity for power plants in past 10 years.

The separation system shall be capable of removing or reducing the water and non-oil bonded solids to an acceptable level which is recommended by the OEM of Gas Turbines.

The equipment will be designed and manufactured in accordance with the following codes and standards, if not mentioned otherwise.

- ISO International Organization for Standardization
- IEC International Electric Codes
- DIN German National Standard Cod EN European Standards
- VDE / IEC German National Electric Standard Codes / International Electric Codes.
- BGV German Safety Regulations.

The control center of FOTP shall be capable of supervising the following operations:

- System Start
- Automatic Process Control
- Alarm announcement for System Fault and Set-Point Deviation
- System Shutdown.

Scope of Supply (Hardware) of Centrifuge shall be included but not limited to:

- separator, self-cleaning total discharge type
- separator motor along with individual terminal box

- feed pump with adequate capacity
- motor for feed pump - flameproof, TEFC squirrel cage ac induction
- base frame with sludge tank and other fabricated items along with canopy
- sludge pump
- VFD control capability
- strainers - cs body, ss304 screen
- flow meter
- flow sight glass
- level transmitter
- various valves, fittings, pipes, hoses, fasteners
- pressure gauges
- air filter regulator with gauge
- pneumatic actuator with 2-way ball valve
- push button station
- set of commissioning spares
- set of tools & tackles
- lifting facility for maintenance

Following test reports and certificates shall be supplied

- Factory mechanical run test of the complete module
- Copies of material certificates for pipe materials and valves will be provided by the individual suppliers.
- Pump factory test report in suppliers' standard format
- Calibration certificates for instruments (indicators, switches -as applicable).
- Routine test report for electric motors
- Paint thickness, slut and adhesion test and visual inspection certificate
- Individual structural design calculation, if any
- Separator vibration test and functional test reports per Alfa Laval standard
- Dimensional check of main dimensions and connections at skid limit
- Hydrostatic pressure/leak test certificate for fuel oil pipe system
- Final inspection certificate

### 2.1.5.2.2 Daily fuel storage tanks

Daily fuel storage tanks shall be with sufficient capacity for diesel fuel to operate the turbine generators at least for 24 hours at base load conditions. There shall be included all the safety equipment, instruments and gauges with these daily fuel storage tanks. The outside of the tank shall be painted according to the category of ISO 12944-C5I. Inside the tank shall have a paint thickness not less than 450µm with insoluble paint with diesel.

### 2.1.5.2.3 Fuel Forwarding pump station for each Gas turbine unit

The fuel oil forwarding pump station shall be within outdoor weather proof enclosure and shall consist and not limited to following main components

- Fuel forwarding pumps set for each Gas turbine unit shall be provided. Each set shall consist of 2 x100% AC motor driven fuel forwarding pumps and a DC pump for emergency, black start and to serve in unavailability of AC power due to such as grid failure. The fuel forwarding pumps shall provide a constant suction pressure for the GT Unit high pressure fuel pump.
- For the fuel forwarding pumps local and remote operation/control indication shall be provided. In case of failure of one pump or of too low discharge pressure, the other pump shall start automatically. In any case of both AC pump failure DC pump shall be started.
- A trip of the pump should not cause a successive trip of the gas turbine. The standby pump shall start automatically on failure of the duty pump.
- Fuel forwarding pumps shall be designed in accordance with requirements of API 610. Horizontal shaft centrifugal pumps are recommended for this service.
- Pressure accumulators shall be provided to ensure buffer capacity during the automatic switch over to the standby pump. The buffer capacity shall be selected to compensate the missing pump capacity during the switch over time.
- Duplex strainers with fasteners required size at delivery side with differential pressure alarm and gauges. The material of the inserts shall be of stainless steel.
- Flow meter with local and remote indication (Mass flow type)

### 2.1.5.2.4 Centrifugal Pumps

Pumps offered shall be of standard design and proven in service.

Pumps shall be designed to meet the requirements API 610 8th Ed. The Maximum Allowable Working Pressure (MAWP) of the pump casing shall be above pump maximum discharge pressure. The rated capacity shall be selected close to the Best Efficiency Point (BEP) of the impeller.

The mechanical seals shall be of a proven and reputed make.

The piping connections to the pump shall terminate in ANSI B 16.5 flanged connection. The flange ratings of all flange connections of the pump shall be the same as of the discharge flange. The discharge flange ratings shall be adequate to withstand the maximum discharge pressure of the pump.

The pump set shall be supplied complete with centrifugal pump, drive motor, flexible coupling, mechanical seal, flushing system with piping and common base plate for pump & motor with drip tray. All carbon steel surfaces shall be painted with manufacturer’s Standard painting system.

The selected impeller diameter shall be smaller than the maximum impeller diameter that can be accommodated by the pump such that a 10% head increase can be achieved by replacing only with the maximum diameter impeller.

Pumps selected shall have stable performance curves with head continuously rising up to shut off.

The pump Net Positive Suction Head (NPSH) required shall be lower than NPSH available. Preferably the margin between NPSH required & NPSH available shall be 1m. The minimum acceptable margin between NPSH required & NPSH available shall be 0.5m subjected to a NPSH test.

The motor drive shall be selected such that the motor rated power is equal to or greater than the following:

a). Motor rating allowance as per API 610

b). End of curve power

Certified performance test & hydrostatic test reports are required in the event of an order. NPSH test shall also be performed when the margin between NPSH required & NPSH available is lower than 1m. The pump performance test shall be performed with contract equipment such as motor, seal & coupling. The medium for performance test shall be water. In this situation where pumps are selected to handle fluids of density lower than water, performance test with vendor's shop test motor can be accepted.

All pump bearings shall be well lubricated as per the application.

The motor shall be supplied as per the requirements.

The following documents & technical details are to be furnished by the pump vendor;

a). Performance curve indicating maximum, minimum selected impeller diameter curves, NPSH & absorbed power corrected to product density. Vendor shall indicate rated conditions, BEP capacity, minimum flow & shut off head.

b). Material of construction of casing, impeller, shaft, shaft sleeve, mechanical seal, stationery & rotating parts, gaskets & sealing elements.

c). MAWP of pump, flange sizes & ratings, Design code of pumps.

d). General Arrangement (GA) drawing of pump sets with details of pump construction features such as dimensions of base plate, total weight, bolting locations etc. The dimensions & weight, bolt locations, shall be inclusive with motor drive.

e). Motor data

f). Pump lubrication details.

g). Make & description of mechanical seals & seal system

h). Make & description of couplings.

i). Painting/protection coating specification.

j). Reference list of previous supplies.

k). Inspection & test procedures.

l). Deviations/compliance from/with specifications

#### 2.1.5.2.5 Fuel oil Pipe Work

For all fuel oil pipes except stainless steel pipes the corrosion allowance shall be 2.5 mm. The allowance has to be added to the minimum thickness resulting from stress analysis.

All nuts and bolts shall be corrosion resistant to ASTM specification A-325, type 3 or equivalent. Other corrosion resistant fasteners may be used with the approval of the Employer. The gaskets shall be of fuel oil resistant type.

Provisions shall be made to neutralize all possible static electric charges arise on fuel oil system, e. g. see NFPA Standard 15/77.

The following velocities shall be applied for the fuel flows in the pipe work.

- Max. velocity of fuel oil 2 m/s (pressure pipe)
- Max. velocity of fuel oil 0.8 m/s (suction pipe)
- Max. velocity of fuel oil 0.75 m/s at entrance to fuel tank diffuser

The pipes shall be anchored, supported and guided in such a way to prevent excessive thrust of stress due to the combination of internal pressure, thermal expansion and weight of the connected items.

#### 2.1.5.2.6 Cleaning & Flushing

During manufacture and erection, the open ends of all pipe work shall be protected at all times by suitable temporary covers, which shall be fixed securely. After completion of the fuel pipe erection work and testing, the entire piping system shall be cleaned by flushing for a minimum of six (6) hours with distillate fuel.

An arrangement of a closed loop pipe system shall be provided with circulation pump(s) and 80µm fine filters.

Additional piping if any required shall be supplied by the Contractor with working tools and shall remain his property. The pump size shall be such as to maintain a flow velocity of 4 m/sec in the pipes during the cleaning procedure.

Special care shall be taken that all pipes are thoroughly cleaned and free of grit, scale, sand, jointing material etc., before starting of the commissioning operations. The Contractor shall be fully responsible for any damage that may cause to any plant components by negligence of such care.

#### 2.1.5.2.7 Valves

All valves shall be cast or forged steel. Ball valves and ranged face flanges shall only be used. The seals shall be Viton or equivalent. The valves shall be located to allow easy access. All valves shall have indicators to identify open or shut position easily and the valves shall be easily operated by a single person from a working platform. The closure torque shall not be greater than 250 Nm.

#### 2.1.5.2.8 Drains & Vents

All pipe sections between valves shall be equipped with pressure relief valves. To allow proper venting and draining of all pipe sections, all necessary vents and drains required must be provided, at each section. Sufficient slope to each vent and drain must be provided. All vents and drains shall be piped to the relevant drain tank with required drain pump and pipe work. Sight glasses shall be installed on each drain pipe. The vents shall be piped to a safe area and provided with flame arrestor valves.

#### 2.1.5.2.9 Corrosion, Protection, Marking

Painting shall be provided for protection of all equipment and piping in the fuel oil system against the heavy environmental conditions prevailing at site.

In any case, the kinds of paint used and the procedure of painting shall be as recommended by a paint manufacturer.

All pipe surfaces shall be easily accessible for inspection and paint repair, especially the pipe bottom surface.

Underground pipes shall be coated and wrapped or any other further measures. Wrapping shall be complied with following Codes and Standards.

- NACE (National Association Corrosion Engineer) NACE RP-02-74
- SSPC (Steel Structures Painting Council) SSPC-SP3 Power Tool Cleaning

All piping shall be marked with colour code, flow direction arrows and line numbers.

### 2.1.5.3 Inspection & Testing at site

#### 2.1.5.3.1 Testing of piping at site

Piping installation shall be inspected to assure compliance with the engineering design. Visual inspection shall be done during installation in accordance with API specifications.

Types of imperfections to be examined;

- Cracks
- Incomplete penetration
- Weld Undercutting
- Weld reinforcement Testing & Recording
- Radiographic Examination
- Piping welds at site shall be examined by 10 % radiography during installation work progresses.
- Records shall be written with reference to DIN 8524 or equivalent

- Inspection of pipe coatings shall be done visually and by an ultra sound detector.
- Hydrostatic pressure testing

Pipe system shall be tested with potable water. The lines shall be immediately drained after testing and flushing, and shall be purged by blowing with air.

A strainer shall be installed in the fill line to minimize the possibility of entering foreign matters into the system during pressure tests and flushing operations. Prior to initial operation, painting and wrapping, piping shall be hydrostatically pressure tested with 1.5 times design pressure, but not lower than 7 bar. (API 325)

The duration of hydrostatic test shall be four (4) hours. Records of test results shall be prepared on each piping system tested.

Each test procedure of lines of systems shall be approved by the Employer. Each test shall be witnessed by the Employer.

**2.1.5.4 Testing of pumps**

**2.1.5.4.1 Workshop Test**

All pumps shall be subjected to running tests witnessed by the Employer. Hydrostatic tests on liquid-end pressure casing shall be performed with pump fully assembled, at a Test pressure 1.5 times maximum casing discharge pressure within the temperature range of 0-100 °C.

**2.1.5.4.2 Running Test**

The manufacturer shall conduct his standard running test of the pumping unit. The pumps shall be operated at specified design speed and discharge pressure. The test shall be complied with ISO 9906: 2012 or particular API standard or any other equivalent standard.

**2.1.5.4.3 Test Data**

The following test data shall be furnished to the Employer by the Contractor. The data shall include performance data for all final tests and mechanical operation, including details of any difficulties during the tests. A sketch showing measured casing thicknesses shall be provided.

- Physical and chemical test data on liquid-end pressure casing.
- Evidence such as purchase specification or bills of material, to establish that other critical parts are of specified materials.
- Certified copies of test data.
- NPSH suppression and performance test data.
- Measured shaft vibration amplitudes.

**2.1.5.4.2 Tests at Site**

The following tests and inspections shall be carried out and certified:

- Check of base plate alignment by using a spirit level
- Check of proper grouting of base plate
- Check of anchor bolt fixing
- Check of free turn of pump shaft
- Check of free turn of motor shaft
- Check the direction of motor rotation (uncouple the coupling)
- Check coupling alignment in accordance with manufacturer's recommendations
- Check connecting piping to be free of tension
- Check of proper greasing and oil level of bearings
- Check of stuffing box for sufficient guide and tightening
- Check of auxiliary connections with respect to proper installations.
- Check of bearing temperature
- Check of smooth run of pump
- Functional tests

#### 2.1.5.5 Instrumentation and Control

Independent safety devices like safety valves, the instrumentation and control shall protect all equipment of the system against maloperation by operators, equipment failure, etc. It shall also enable operators to undertake suitable action when gas turbine operation is endangered due to fuel oil shortage. The special requirements for the design and installation of I&C equipment in areas handling RLNG must be considered.

All field instruments shall be explosion proof designed in accordance with NFPA and VDE/VDI Regulations as well as DIN Standards and shall be suitable for installation in Class 1, Division 1 & 2, Group D hazardous area environment.

#### 2.1.5.6 RLNG System

This system covers RLNG supply pipe work and connected equipment from RLNG supply terminal point at the site boundary to off-base RLNG skid and from off-base RLNG skid to terminating points of on-base systems. This system shall include but not be limited to

a. Natural gas pipeline connection from gas supply pipeline at the terminal point, which is expected to be at the Facility boundary

b. A metering installation

c. A gas compressor installation or regulating system with its auxiliary equipment and interconnecting piping

d. Treatment skid to ensure that fuel gas is supplied to the turbine in a suitable condition to meet the machine requirements.

The location and space shall be available in the final design layout drawing supplied by the bidder with the pipe interconnection points from the turbine side indicating all equipment and instrumentation required to meet startup fuel gas requirement such as supplementary compressors and pilot coolers etc. Up to proposed RLNG delivery point at Facility boundary shall be provided for the RLNG piping system diagram as per the requirement of site conditions. Proposed sketch shall be given by bidder

The RLNG supply pressure at the site boundary will be 45-65 bar and the minimum temperature will be $10^0$C.

### 2.1.6 Atomizing Air System

Atomizing air supply system to fuel injector nozzles shall be available for proper atomization of distillate fuel. A suitable compressor with sufficient flow to ensure proper atomizing with clourless exhaust at any stage of operation shall be installed.

### 2.1.7 Lube Oil System

Lubricating oil systems complete with tanks, pumps, valves, coolers, filters, supervisory equipment, automatic control gear, instrumentation, pipework and all things necessary for a self-contained system for the automatic supply of oil to various parts of the plant shall be provided under this Contract.

Starting and stopping of the motor driven pumps shall normally be automatic but manual control facilities shall be incorporated. Interlocks shall be provided to prevent damage to the plant in the event of malfunction of the lubricating oil system.

All bearing drain pipes are to be provided with visual oil flow indicators wherever possible.

The first fill of lubricating oil and any oil necessary for preliminary flushing procedures shall be supplied as part of this Contract.

#### 2.1.7.1 Tanks

Lubricating oil storage tanks shall be of sufficient size and suitably baffled to ensure adequate settling time for the oil. Sufficient bolted covers shall be provided for convenient access to each compartment for cleaning purposes. Duplicate strainer baskets shall be provided at the return side of the tank and inspection of the baskets shall be possible whilst the machine is running.

A tank vent shall be provided, complete with pipework, and if necessary, a motor driven extractor, to discharge oil fumes outside the package unit. Tank draining complete with a lockable valve and pipework to a suitable point from which oil can be run into containers, shall be provided.

Level switches shall be provided in the lubricating oil tank to initiate a low-level alarm followed by a trip. Visual indication of level in the tank shall be provided and it shall be readily possible to check the level and, if necessary, replenish the tank under all operating conditions.

In addition to level switches in the tank, pressure switches shall be provided in the lubricating oil system and these shall be set so as to initiate an alarm and subsequently trip the machine before there is any risk of damage to the gas turbine generator in the event of a malfunction of the lubricating oil system.

#### 2.1.7.2 Pumps

2 x 100% capacity main lubricating oil pumps with duty/ standby selection, AC motor driven with pressure accumulator complete with panel mounted pressure gauge and pressure relief valve

or

A main lubricating oil pump, shaft driven from the accessory gear and one (1) 100% capacity AC motor driven auxiliary lube oil pump complete with pressure relief valve, panel mounted pressure gauges and provisions for automatic start of the auxiliary lube oil pump

and

An automatic emergency DC motor driven pump of adequate capacity to provide the necessary oil supply for run-down and cool-down of the unit in the event of an AC failure shall be included.

#### 2.1.7.3 Filters

The lubricating oil system shall include duplex 2 x 100% capacity full flow filters with necessary gauges and online filter changing capability.

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#### 2.1.7.4 Coolers

Lubricating oil coolers shall be of the air blast heat exchanger type, cooling the oil either directly or through a closed water circuit system.

The lubricating oil cooling system shall include thermostatically operated bypass valves and automatic on/off control of the cooler fans to maintain the lubricating oil supplied to the unit at a safe operating temperature.

#### 2.1.7.5 Jacking Oil System

If a jacking oil system is required, this shall include all necessary interlocks for completely automatic operation.

In addition to AC jacking oil pump, One DC motor driven jacking oil pump with panel mounted pressure gauge and provisions for automatic starting, and testing shall be provided.

### 2.1.8 Intake air System

The air inlet shall be provided with a weather hood, a bird screen and rain droplet catcher. The weather hood shall be made from corrosion resistant material and shall be shaped to allow the air flow to the intake opening from direct rain entrainment and shall be shaped to allow the air flow to the intake opening from down side only in such a way, that the rain cannot come directly to the inlet air opening.

The Contract shall include gas turbine intake filter chamber, intake weather louvers, filtration equipment, ducting, guide vanes, silencer, internal lighting and all necessary supports and fittings.

Cross windows, if any, shall be installed not to cause detrimental effects regarding entrainment of dust and rain.

Droplet catchers/weather louvers made from corrosion resistant material are selected to be installed for removal of mist droplets with a maximum efficiency.

The materials of construction and surface finishes for all components of the air intake system shall be chosen for maximum resistance to corrosion under the prevailing ambient conditions. The equipment shall be of robust construction suitable for an industrial environment. All seals and gaskets shall be of neoprene rubber and not "plastic foam".

All ladders, platforms and special lifting and handling devices necessary for access to, and maintenance of the filtration equipment shall be included. Inspection doors shall be provided in such number and position as to allow access to all parts of the intake works for inspection and maintenance. In particular, it shall be possible to carry out a close-up visual inspection of the first blade rows of the gas turbine compressor. All doors shall be provided with locks and seals.

A differential pressure gauge and alarm shall be provided to monitor the condition of the filters and for the safety of the compressor and the turbine.



### 2.1.8.1 Inlet Air Chilling System

If inlet air chilling is provided with the offered unit, the technology used for inlet air chilling shall be based on a proven technology which has been established in gas turbines at least for five years. A list of gas turbines operated with this technology shall be provided in Appendix-J, the proof of ability section. In proposed inlet air chilling system in this contract shall be comprised of all the necessary safety devices to protect the gas turbine compressor from forming of ice, carry over water and etc.

Design of the inlet air chilling system shall ensure the minimum usage of water.

Power improvement due to inlet air chilling shall be furnished on a graph with respect to the variation of ambient temperature and the relative humidity conditions of the site.

### 2.1.8.2 Inlet Air Filters

Filtration equipment shall comprise with high efficiency media cartridge filters and shall be suited for the site ambient condition. The Kelanitissa power station (proposed site) is situated in an industrial area containing vehicular emissions and dust, close to the coast and the bidder shall describe in his bid the advantages of the system offered.

The gas turbine air inlet and filtration system shall be equipped with adequate measures to

provide clean suction air with a minimum pressure drop to the unit. The air filtration system shall be with maximum feasibility of maintenance.

In general, the filtration system shall include but not limited to weather hoods and stainless-steel trash screens in front of each intake section, inlet air demisters, silencers, filter doors, internal and external lighting, ladders, platforms, inspection doors, bypass flaps and all equipment necessary for inspection and maintenance. All doors shall be panic proof.

Inlet air filtration system shall be designed and installed to protect compressor and turbine from erosive and corrosive damages by entering water droplets, salt, sand, dust, oil fumes and insects. Inlet air filtration system shall ensure no cause of incremental performance losses of compressor or turbine due to causes which are possible in tropical environmental conditions.

Pressure drop caused by filtration system shall be minimum as possible.

All sections of the air inlet and filtration system must be provided with appropriate drainage facilities, connected to a drainage system able to work against vacuum conditions. Water catching flat bar made from corrosion resistant material shall be provided on the duct floor at the clean air side in front of the downwards corner of the duct, connected to a drain, in order to remove water coming in the duct system.

The filter material shall be corrosion resistant at 100 % relative humidity and shall not absorb water and shall be resistant to fungus, bacteria development and any other harmful microbial activities.

#### 2.1.8.3 Inlet Air Ducting

All sections of the inlet duct system shall be accessible by doors with appropriate sealing and interlocking. The inlet duct system shall be made from steel sheet material with a thickness of at least 2.5 mm and provided with appropriate insulation and cladding. Structural members are to be provided at duct outside only.

If by pass flaps are provided, same shall be installed at the clean air side ducting system in front of the silencer. These flaps shall open in case of high vacuum, in order to protect the system against damage. These flaps shall open automatically in case of a pre-determined differential pressure, and unfiltered suction air is taken from the building outside to the compressor. An alarm locally and to the central control room shall be initiated upon opening of these bypass flaps.

The floor of the inlet ducting shall be sloped and connected to a drain system.

The filter system shall be equipped with pressure measuring devices to indicate the operating conditions and the degree of filter contamination. The differential pressure across the filter system shall be indicated digitally in the local control room and in the central control room.

An inlet silencer shall be incorporated to reduce the noise to the specified level. The silencer shall consist of noise absorbing exchangeable element filled with mineral wool. The element shall be of corrosion resistant material. The design shall allow the exchange of the elements. The average air flow velocity in front of the silencer shall not exceed 7m/sec.

The arrangement of the silencer shall allow later replacement of the noise absorbing baffles with the help of mobile crane, without major modification work. Blind covers shall be provided at the relevant locations for this purpose with proper screwed connections and seals. The overall design shall consider that all sections of the air intake and filtering system can be cleaned and replaced easily.

### 2.1.9 Exhaust System

The contract shall include gas turbine exhaust ducting, lagging and cladding, expansion joints, guide vanes, silencer, stack and all necessary supports and fittings.

The exhaust flue gases of each gas turbine shall leave the gas turbine through the diffuser and the silencer to the exhaust duct and to the atmosphere.

The exhaust ducting system shall be completed with all necessary expansion joints, vibration isolators, supporting steelwork and flanges, inspection doors, thermal insulation and cladding, and any other plant and equipment required to complete the system for the given design life of the gas turbine.

The material of the ductwork, expansion joints and all other parts of the exhaust system shall be suitable in every respect for thermal cycling and continuous operation at the high temperature conditions pertaining to the maximum load of the GT, during the any mode of operation. The design of the duct system, as well as the selection of the duct material, (hot gas path ducting material) shall be suitable for a temperature corresponding to the maximum GT exhaust gas temperature plus 30 K. This increase of 30 K shall be included for the aging and further uncertainties of GT exhaust temperature evaluation.

The stacks structure shall be of steelwork designed with adequate structural stiffeners.

The exhaust duct system shall be designed to avoid drumming, vibration and any resonance with the exhaust gas pulsation under all operating conditions.

Heat and corrosion resistant flat bar material shall be provided at the duct inside floor, in a cross direction of the gas flow, as water traps at the outlet side of the diffuser with a drain facility. These water traps shall retain the GT-Unit wash water, in order to avoid spoiling of the exhaust gas system. These drains shall be piped to a drain collection tank (header) with a volume of approximately 1 $m^3$ (corresponding to the wash water quantity). Sampling ports for emissions from the stack and working platforms shall be provided in order to decide about the final disposal.

A real time continues emission monitoring system shall be installed in each stack in order to regular monitoring of concentration of $SO_2$, $NO_x$, $O_2/CO_2$, TSP, Opacity, Temperature and flow rate of the flue gas for regular management of the combustion process and flue gas control system.

The bottom of the exhaust gas system shall be sloped towards drain collection points. The drain points shall be provided with sufficient drain pipes (Diameter 80 mm minimum) and connected to the waste water drain system.

**Stack height** - Depend on the emission of Sulfur Oxide ($SO_2$) rate in kg/hour, of the fuel specified in Appendix B by the Ceylon Petroleum Corporation ( CPC). The manufacturer shall provide the value of $SO_2$ emission at 100% load steady state and determine and propose the exhaust stack according OEM's design and height shall not be less than 35m (As per Appendix D).

A continuously operating drain shall be provided at the base of the exhaust stack to discharge moisture or rain water which may be collected at the bottom of the stack.

Lightning arrestors, air craft warning system shall be provided for the exhaust stacks.



### 2.1.10 GT Control

The GT- units shall be provided with an automatic control system for start-up and operation of the system, capable of being controlled locally from local control room and remotely from the central control room.

The GT-Unit shall be supplied with all necessary equipment for fully automatic operation, synchronization, as well as automatic start up and shut down for the different modes of operation.

Gas Turbine instrumentation and control system shall provide advance monitoring and diagnostics designed to prevent damage to the unit and to enable Gas turbine to operate at its peak performance while allowing for off design performances when necessary.

Following shall be the main features of the control system and shall not be limited to those;

a). Speed control and monitoring with over speed protection

The over speed protection shall consist of triple redundant speed pickups and a triple redundant control system. Over speed tripping shall be between 110% - 112% of the operating speed.

b). Temperature monitoring and control with over temperature protection

c). Vibration monitoring with vibration protection

d). Monitoring and control protection for loss of lube oil and low lube oil pressure.

e). Monitoring and control protection for loss of flame

f). Monitoring of low compressor discharge pressure and necessary protection

g). Monitoring and control of exhaust temperature

h). Proper Interlocks shall be included in startups and continuing operations for the safety of the Gas turbine

Complete specification of Gas Turbine Control System is described in Section 4 of Volume 3

### 2.1.11 Cooling & Sealing Air System

If coolers are required for any supply of sealing or cooling air to the turbine, these shall be included in the Contract and shall be of the air blast type. The design of all such coolers shall be based on a maximum temperature of 38ºC. All pipework, ducting, valves and supports which are required to convey the cooling air from the compressor to the turbine, and from any turbine vent to a point outside the enclosure, shall also be provided.

If a filter is included in the cooling or sealing air circuit it shall be positioned as close as possible to the machine and sufficient instrumentation, with the necessary alarm and trip initiation devices, shall be provided to protect the unit against loss of cooling air flow or excessive cooling air temperature.

### 2.1.12 Compressor Cleaning System

Original Equipment Manufacturer (OEM) of Gas Turbine recommended system shall be provided for the efficient cleaning of the compressor for online and offline conditions. If, during the guarantee period, it is found that the cleaning system supplied are ineffective or in any other way unsatisfactory, the contractor shall make necessary modifications at no extra charge.

Full details of the contractor's proposed cleaning procedures and equipment shall be included in the bid together with the contractor's recommendations regarding the criteria to be applied by the power station operating staff in order to access when compressor cleaning should be undertaken.

### 2.1.13 Black Start Diesel Generator

Black start diesel generator/s with adequate capacity and reliability complete with ancillary equipment having diesel storage capacity for 3 hrs continuous operation for supplying power to black start the gas turbine units, shall be provided. Black start generators shall have sufficient capacities to ensure black start capability of one gas turbine unit at a time. It shall be capable of connecting to any of the Gas Turbine in an emergency situation. Black start diesel generator shall have a starting means of dc starter motor for quick start & loading capability. The starting system shall be capable of carrying out at least five (5) consecutive starts without auxiliary power supply. Test facility to run the generator at rated load condition in synchronism with the system shall be provided.

The manufacturer of the black start generator should have an established local agent since last five years to provide proper services for the black start generator.

Manufacturer of the offered Generator set shall have at least 10 years of manufacturing experience and offered Generator shall be the latest model which is in production and same shall possess minimum 5 years satisfactory international operational experience.

### 2.1.14 Emergency Diesel Generators (EDG)

One (1) set of emergency diesel generators with adequate capacity, complete with ancillary equipment with a diesel storage capacity for 8 hrs continuous operation for supplying power to essential auxiliaries, shall be provided. EDG shall have a starting means of dc starter motor for quick start & loading capability. The starting system shall be capable of carrying out at least five (5) consecutive starts without auxiliary power supply. In case of power failure in 0.4 kV bus of gas turbine plant, EDG will start and supply power to 0.4 kV emergency bus in auto mode. EDG synchronizing facility with 0.4 kV live bus is also required. Test facility to run the generator at rated load condition in synchronism with the 0.4kV system shall be provided.

EDG is required for the safe shutdown of all the plant/ equipment under emergency condition and in case of power failure for certain essential applications like battery chargers, emergency lighting and all auxiliaries necessary for safe coasting down of equipment and turning gear/ barring operation of the turbines.

The manufacturer of the emergency diesel generators should have an established local agent since last five years to provide proper services for the emergency diesel generators.

Manufacturer of the offered Generator set shall have at least 10 years of manufacturing experience and offered Generator shall be the latest model which is in production and same shall possess minimum 5 years satisfactory international operational experience.

## 2.2 Balance of plant specifications

### 2.2.1 Power Station Firefighting System

This specification covers all firefighting installations, supplement by a fire detection and fire alarm system, complete in every respect and suitable for satisfactory operation to offer protection for all installations of this Gas turbine power plant, wherever needed.

The scope of supply comprises design, manufacturing, testing, delivery, erection and commissioning as well as all required documentation for the equipment as specified and

The fire pumps shall be sized to cover the water demand for fighting the maximum risk of the proposed Gas turbine power plant and to cover the required demand

One electric motor Driven fire pump and one Diesel engine driven stand-by fire pump, both pumps vertical shaft turbine-type, the diesel pump with a right-angle gear shall take suction from the screening and pumping station and supply firefighting water through a ring main system to outdoor hydrants, indoor hose stations, foam systems(mobile), sprinkler systems and water spray fixed systems.

Under normal stand-by conditions, the firefighting system shall be pressurized by one (01) electric motor driven jockey pump.

The jockey pump shall make up leakages and meet the demand of one (01) indoor hydrant without the need to the start the fire pumps for such a small consumption.

All water based extinguishing systems shall be connected and drained to the plant drainage system.

All pumps, pipes and any other parts of extinguishing systems and components for the firefighting water system shall be made of sea water resistant material.

The system shall be complete and functional in every respect, mentioned or not in this specification.

The scope of equipment shall mainly consist, but shall not be confined of the following;

- Fire pump installations
- Underground fire service main
- Hydrants and hose cabinets
- Standpipes and hose systems
- Sprinkler systems
- Water Spray fixed systems
- Foam-water spray systems
- Fire detection and fire alarm system
- Mobile and portable fire extinguishers
- Installation material such as supports, hangers, sleeves, clamps, gaskets, sealing, bulk heads, isolating valves, fire stops, electrical cables etc. for the complete protection system
- Spare parts and special tools
- Provisions to expand the system to the existing power plant.

Complete specification of Power Station Fire Fighting System is described in Section 6 of Volume 1.

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### 2.2.2 Air conditioning

Duel redundant Air conditioners shall be included for the gas turbine Local control Rooms and CCR and other areas identified as required, and shall be designed on a 24 hours operation basis. No water will be available for heat rejection purposes and air-cooled condensers shall be used. The cooling equipment; shall maintain the temperature within the control cabs between 22°C dry bulb and 25°C dry bulb and the retaliate humidity between 45% and 55% over this temperature range. Proposed air conditioners shall have local agent for maintenance and supplying spare parts.

### 2.2.3 Painting

#### 2.2.3.1 Scope

All areas of surfaces open to atmosphere shall be painted with Marine Grade Epoxy paint according to ISO 12944 C 5-I, Durability Range > 15 years. Contractor shall obtain the prior approval from the employer for the make and colour of the paints.

This specification covers the minimum requirements for shop priming, shop painting and field painting of metal surfaces Gas turbine plant where applicable.

In addition to the requirements of this specification, the Paint Manufacturer's instructions, shall be carefully followed.

#### 2.2.3.2 General

All painting operations shall be performed by skilled workmen. Standards of workmanship and materials not described in this specification shall be in accordance with accepted good practice. Tools and equipment to be used shall be clean, of good condition and of a design acceptable to the Employer's representative.

No work shall be done during rain or mist. However, work may be executed during rain provided that, adequate cover has been installed and all instructions and ambient conditions given in this specification are met.

Where surface preparation in-situ is required, the work shall commence after mechanical completion or successful pressure testing. Final painting shall follow within one week after application of the prime coat, or, if circumstances require, within an acceptable period.

Shop primed surfaces shall be touched up as soon as possible after erection. Final painting shall follow immediately after mechanical completion or after successfully completed pressure testing.

Surfaces that will be inaccessible after assembly shall receive the complete painting system before assembling. Contact surfaces of bolted connections are to be primed only.

Platforms, gangways and stair beams shall receive the complete painting system before the gratings or stair treads are mounted.

#### 2.2.3.3 List of Items to be Painted

Structural steel:

- Structures, equipment, supports, etc.
- Miscellaneous steel structures, such as stairs, ladders, handrails, platforms, pipe supports, sleepers, etc.
- Fuel piping system
- Fire Hydrant piping system

#### 2.2.3.4List of Items to be left Unpainted

- All surfaces made of non-ferrous metals, plastic, fibreglass, and other non-corroding materials.
- Capillary tubing of temperature instruments
- Nameplates and markings
- Non-insulated stainless-steel surfaces

#### 2.2.3.5Preparatory Work

The careful and adequate preparation of the steel surfaces is very important for the durability of the painting.

As a rule, all parts which must be painted shall be carefully cleaned and must be free of dust and grease. Rust must then necessarily be removed as well as any sticky deposits.

This shall be done:

(a) With dry abrasives

(b) When the hygrometric degree of ambient air is below 80%

When the temperature is higher than 5°C

In order to eliminate any abrasive, each cleaning operation will be followed by careful de-dusting with dry compressed air free of any oil traces.

**Pre-cleaning**

Removing weld splashes and any loose rust particles and/or rolling scale.

Removing oil, grease and dirt, with solvents or emulsifiers.

Removing complete emulsifiers by washing with clean water and then dry as quickly as possible.

**Cleaning**

(a) Cleaning by blasting with abrasive agents on carbon steel surfaces:

Rust, roll scales and impurities are removed by blasting with abrasive agents.

Before blasting, the pre-cleaning described in the above paragraph must done and the surface must be completely dry.

(b) Cleanliness of the surfaces after blasting with abrasives:

The degree of cleanliness is determined in accordance with the standard ISO 8501 or equivalent.

The required degree of cleanliness is indicated as follows:

SA 2½ rust, roll scales and any foreign matter must be removed as much as possible. Minute traces of rust and scales are accepted in certain cases.

## 2.3 Spare parts and Equipment

### 2.3.1 Spare parts for Inspections and Security Spare parts

List of essential spares required for each type of inspection of Gas Turbine (CI, HGPI, MI) which may occur depending on the hours of operation shall be provided. A separate list of security spares shall also be provided. The FOB cost of each spare part shall be included.

Components, parts and accessories damaged during the defect liability shall be provided by the bidder at contractors' own cost.

### 2.3.2 Special Tools

The bidders shall provide a detail list with prices of special tools and fixtures required to disassemble, assemble or maintain the unit. The price of the special tool and fixtures shall be included in Schedule 3, Special tools of Volume 5 and same will be considered for the total evaluated price of the project. Procurement of these special tools and fixtures depend on the discretion of the CEB

- One set of lifting tugs, guides, beams, slings or, other equipment required for removal and re-installation of the gas turbine rotor and generator rotor or any suitable equipment required for removal and re-installation as recommended by OEM, shall be provided under this Contract.
- This shall include a purpose-built stand or cradle to support the rotor when it is removed from its permanent support frame.
- Any special protective devices required for overhaul and maintenance purposes shall be provided under this Contract.
- The supply of one set of optical instruments (Borescope) with the capability of data logging and data transferring or other special equipment with these features for the whole gas turbine engine inspection shall be provided under this Contract.
- Thermal Image Camera suitable to inspect of possible hot gas leakages and current hotspots in electrical system.
- Hydraulic Torque Wrench with necessary impact sockets.

### 2.3.3 General Tools & Equipment

#### 2.3.3.1 Scope of Supply

Tools and equipment shall be supplied and set to work under the Contract. The sizes and other details of the tools and equipment specified shall be regarded as approximate only and the contractor may supply, subject to the Employer's approval, standard equipment most nearly representing that detailed.

It is the intention that the machine tools specified in this item shall enable the station maintenance, staff to carry out all general repairs, testing and inspection of the plant installed. The Contractor is therefore required to recommend any alteration or additions necessary to enable maintenance work to be carried out in the workshop with these tools. All additional tools or equipment recommended by the Bidder shall be quoted separately as an optional item for the consideration of the Employer.

The contractor shall furnish one set of general tools and equipment sufficient for the proper maintenance of power plant. The general tools and equipment shall include, but shall not be confined to;

- Set of tools for general use as slogging and impact wrench sets, iron levels, hammers, vices, jacks for lifting the casing of turbine/compressor and shaft etc.
- Set of cargo work tools such as lever blocks, chain blocks, snatch blocks, pull lifts and wire/Nylon slings Set of measuring instruments such as calipers, dial gauges with magnetic bases, digital thickness gauge and stroboscope
- Any other OEM recommended tools and equipment.

### 2.3.4 Maintenance

The equipment and plants supplied under this contract shall have the 100% maintenance feasibility and the accessibility.

Maintenance activities which have to be necessarily intervened by the Original Equipment Manufacturer (OEM) shall be listed and provided separately with the charges of OEM up to a Major Inspection of the offered gas turbine and the compressor.

Bidder shall provide the cost of maintenance activities to be carried out by the OEM under the schedules in Volume 5 of the document. The Employer has the right to enter into maintenance contract agreement based on the prices given in this schedule.

## 2.4 Cranes, Hoists and Lifting Devices

This specification covers the requirement of cranes, hoists and other lifting devices for all the maintenance activities of the offered gas turbine units during their life cycle period.

If the proposed gas turbine units of this bid are planned to be installed in a machine hall, a new electric overhead travelling crane/ cranes with appropriate load capacities shall be supplied in this contract.

### 2.4.1 Electric Overhead Travelling Crane

The contractor shall supply a new Overhead Travelling crane, if the power plant is installed in a building, complied with the specifications given below, manufactured by an internationally reputed manufacturer who has experience in crane manufacturing for a period not less than 15 years. The manufacturer shall have supplied at least 20 units of overhead cranes with equal or higher capacity required for this purpose in past 10 years for the thermal power plants in international markets. The contractor shall submit proof of supplying cranes for past 10 years for the particular manufacturer.

#### 2.4.1.1 Layout

The overhead travelling crane shall be preferably operated in longitudinal and transverse direction of the subject building. Crane shall be capable of handling a weight equal to 1.5 times of the weight of the heaviest part of equipment installed in the subject building, i.e., the rotor of the turbine or the rotor of the generator.

The crane shall be double girder overhead travelling crane, main and auxiliary hoist with electrically operated with a pendant switch/remote switch and cabin.

Crane shall be provided with an auxiliary hook with a capacity not less than 10 Tons additionally to the main hook.

#### 2.4.1.2 Scope of Services

Scope includes;

##### 2.4.1.2.1 Design, detailed engineering, transportation, erection, testing and commissioning

- Complete documentation such as foundation drawings, statically and dynamically calculations, stress calculations, arrangement drawings, single line diagrams, test procedures, manuals, spare parts lists, etc.
- Pre-approval of calculation and drawings by an independent inspecting authority.
- Type test certificates of standard hoists and lifting equipment.

#### 2.4.1.3 Design /Construction Requirements

The crane drive and trolley arrangement shall be designed to require a minimum of space while optimizing the accessible working area. Furthermore, the design shall provide easy accessibility of all important parts which require regular maintenance and inspection.

The maximum full load starting speed shall be 10% (Ten percent) of the maximum operating speed of the crane hoist, the gantry drive and trolley drive. Electrical driven cranes, hoists and lifting equipment shall have a nominal and creep speed.

The crane shall operate with the following tolerances:

- If the hook carrying 125% of the nominal load and with the hoist brakes properly set and operating under normal conditions, the vertical motion at the rated inching speed shall be controllable with in 3mm

#### 2.4.1.4 Design and Calculation Standards

Generally, for design, stress calculation manufacture and installation, the following standards and codes, apart from various other relevant standards and regulations shall be applied:

- DIN 4100 Welded Steel Structures
- DIN 4114 Stress calculation of Steel Structures
- DIN 15018 Cranes, Steel Structures, Calculation and Design

- T1 cranes, principles for steel structures, stress analysis
- T2 cranes, structures of steel, design principles
- DIN 15020 Lifting appliances, basic principles for rope reeving components, computation and design
- T1 computation and design
- T2 maintenance in service
- DIN 15030 Lifting equipment; acceptance testing of crane installations; principles
- DIN 18800 Steel structures T1/T7 weldability proof

Safety devices for the operating personnel shall be provided in accordance with the safety rules and regulations

Unless otherwise specified, the lifting equipment shall be classified to DIN 15020 as follows;

- For lifting capacity larger than 10,000 kg (10 Tons) "class 1Am", representing an average daily working time of 3 or 4 hrs and a small share of heavy load lifts (light duty).

The contractor shall state the various load combinations and factors of safety taken as a basis for calculation of the different components and equipment items of the cranes and hoists.

In addition, the various factors of safety for different load combinations shall be stated.

Steel structures of lifting equipment shall be of welded construction, which can be assembled at site. All field connections and joints shall be bolted.

For lubrication, inspection and maintenance, ladders, platforms and stair treads shall be provided. All walkways shall have non-slip checkered plate treads and/or non-slip floor grating and shall be equipped with tubular handrails and skirting. Walkways, stairs and platforms for lifting equipment shall be designed generally for a live load of 3000 $N/m^2$.

### 2.4.1.5 Material Standards

The material to be used for the manufacturing of the lifting equipment steel structure shall conform to DIN 17100 or to the equivalent ASTM standards. However, the Contractor shall restrict the structural steel to St. 37-2 and St. 52-3 or ASTM A 36; the latter may be regarded as equivalent to St. 42. For these structural steels, connecting bolts and welds, the allowable stress given in DIN 15018 or equivalent shall apply.

### 2.4.1.6 General Design Particulars

Nameplates stating the nominal load capacity in kg or tons (as required by the Employer) shall be attached to both sides of the lifting equipment structure and to both sides of the rope block. The printing shall be clearly legible from the floor.

Flexible couplings shall be installed to relieve the bearings and shafts from any stresses due to misalignment and to facilitate the removal of motors, wheels and gears. The motor couplings also shall be of the flexible type.

All couplings, drive wheels and gears shall be press fit and keyed to the shaft.

All wheels shall have a hardened tread with a minimum Brinell hardness number of 320, and shall be made of Carbon steel or low-alloy steel forging. They shall have double flanges, shall be machined to a uniform diameter concentric with the hub bore.

All bearings preferably shall be anti-friction bearings designed to permit easy shaft disassembly and easy replacement. The minimum average life time under design load conditions shall be 5000 hours.

All bearings except those for the hooks and rope sheaves shall be lubricated by central lubrication systems. An independent system for the trolley and one or two independent systems for the bridge will be acceptable.

All gears shall be designed and executed as bevel gears. For all high speed gears and pinions, oil bath lubrication shall be provided. Low speed gears may be lubricated with soft grease. Suitable oil and grease catching drip pans shall be installed and be readily accessible for draining and cleaning.

**Trolley**

The trolley frame shall be made of welded structural steel and shall have a rigid construction to ensure a uniform distribution of the loads to all wheels without undue deflection. After manufacture, the trolley frame shall be stress relieved.

Flexible bumpers shall be provided at the end of the trolley frame; they shall be designed to absorb the impact forces arising when the trolley, running at maximum speed with the nominal load suspended from it, is stopped with the motor switched off.

**Ropes**

The wire ropes for the hoists shall be of twist-free construction preferably with a fibre-core; the wires shall consist of hardened and tempered plow steel. They shall be long lay-ropes with heavy duty permanent lubrication.

The stresses in the ropes shall be assumed at the maximum point and shall include the overall efficiency of the hoist in the parts of the line from the drums as well as the weight of the load, hook and rope sheaves.

The ropes shall be attached to the drum in a simple and safe manner so that for their adjustment and replacement, only a minimum number of parts to be removed.

**Drums**

The drums shall have machined groves to the right and left to receive the ropes. The center of the drums shall not be grooved.

The drum bull gear shall be press or shrink fit to it and secured by dowels or keys or similarly fastened to the drum shaft if the drum is driven through the shaft.

The drum shall be dimensioned adequately to leave at least three complete windings of the lifting rope in the grooves on each side with the hook in lowest position for the specified lifting distance, and it shall not be necessary for the rope to be wound in a double layer when the hook is in its highest position.

**Sheaves and Blocks**

The rope sheaves shall be cast steel or steel weldments with machined grooves which have suitable diameter tolerances and are sufficiently smooth to minimize wear on the ropes.

The sheave pins shall be made of annealed carbon steel or steel alloy and shall have an ample sheave bearing surface. All moving sheaves shall be fitted with roller bearings, each suitable for force-feel lubrication, they shall be accurately balanced for smooth running.

The load blocks shall be built so that they will entirely surround the lifting ropes and will prevent rope from coming out of sheave for all operating conditions.

The rope guard shall be of grease-tight cast steel or welded construction and shall fit close to the rope sheave circumference.

**Hooks**

The load hooks shall be made of forged steel subject to the Employer's approval. The yield point shall be approximately two thirds of the ultimate strength. The hooks shall be load tested to 150% of the rated load and x-rayed or magnafluxed after testing to ensure that there is no hidden damage to the hooks.

The hooks shall be finish-ground by hand and shall rotate freely on anti-friction bearings. The bearings shall be totally enclosed, dust-tight and properly sealed to avoid the ingress of grease. The main hoist shall be equipped with a double hook. The double hook shall be provided with a horizontal bore of approximately 150mm diameter.

**Brakes**

The main hoist and the auxiliary hoist shall be equipped with brakes.

Holding the load shall be affected by means of an automatic spring set, electrically or electro-hydraulically released double shoe type brake. The brake capacity shall be not 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 when it is lowered.

The load control brake preferably shall be an electrical brake, working on the basis of frequency transformer control.

An electrical brake of the eddy-current type or a combination of electrical and mechanical brakes also will be accepted. Friction load braking will not be accepted.

Bridge and trolley drives shall be equipped with a spring-set, electrically (solenoid or electro-hydraulic) released shoe or disk 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 the 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 certain time lag.

**Operator's Cabin**

The cabin walls shall be provided with the best visibility and the lighting for the operator. Provisions shall be made for proper ventilation by an electric air fan. Additionally, the turbine hall travelling crane shall be operated by a pendant switch panel.

All electrical items shall be suitably enclosed to protect the crane operator from accident hazards. The minimum clear height between the floor and any equipment item mounted on the ceiling shall not be less than 1.90 m. The floor of the cabin shall be timber covered with a rubber mat. The lock on the entrance door or cover shall be capable of being opened or closed from both inside or outside. Three keys must be furnished.

A swivel seat shall be provided for the crane operator. It shall be located conveniently in order to enable the operator when sitting on it, to have an unobstructed view of all operations of the lifting elements in connection with the operational requirements of the powerhouse equipment.

Wherever possible, provisions shall be made for control levers of handles to move in the same direction as that in which the crane and/or load are intended to go. The selection of any velocity stage shall only be possible with the equipment de-energized. Adequate interlock arrangements shall be provided against the possibility that the crane controls being energized unless all control switches are in the "off" position.

The following items shall be provided at convenient points in the cabin:

- An emergency push-button to stop all motions
- Complete instructions for operation, maintenance and lubrication of the crane (to be placed in a suitable cabinet with glazed front)
- 6kg Carbon Dioxide fire extinguisher
- Actuating elements for the signal horn which shall be mounted outside of the cabin. It shall be possible to actuate the horn by hand as well as by foot
- Two battery operated headphones with 40 m of connection cable for direct communication between crane operator and the person giving instructions during difficult hoisting processes (fitting generator and turbine shaft etc.)

### 2.4.1.7 Instrumentation Control Equipment and Electrical Equipment

The crane control system shall be of the full magnetic type, complete with main circuit breakers, master switches, controls, resistors, time or current relays, reversing contactors, overload relays, auxiliary relays, accelerating contactors, limit switches and all other accessories required for speed and operating control as specified.

The coils and contacts of the magnetic control must be enclosed in metal cabinets. The manufacturers shall supply detailed information about the materials used in these components, such as contact life, closing and opening time of the contacts, etc. The main contacts shall be able to operate without excessive wear, overheating, sticking or any other malfunctioning. The insulating material shall be class “A” for a temperature rise of 60 °C above the 40 °C ambient temperature.

The electrical control devices shall be installed in panels and steel cubicles mounted inside the cabin which provide maximum safety to the crane operator and the maintenance staff. All controls shall be conveniently grouped in the cabin to enable the operator to operate the crane from a point where he can best watch all crane movements.

All master switches, hand operated switches, circuit breakers, contactors and relays shall be distinctly and durably marked.

The control switches shall be reversible. All control switches shall be accommodated in adequately ventilated sheet steel housings. Each housing shall have a small heater to prevent condensation. The heating system shall be controlled by a thermostat which will disconnect the current in the event of an undue temperature rise. The resistors shall be air cooled, and corrosion and fire resistant. They shall be dimensioned adequately to withstand all stresses from the crane movements.

**Limit Switches**

The crane shall be equipped with the following enclosed limit switches of the closed-circuit type;

- Block actuated switches to limit upward travel of the load blocks
- Two switches to limit travel of bridge and trolley in both directions, first switch to reduce the speed to creep speed 0.5m before the end position is reached, second switch to stop at end position
- Lower hoist limit switch, gear or chain driven from drum (on auxiliary hoists acceptable for upper and lower hook position)
- 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.

### 2.4.1.8 Electrical Equipment

a) Motors

The motors to be provided shall be induction motors with adequate rating to cope with the load involved.

The motors shall have class F insulation or better and shall be rated for service at an ambient temperature of 60°C. Motors of relatively low-speed shall be given preference.

b) Current Feed cable for trolley

The current feed cables for the trolley shall be arranged so that they are readily accessible for replacement. A sufficient number of cables shall be furnished and installed so that each motor is electrically controlled independent of all other motors and controls. Additional cables shall be provided for grounding the trolley to the ridge frame and for one socket (220 V 20 Amp) which shall be suitably located on the trolley for maintenance purposes.

c) Cables, Cable Conduits and Terminals

All cables shall be supplied by the Contractor. They shall be laid in rigid, galvanized steel conduits with screwed connections and draw-in boxes which shall be suitably built into the crane structure. All cables shall run to terminal strips for making the outer connections. The cables must not be spliced.

Unless stipulated otherwise, stranded cables with PVC insulation or equivalent protection for at least 600 Volts shall be used.

All cables shall be clearly identified by suitable tags or durable markings to facilitate installation and maintenance.

Separate cable conduits systems shall be provided for the power, light and control circuits. The entire cable conduit arrangement shall be grounded. The configuration of all lines, terminal strips and cables shall be subjected to the approval of the Employer.

d) Power supply line for the crane

Power shall be fed to the crane by 4-wire (3-phase plus grounding) rigid copper conductors of the protected type located on the upstream wall of the power house. These conductors, complete with insulating wall-mounting brackets and collectors mounted on the crane, shall be included in the supply.

**2.4.2 Tests**

The following workshop inspections shall be carried out;

1. Overhead travelling crane set, turbine and generator hall
2. Inspection cradle for stacks

**Site Tests**

The contractor shall take notice of the special importance of the availability of the cranes. In addition to the workshop tests, the crane hoist shall be field tested. Concrete and formwork for the test load (125% of nominal load with movement of all direction and 140% for static test) shall be supplied by the Contractor. The Contractor has to provide the design of the subdivided concrete test blocks and the supply of the reinforcement and suspension elements without extra payment. Withdrawal of test blocks is also included in the scope of supply.

Performance of the brakes shall be proved as follows;

- Check of overload trip
- To suspend 125% of the nominal load without drift
- To stop the nominal load with within 10mm of vertical travel when lowering at maximum rated speed
- Deflection of girder and hooks at nominal speed
- To control lowering of nominal load within 2mm when inching the main hook and 3mm when inching the auxiliary hook
- To lower nominal load without exceeding the hoist motor synchronous speeds;
- To lower empty hook at maximum rated speed

During trial operation, the crane shall be tested under operational conditions and with the specified speeds under loads for lifting, lowering inching, braking and transporting. The actual deflection shall be measured and compared with the allowable ones stated the applicable standards.

A complete inspection and overhaul shall be performed at the expense and by the Contractor to bring back the cranes and hoists to the conditions of new equipment if, according to the Employer's approval, they have been used by the Contractor on site for erection purposes, prior to being taken over by the Employer.

### 2.5 Factory Inspection & Testing

The purpose of the test program is to eliminate the transfer of problems in all the equipment in manufacturers' facilities to the site and to minimize installation and startup time. It shall be required to ensure the plants and equipment being purchased, meet the agreed upon design requirements and allowing any issues to be corrected either at manufacturers' facilities or before completion of production.

These tests shall be conducted as per the international standards; ISO 2314, API 616, API 614, API 613, API 617, ASME PTC 22, which ever applicable to the particular test.

The following tests shall be performed at the manufacturers' facilities but not necessarily limited only to those; and any additional tests can be added as per the requirement of employer.

| No. | Equipment and Plants | Type of Test |
|---|---|---|
| 1. | Gas turbine | Mechanical Running & Performance (for both types of fuel) |
| 2. | Gas turbine | Lube oil Console |
| 3. | Gas turbine Compressor | Mechanical Running, Part load running & Full load full pressure, Sealing, Performance, Seal Oil |
| 4. | Gas turbine | Control /instrumentation/ SCADA |
| 5. | Blade, impeller, Rotor | Frequency Response, Rotor Balance |
| 6. | Generator | Mechanical Integrity, Standard Electrical & Mechanical Testing |
| 7. | Intake air cooling or Chilling Plant (if applicable) | Mechanical running and Performance |
| 8 | Fuel Oil Treatment Plant | Mechanical running and Performance Testing of the centrifuge |
| 9. | Water Treatment Plant | Mechanical running and Performance Testing of main equipment of the process |

Any other tests requested by the Employer at the time of manufacturing not necessarily limiting to the above-mentioned tests, shall be performed by the contractor in accordance with the relevant international standards; ISO 2314, API 610, API 613, API 614, API 616, API 617, ASME PTC 22 or any other equivalent, internationally recognized standard which ever applicable for the particular test.

All units of the Gas turbines shall be tested at factory before delivery for declared performance in Gas and Liquid fuel in the presence of Employer's representatives. It is the responsibility of the bidder to facilitate such inspection.

Standard factory acceptance tests for following individual equipment shall also be facilitated on Employer's request.

- Emergency Diesel Generator
- Black start generator/s

## 2.6 Installation & Commissioning

Installation & Commissioning shall be done by the bidder in the presence of Employer's representatives according to the mentioned standards ISO 2314/ASME PTC 22. The final certificate of conformity for each equipment shall be issued on the agreement of both parties.

## 2.7 Documentation

Following Documents shall be provided under this contact;

- Manufacturer's standard installation instructions manual

- Operation Manual for Gas turbine, Generator and auxiliary plant
- Field repair Guide lines
- Maintenance Manuals
- Piping & Instrumentation Diagrams
- Project As-Built Drawings
- Degradation charts of the turbine and compressor for the life cycle period
- Operational Envelope - Accurate charts illustrating design limitations and the performance limitations
- Campbell Diagram of the gas turbine which illustrates the relationship between turbine vibration frequencies with Percent maximum turbine speed.

All the Documents shall be in English Language and for each gas turbine 06 copies shall be Provided. The Soft copies in PDF and AutoCAD shall also be submitted.

### 2.8 Gas Turbine acceptance testing

Gas turbine acceptance shall be done by the contractor in the presence of Employer's representatives according to the ISO 2314/ASTM PTC 22. The results shall be compared for conformity with declared performance values in the Guaranteed Technical particulars.

Any applicable documentation for particular model of Gas turbine such as Heat rate variation with ambient conditions, Performance variation with ambient conditions, Design limitations with ambient conditions shall be provided with the bid in tabulated format and graphical format. Degradation charts of the plant, Surging and stalling limitations of the compressor for design and off design performance shall be provided.

Any negative deviations for Heat rate and Power and Performance of the gas turbines are subjected to penalties mentioned in the special conditions of contract.

### 2.9 Issue of Taking Over Certificate

On successful performance testing of the Gas turbine and with conformity of all the commissioning reports Employer shall issue the Taking Over Certificate.

# 3 Electrical Specification

## 3.1 General

The transmission system voltage for the project is 132 kV. Generation voltage shall be within 11kV to 15kV as per the manufacturer's standard product offered & auxiliary voltages shall be 400 V. Intermediate voltage level of 6kV shall only be used, if necessary, for the switchgear requirement of the starting means of gas turbines.

All plant and equipment shall be designed to ensure satisfactory operation under such sudden variations of load and voltage as may be met under working conditions, including those due to starting loads, transient short circuit, internal and external fault conditions.

The design and installation shall be carried out so as to minimize the risk of outbreak of fire and consequential damage. Where possible materials used shall not support combustion.

Capability curves for the gas turbine driven generator shall be submitted which shall demonstrate that the generator, main connection system, and the associated cooling systems are adequately rated to transfer the output of the turbines over the complete range of loading conditions, grid voltage variations, operating modes and ambient conditions.

The Contractor shall carry out all electrical studies to determine short circuit levels, protection setting and co-ordination taking into account the technical requirements for transmission system interface.

The electrical AC and DC auxiliary systems shall be designed to give adequate and reliable supplies to the various items of plant, together with the necessary standby or duplicated supplies. As a general principle, the failure of no single item of auxiliary plant shall result in the complete loss of unit electrical output. Plant failures may result, at most, in a reduction of electrical output. One gas turbine in the plant, preferably a unit connected to 132kV system shall continue running (on-load) under grid failure conditions and the essential supplies system shall be capable of maintaining the supply to all instruments, controls and auxiliaries required for the safe and reliable operation of the plant and equipment under all normal and abnormal operating conditions. Where electrical equipment is essential to the continued running of the installation, the associated auxiliary power supply systems shall be arranged to allow recovery from fault conditions and also permit inspection and maintenance to be carried out without interference with normal operation.

Electrical earthing arrangement has to be as illustrated in Single Line Diagram (SLD), Appendix E2. The generator voltage system shall be earthed at the neutral of the generator as described in the generator section of this document. The generating voltage side of the unit auxiliary transformer shall be earthed as describe in transformer section in clause 6.3.

Protective relays and systems shall be provided to detect all credible faults on each item of plant and equipment and their primary interconnections. In the event of unacceptable electrical system disturbances occurring, the protection shall operate, as rapidly as possible, consistent with maintaining adequate discrimination, to minimize damage to the plant and equipment and disturbance to the system as a whole. Each protective scheme shall be designed so that it does not cause incorrect tripping of a circuit breaker if a fault occurs outside the zone of protection covered by the scheme. A single protection failure should not prevent fault clearance or cause plant tripping. The plant and equipment shall be capable of being controlled under normal operation from the Central Control Room or locally.

Automatic and manually initiated synchronizing facilities backed up with check synchronizing circuits shall be provided. Synchronizing equipment shall operate satisfactorily in conjunction with the automatic excitation control and the respective gas turbine speed governing equipment. Synchronizing shall be carried out in general, at the generator circuit breaker. However, synchronizing facility shall also be provided at the 132kV Circuit breaker.

As a minimum, the Contractor shall undertake the electrical system studies listed below. The results of these studies shall be provided in report format for review and comment by the Employer.

The design of the electrical power system infrastructure shall be based upon the results of these studies:

**i) Cable sizing calculations**

The continuous current rating sizing calculations for all HV & MV cables shall be done based on appropriate standards and shall verify the short circuit capacity and the voltage drop of the cabling. The sizing calculations for all LV power cables shall be based upon the requirements of IEC 60364/60227 / 60502.

**ii). Auxiliary supplies**

The Contractor shall determine the design of the auxiliary power system; comprising unit auxiliary transformers, capacity of black start/emergency generator. The auxiliary system shall provide a suitable level of redundancy to ensure that the failure of a single item of plant does not cause a loss of generation. To meet this requirement one or two auxiliary transformers shall be provided as illustrated in the single line diagrams (Appendix E2).

**iii). Fault studies**

Studies shall be carried out to determine the voltage profile for the station based upon the full range of working conditions, to ensure that they remain within acceptable limits. The fault studies should take into account the specific requirements for switching generator fed faults and the results shall be taken into account when generator switchgear is selected.

**iv). Transient and dynamic stability studies**

Studies shall be carried out to determine the transient stability during grid fault conditions and the Critical Clearance Times and the Fault Ride Through capability of each generating unit.

**v). Earthing studies**

Studies shall be undertaken in accordance with BS 7671, BS7430, and IEEE Std 80, as a minimum, to design the earthing system for the plant and determine the following:

- Soil resistivity measurement and analysis and derivation of a multilayer soil resistivity model at Power station and 132kV transformer yard
- Safety criteria
- Conductor sizing and earthing system resistance

- Derivation of the earth fault currents and grid currents
- Earth potential rise
- Touch, step and transfer potentials
- Lightning protection earthing calculations

**vi). Protection coordination studies**

The Contractor shall determine the protection arrangements for the station, taking into account the technical requirements listed elsewhere in this document. The Contractor shall also undertake a protection co-ordination study to determine the optimum settings for the protection relays and systems. This shall take account of the interfaces with CEB protection system at their substation and the requirements of the grid Code. This study shall derive settings for all of the protection relays installed on the plant and provide a separate setting sheet for each relay listing the settings to be applied. These settings shall ensure discrimination is achieved where possible to ensure only the faulted section on the power system is isolated in the event of a fault. The protection settings shall be based upon the fault currents and loading shall highlight any co-ordination and protection issues that may occur when the system is expanded to its full development.

**vii). Insulation coordination studies**

The Contractor shall undertake insulation co-ordination studies in accordance with IEC 60071 which take account of the following:

- Temporary over voltage resulting from HV earth faults
- Temporary over voltage resulting from LV earth faults
- Temporary over voltage resulting from load-rejection and short-term unearthing of the site
- Transient over voltages resulting from lightning impulses, originating from the external network
- Switching transient over voltages resulting from fault and fault clearing at HV ( and MV, if any) point-on-wave
- Switching transient over voltages resulting from load rejection: point-on-wave Switching transient over voltages resulting from transformer energization

**viii). Lightning protection studies**

The Contractor shall undertake a study to assess the risks and provide a suitable lightning protection system and design in accordance with IEC 62305.

## 3.2 Generator and excitation system

### 3.2.1 Scope

This section covers the generators, excitation equipment and associated auxiliary equipment of the Power station. The generator shall be of an established design having a proven record of reliability for similar applications. The generator shall comply with the requirements of the relevant sections of IEC60034.

Manufacturer of the offered Generator shall have at least 15 years of manufacturing experience and offered Generator shall be the latest model which is in production and same shall possess minimum 10 years satisfactory international operational experience in gas turbine power plants. Generators and excitation systems manufactured under license of parent companies are not acceptable.

### 3.2.2 AC Generator operating conditions

The generators shall be designed for the following operating conditions:

Generator shall be of duty type S1 as stipulated in IEC 60034 and coupled to the gas turbine. The generator cooling system shall be totally enclosed water to air cooling system filtered at the inlet and hot air outlet from the bottom of the stator casing. The design and supply of the entire cooling system shall be part of this contract and shall be based on a maximum ambient air temperature as specified in Clause 3.4 of Volume 2.

The number of generator sets shall be three (03) units and those shall deliver the total plant output specified under this document. Each Generating Unit shall be capable of continuously delivering the maximum continuous rating (MCR) of the 3 phase 50Hz generator at any point between the Power Factors of 0.8 lagging and 0.9 leading, in accordance with its reactive power Capability Curve. When operating at above power factor range, MCR plus the generator losses shall not be less than the base load rating of the associated gas turbine when operating at any ambient air temperature between the limits of 15°C & 38°C. The generator shall have the capability to match the gas turbine operation for limited periods of time at a peak load rating equal to at least 105% of the base load rating.

The following shall also be considered in deciding the Generator ratings;

| | |
|---|---|
| Rated MVA at 0.8pf at maximum ambient temperature as in clause 3.4 of Volume 2 | :to meet the capacity of Generators in excess |
| Number of Phases | :3 |
| Frequency | :50 Hz |
| Rated Power Factor | :0.8 |
| Insulation Class of the insulation system | : Class F (According to IEC60085) |
| Maximum Ambient Temperature | : See Clause 3.4 of Volume 2 |
| Altitude | : Less than 1000 m above mean sea level |
| Unbalance operating condition | : According to the IEC60034-1 Voltage variation at MCR and Rated |
| Frequency | : ± 5% |
| Frequency variation at Rated Output | : 47Hz to 52Hz rated voltage and rated power factor |
| Degree of protection | : IP44 according to IEC 60529. |

#### 3.2.2.1 Performance Curves

Performance curves for the offered generator with its excitation system shall be provided with the bid documents. The following curves provided shall be provided and shall not be limited to the same.

1. Output Vs Air inlet temperature
2. Reactive power capability diagram
3. Efficiency Vs Output
4. Open and Short circuit curves
5. Generator V Curves
6. Permitted voltage / Frequency variation
7. Pilot exciter regulation characteristic

### 3.2.3 Stator

#### 3.2.3.1 Stator Core, frame and covers

The stator core shall be built up of high permeability low loss thin laminated silicon steel stamping, tightly clamped together to reduce noise and vibration to a minimum. Strict quality control shall be practiced in stamping to ensure a minimum height of burr of lamination and as far as practicable the lamination shall be without burrs. The lamination shall be adequately keyed or dovetailed to the stator frame and shall be held securely in place. Manufacturer shall use his standard method of core clamping to ensure even distribution of the clamping force throughout the core laminations and to avoid core slackness and distortion in long term use. Description of the method of core clamping shall be provided with the bid.

Manufacturing process shall select lamination insulation material with low dielectric permittivity and good insulation properties under higher stress and shall ensure that optimum use of core insulation material to avoid core relaxation in long term use. Information of the method use in core insulation shall be provided with the bid.

Conductor slots shall be smooth and free from sharp corners.

Design of the core shall ensure sufficient amount of ventilation ducts to have uniform cooling of the stator core.

Stator frame shall be of fabricated construction and shall preferably be of box section to resist the stresses due to short circuit or other abnormal forces. Flanges shall be provided on the frame to facilitate inlet, outlet air ducting and CT chambers.

CT chambers shall be of metal clad design and shall be sufficiently earthed. It shall be possible to test and replace CTs without any difficulties or major dismantling of other parts. Contractor shall coordinate with generator protection design to provide enough space for all the protective and metering CTs to be installed in the neutral end of the stator winding.

The generator end shields at both ends shall be designed to prevent contaminant such as oil, moisture, dust and other material ingress into the rotor and stator. Filters, seals and gaskets to be used on the end shields shall be heat and oil resistant type. All the protective covers and air shields shall be manufactured of steel plates welded together, stiffened with suitable angles and channels and formed in segments for ease of handling. The sections shall be bolted together and to the stator frame. Stator casing including all joints and duct connections shall be gas tight. Stator core end shields shall be approved type nonmagnetic material.

The stator frame shall be provided with suitable lugs or bobbins for receiving the wire slings for suspension of the complete stator. Sufficient number of such wire slings shall be provided as special tools.

List of all special tools required handling the stator frame and complete stator with winding and core during major dismantling of the unit shall be provided with the bid and cost of such special tools shall be included in Schedule 3, Special tools of Volume 5.

Design of the complete stator and installation method shall be to prevent vibration being transmitted to the foundation of the generator or any associated equipment.

### 3.2.3.2 Stator winding

The stator winding shall be star connected. The stator winding insulation shall be of Class F design and uniform thickness with non-hygroscopic material. Form wound stator winding insulation shall be either VPI of individual coils and bars or Global VPI of complete stator. Design and material selection of the insulation system shall ensure increasing thermal conductivity and increasing resistance to partial discharges.

The design shall ensure that no fretting of the coils in the slots and the winding overhang occurs under normal operating conditions. The integrity of the stator winding shall not require post manufacture resin injection of the slot portion in order to achieve this requirement. Slot and end winding discharge shall not occur and the design shall ensure that slot wedge tightness and radial pressure on the coils is maintained to ensure satisfactory operation for the life of the plant. It shall be possible to re-tighten slot wedges if required. No retightening of the end-winding clamping between major maintenance overhauls shall be required.

The generator shall be specifically designed to operate at 50 Hz. In particular, stator end windings, terminal connections and their support structures shall be designed such that the natural vibration frequencies are well outside the forcing frequency of 100 Hz, and this shall be confirmed by bump testing. There shall be no significant dusting of the end winding insulation indicating insulating fretting and damage. The stator end windings shall be designed to last the design life of the generator without failure.

The stator slot wedges shall be capable of withstanding the bursting force imposed during the most arduous electrical short-circuit between adjacent coil connections of different phases.

Bracing of the winding overhangs shall be done to avoid any strains at the point of leaving the core and to have enough space to the adjacent winding to avoid partial discharges between phases during the long-term use.

### 3.2.3.3 Stator winding Terminals

Shall be phase segregated designed according to IEC 60034. Terminal marking shall be according to IEC 60034-8. Both ends of each phase winding shall be brought out to insulated terminals. Neutral star point shall be connected to the earth via earthing cubicle specified in clause 6.5.2.3.

The connections between the generator and the generator circuit breaker shall comprise of suitably rated sized medium voltage Isolated Phase Busduct (IPB) as per the standards IEEE C37.23.

### 3.2.3.4 Heaters

Low temperature heaters along with supply cables shall be installed for maintaining the stator and exciter surrounding air temperatures at about 5 ˚C above ambient for the purpose of preventing condensation of moisture on the winding during shutdown periods. An On/Off/Auto switch and a red "heater on" indicating lamp shall be fitted on the Generator Control Panel. A further auxiliary contact shall be included on the generator circuit breaker to automatically cut-off the supply to the heaters after synchronizing. This auxiliary switch shall be paralleled by a further auxiliary switch which closes if the circuit breaker is isolated.

### 3.2.3.5 Temperature Rise and Measurements

The generator temperature rises as determined by heat run tests and measured by the machine temperature devices shall not exceed the limit for Class B insulating materials specified in IEC 60034-1 for site and operating conditions.
The following temperature detectors shall be provided on the machine

- 09 Nos of RTDs, 3 per phase, in the stator slots
- 03 Nos of RTDs embedded in the stator core/teeth with one in the core end region where it is anticipated the maximum temperature will occur
- 02 Nos of RTDs in the alternator cooling circuit inlet and outlet
- 02 Nos of RTD in the exciter air inlet and outlet

In addition, arrangements shall be provided for the local indication of the temperature and flow of oil from each bearing pedestal. Instrumentation shall also be provided to continuously monitor the temperature of the generator major components which, as a minimum, shall include the following:

- Bearings
- Cooling media to and from the stator and rotor cooling system
- Rotor
- Shorted turns in the rotor winding
- Adequate spare temperature sensors shall be fitted to the generator but not connected.

These shall be wired back to the control room and shall alarm on high temperature.

The temperature detector leads shall be brought out to a terminal box at the side of the generator where the detectors may be tested.

#### 3.2.3.6 Miscellaneous

Bearing pedestals shall be insulated from the bedplate foundations and oil pipes to prevent circulation of shaft current through the bearings. It shall be possible to test the insulation without having to dismantle the bearing.

Each coupling assembly shall be designed to withstand the forces that may be experienced at that coupling during the stated fault conditions without sustaining permanent deformation of components.

Journal bearings shall be readily accessible, adjustable and replaceable with minimal disturbance to adjacent components.

All necessary measures shall be taken to prevent leakage of oil from bearing pedestals and pipe work under all conditions of operation including shut down.

### 3.2.4 Rotor

The rotor shall be of Cylindrical rotor type with solid forged steel designed to have a large margin between the critical and running speeds under normal operating conditions. The rigidity of the rotor body along the pole axis and along the winding axis shall be equalized as far as possible to avoid double frequency vibrations. The body of the rotor shall consist of a single-piece steel forging of high-grade carbon steel or alloy steel, quality tested according to the most modern practice.

The winding slots for the rotor and damper windings are to be arranged to ensure even heat distribution and to avoid local overheating under all operating conditions. To equalize the different amount of inertia of the neutral and pole axis, additional transverse slots are to be provided for in the pole axis.

Provision shall be made to prevent arcing under short circuit conditions between the end rings and the rotor body. The support of the endings shall be such as to minimize any hammering action between the rotor body and the end rings due to altering deflection of the shaft ends.

The rotor end winding retaining rings manufactured of high-grade alloy steel or non-magnetic steel with high mechanical properties, are to be shrunk onto the rotor body with a free-floating end. Additional measures should be taken to prevent axial movement.

Adequate provision shall be made for cooling the conductors and slot teeth with a view to obtaining a uniform temperature gradient throughout the length and depth of the slot. At either end of the rotor, axial or radial-type fans are to be mounted to establish the internal air circulation.

The complete rotor shall be balanced statically and dynamically and shall withstand 1.2 p.u. rated speed. Under the same conditions the mechanical stresses of the rotor body and retaining rings shall not exceed 70% of the yield point.

### 3.2.5 Fire Protection

Suitable Approved Fire Protection to the employer's approval shall be provided unless the generator comprises entirely of material which are non-inflammable or self-extinguishing.

### 3.2.6 Generator Neutral Earthing

The generator neutral shall be earthed via a dry type, cast resin, single phase power distribution type transformer as depicted in the Appendix E2. The secondary winding of this transformer shall be loaded with a grid type resistor. Design shall be based on IEEE 665, IEEE 80, IEEE 32 and other relevant IEEE standards.

The neutral earthing transformer ratings such as Maximum short time thermal power rating (60 seconds), Rated continuous power, Rated ratio and Primary / secondary voltage rating shall be designed according to IEEE C62.92.2-2017 and design calculation shall be provided to the CEB for prior approval.

The knee point primary transformer voltage shall be not less than 130% rated system voltage (phase to phase).

The secondary winding of this transformer shall be loaded with a grid type resistor and its ratings such as Resistance, Maximum short time thermal power rating (60 seconds) and rated continuous thermal power rating shall be designed according to IEEE C62.92.2-1989 and other relevant IEEE standards. The value of the resistance shall be designed such that the current through the primary of the neutral earthing transformer, for a single phase to ground fault is limited to between 5 to 15 A. The design calculation of this resistor shall also be based on IEEE C62.92.2-2017 and shall be provided to the CEB for prior approval.

### 3.2.7 Special tools

Special tools for assembling and dismantling the generator, including jacks, slings, lifting beams, skids, shaft extensions, shall be provided.

### 3.2.8 Excitation system

#### 3.2.8.1 Mode of Operation

It has been identified that Load operation (active power and reactive power), blackout restoration and frequency controlling are the major operation mode of this plant. Excitation system for the generator assembly shall be capable of catering all these operation modes in steady and transient conditions.

#### 3.2.8.2 Basic requirement

Excitation system offered shall be a continuously acting on electronic system of proven and state of the art technology.

The system proposed shall be a standard product of the manufacturer's product line.

Manufacturer shall have experience in manufacturing excitation systems for synchronous generators of capacity above 30 MVA, 0.8 pf and rated speed around 3000rpm, for at least fifteen (15) years and minimum 10 years satisfactory operational experience in outside the country of manufacturing.

The continuous rating of the exciter shall be such that all conditions of the generator loading can be obtained without exceeding permissible temperature rises (Refer IEEE Std C50.13 - 2014). The offered excitation system shall work lively with the generator controls during starting, synchronizing, steady state running, stopping and during transient states.

The response time of the excitation system shall be less than 40ms and with high initial response to transients of power system in both positive and negative ceiling direction.

The voltage regulation accuracy shall be equal or less than 0.5%.

The excitation system shall be capable of maintaining its operation correctly for the frequency variations in range of 40 – 60 Hz (Refer IEEE Std C50.13-2014). The rotating mechanical parts and the electrical parts shall be capable of withstanding transient and steady state mechanical stresses and voltages due to over speed of 120% (Refer IEEE Std C50.13-2014).

AVR power supply shall highly reliable system with dual redundancy and inputs from excitation transformer, AC station auxiliary supply and station DC power supply.

The power supply units for excitation system shall ensure the continuous and stable operation of the excitation system under all working conditions. Effects from voltage fluctuation in generator terminal any voltage dips due to three phase short circuit fault on generator shall not reflect on excitation system or mal operation of protection.

Contractor shall give Mathematical model of exciter and transfer function of AVR control loops including limits and PSS function.

The excitation system shall meet all technical requirements set forth in this specification under the operating ambient condition of 0°C to +50°C with a maximum monthly relative humidity of 98%.

**3.2.8.3 Excitation type and power supply configuration:**

Excitation system for each generator shall Direct control static type excitation system (ST1A dynamic model of IEEE std 421.5.2016) with high initial response (IEEE std 421. 1-2007).

Excitation power shall supply from generator terminals through suitable excitation transformer, fully controlled three phase thyristor converter and slip rings and is applied to the generator field. The initial excitation power shall provide by field flashing.

### 3.2.8.4 Exciter Ratings

#### 3.2.8.4.1 Steady state ratings.

**Rated continues current**

The continuous current rating shall equal or exceed the maximum required by the synchronous machine field under any allowed continuous operating conditions which specified by generator performance chart and within ±5% of rated terminal voltage. The excitation system shall capable to provide at least 105% of field current continuously (ANSI C50.13-2014)

**Rated continuous voltage**

The continuous voltage rating of an excitation system shall sufficient to supply the necessary continuous current to the synchronous machine field, with the field at its maximum temperature under rated load conditions. In addition, the continuous voltage capability shall allow operation of the synchronous machine at rated MVA and within ±5% of rated terminal voltage. The all voltage drops up to the field winding terminals shall be considered in designing stage.

#### 3.2.8.4.2 Transient Requirement

**Ceiling current**

The ceiling current of the excitation system shall have a transient time capability equal to or greater than the short-time overload capability of the synchronous machine to which it is connected. ANSI C50.13-2014 gives the field winding short-time thermal overload requirements for cylindrical rotor (IEEE 421.2-2014). This ceiling current shall ensure sufficient current flow for the satisfactory operation of the over current protection and to permit continuous AVR operation during, and immediately after system faults.

**Ceiling voltage**

The excitation system shall be designed to provide a positive ceiling voltage of 2 times of rated field voltage for the duration of 10s (ANSI C50 13-2005) and this ceiling voltage shall capable to reach allowable maximum response time of 40ms (two cycles), while the negative ceiling voltage shall not be less than 1.6 (70% of positive ceiling) times of the rated voltage. The basic insulation level (BIL) of excitation transformer, converter and generator field shall be complied with is ceiling voltage.

The excitation system shall operate during fault conditions down to a specified percentage of rated terminal voltage (25% of rated synchronous machine voltage is suggested, Refer IEEE Std 421.4-2014). After restoration of the supply voltage, the excitation system shall be capable of immediate recovery and shall be able to provide maximum available voltage to restore the system voltage.

**Small signal control system performance**

Characteristic for the small signal performance shall be follow the following values of the performance indexes described in characterizing good feedback control system performance, refer table 01of IEEE Std 421.2-2014.

- Gain Margin ≥ 6 dB
- Phase Margin ≥ 40º
- Overshoot - 0 to 15%
- Damping ratio ≥ 0.6

### 3.2.8.5 Excitation controls

Excitation control shall coordinate with turbine controls, generator controls and protection. Excitation system shall be interfaced with generator controls to accomplish the commands and feedback signals in a conventional manner (hard-wired commands via direct and relay logic circuits). Facility shall be available for remote communications through 100 Mbps Ethernet with OPC server and SCADA facility to interface with DCS. For this purpose, the manufacturer shall supply the drivers/license for the OPC server, which is based on Windows.

The excitation system shall have both “local” and “remote” control modes, which can be chosen by a control terminal mounted on excitation panel. When remote control selected, the operator at the remote end shall be able to issue commands such as increase, decrease of generator voltage/Reactive power, and Automatic / Manual controller selection, synchronizing commands, etc. The contractor shall provide Increase / Decrease generator Voltage / Reactive power, center zero spring return control knobs and Automatic / Manual selection knobs at the control room as well as at the excitation panel. Selector switches shall also be provided to select AVR (voltage control), FCR (Field Current Regulator) modes, PF mode (power factor control), reactive power control (MVar), and Joint control (JC) modes at the excitation panel and remotely at Central Control Room. The excitation system shall be equipped with self-diagnostic facilities for a fast problem identification and rectification. The modern computer-based tools for local and remote maintenance and diagnostic purposes shall be used as a part of the diagnostic facilities.

The Excitation system shall comply with EMC (Electromagnetic Susceptibility) and shall be type tested according to the standards for anti-interface emission and immunity. The annual forced outage ratio (FOR) of the excitation system shall be not more than 0.1%.

### 3.2.8.6 Automatic voltage regulator (AVR)

The automatic voltage regulator unit (AVR) shall be of continuous acting, and based with state of art technology. The automatic voltage regulator (AVR) shall consist of an Automatic channel for generator (terminal voltage) voltage control, power factor control, reactive power control or joint control and shall facilitate smooth bump less online transfer between four control modes if needed.

There shall be a Manual channel for Field current control with field current feedback. The Manual controller for the Field current regulation shall be used mainly for the test purposes (during commissioning and maintenance of the equipment) or as a backup control mode in case of loss of measuring signals for AVR, i.e., due to PT failure or PT fuse failure, which shall be alarmed at each operator level locally and remotely.

The AVR shall apply PID control with three individual sets of parameters in order to achieve a perfect dynamic performance of excitation system of synchronous generator on network.

One set of parameters is assigned for the automatic voltage regulator. The other two sets of parameters shall be automatically selected upon activation of a certain limiter, e.g., under excitation field current limiter etc. & activation of Power system stabilizer (PSS).

Bi-directional self-balancing follow up control shall be provided between AVR and Manual Mode of operation. The control logic shall ensure an intelligent and smooth change over between AVR and manual mode. The balance condition shall be indicated at Excitation panel locally and at control room. A change over shall not cause any noticeable change in excitation current and generator voltage.

There shall be a provision for the automatic synchronizer to raise/lower the set point during synchronizing process.

The AVR shall include the function for the active and reactive power compensation. This function is needed partly to compensate for the voltage drop across the unit transformer and/or the transmission line. The AVR shall also include the reactive power sharing/quadrate droop facility.

Power System Stabilizer (PSS) shall be provided to allow the generator unit to produce a damping effect to the electro-mechanical oscillations originated either from the power system disturbance or from the generator operation itself, and consequently, to improve the machine

response to the power oscillations. PSS control algorithm shall be based on IEEE 421 5. 2005-type 2B standard and the stabilizing signal shall correspond to the acceleration power signal resulting from a combination of the electrical power and rotor angular frequency input signals. PSS shall cater inter plant oscillations, Local area oscillations and inter area oscillations (0.2Hz to 3Hz range) Summarized AVR required functionality.

Required functions and feature of the AVR is listed in Table 01.

**Table 01 – AVR Functions and Features**

| Feature | Description | Comment |
|---|---|---|
| Technology | State of art technology | Modern and fully developed |
| Regulator functions | Relevant PID and feedback loops and relevant PID arrangement (PID block position)<br><br>Ability to onsite reconfiguring and tuning of PID parameters, parameters of Lead – Lag compensate | PID control block should be placed in optimum position of control loop to get perfect dynamic performance. |
| Limiter functions | To ensure the operation within generator safe region and allow very short-term operation from out of continuous operation region. (Example -Imax thermal and Imax ceiling. (Refer IEEE Std C50.13-2005) | |
| Monitors | As protection | |
| AVR Mode | Regulate generator terminal voltage | Ability of on-line selection and smooth on line transferring between other operating modes. |
| PF Mode | Regulate generator terminal power factor | Ability of on-line selection and smooth on line transferring between other operating modes. |
| MVAR Mode | Regulate generator reactive power generation | Ability of on-line selection and smooth on line transferring between other operating modes |

| Feature | Description | Comment |
|---|---|---|
| Joint Voltage Control Mode | Control strategy responding together in a coordinated response to two or more machines causing a proportional change in multiple generator outputs. The adjusted machine quantity can be voltage (or vars if appropriate). When the control strategy signal is raised or lowered, all machines will increase or decrease their output accordingly. | |
| $I_f$ Mode or Manual mode | Regulate generator field current (manual channel) | When AVR or MVAR is in operation, $I_f$ mode shall act as backup mode<br><br>Auto follower with other channels for bumpless transfer. |
| Line charge mode | Need for long transmission line energization in blackout restoration. | To avoid over voltages black out restoration. |
| PSS | Mitigate inter-plant, inter-area, local area power oscillations (0.2Hz -3Hz).<br><br>Shall get dual inputs (active power and rotor angular frequency. | Must be commissioned in site conditions. Refer IEEE .421.5.2016 |
| Voltage droop compensation | Control and sharing of reactive power in parallel generators operation. | |
| Voltage drop compensation | Compensate transformer inductive drop in voltage regulation | |
| Soft start | Starting excitation in ramp mode to avoid overshoot. | |
| Reverse polarity voltage injection | To minimize stored energy during field breaker opening. | Inverter mode operation of converter |
| High initial response | Quick response to transient state variations. (An excitation system capable of attaining 95% of the difference between Ceiling voltage and rated field voltage in 0.1 s or less under specified conditions.) Refer IEEE Std 421.1-2007. | Excitation should be sized for required ceiling limits i.e., high ceiling level should give low response time. |

| Feature | | Description | Comment |
|---|---|---|---|
| Redundancy concept (n-1 concept) | Control channel | Two no of complete AVR module with all hardware (one operation and one backup) | |
| | Power supply | Three separate sources (PT from generator terminal, Auxiliary AC, from DC bus) | |
| | Converter | Two Complete converter modules with all protection cooling, sensing equipment. | |
| Operating mode changeover | | Smooth transfer without any over or under shoot. | |
| Auto – follower | | Manual channel shall follow auto channel set point to smooth transfer when auto channel fails. | |
| Protection coordination with generator protection relays | | Mainly following functions of AVR shall coordinate with generator protection.<br>1. Voltage per Hertz<br>2. Under voltage<br>3. Over voltage<br>4. Loss of field | |
| Separate Protection | Rotor earth fault | Frequency injection scheme shall cover 100% of field winding. | |
| Online real time monitoring | | To check operating condition parameters (analog/digital), Setting Parameters and AVR control logic | |
| Historical data recoding | | Ability to plot selected parameters with respect to time with high sampling rate. (During transient conditions)<br>Ability to provide correct trends in sampling. | |
| Control and communication | | Shall have several programmable levels of password protection, in order to view data records, retrieve data records and to change parameters.<br>Shall communicate with Unit Controller.<br>Shall able to connect through local PC with the software with uploading, calibration, tuning, editing and commissioning. | |



### 3.2.8.7 Redundancy

**1).** Shall provide complete redundant electronic excitation control unit with identical configuration of the running unit. Shall carry out continues monitoring on running unit and smooth transfer at a fault of the running unit. (Dual channel or n-1 redundancy).

2). Shall provide complete redundant fully control thyristors converter module with firing module, protection and thyristors cooling system.

3). Shall provide redundant equipment for input signals (VT, CT), measuring signals (Hole effect transducers etc.) and AVR power supply unit.

### 3.2.8.8 Availability

The annual forced outage rate (FOR) of the excitation system shall be not more than 0.1%. The FOR is calculated as ratio of number of hours the unit is on forced outage over the total number of hours in a year, as specified in IEEE 762-2006.

### 3.2.8.9 Limiter functions

#### 3.2.8.9.1 Maximum field current limiter

Maximum field current limiter (Over excitation limiter) shall be provided with an instantaneous and inverse time characteristics in order to limit the field current for maintain operation under rotor thermal capability limit. (Refer IEEE Std C50.13 -2005) The instantaneous maximum field current limiter shall be provided with due consideration to the ceiling (field forcing) limitation and thermal limitation (maximum continuous current) with corresponding heating-up and cooling-down time constant. Maximum field current limit shall provide with recalibration methodology based on generator cooling.

#### 3.2.8.9.2 Under excitation limiter (PQ Limiter)

This limiter shall have the function of active power versus reactive power absorption (PQ limiter) and shall prevent generator stator end ring heating and shall prevent operation beyond under excitation limit which is specified by performance curve of the generator or steady state stability limit. This limiter shall coordinate with generator loss of field protection and PSS function. The under-excitation limiter may be specified for recalibration based on synchronous machine operating temperature.

#### 3.2.8.9.3 Minimum field current limiter

Independently on the under-excitation limiter, a minimum field current limiter shall be provided to prevent the flow of a very low field current and to prevent interruption to the field current. This shall coordinate with generator loss of field protection function.

#### 3.2.8.9.4 Stator Capacitive current limiter

In addition to PQ limiter and field current minimum limiter stator capacitive current limiter shall act as a backup protection.

#### 3.2.8.9.5 Volts per hertz or over flux limit (v/f)

This limiter shall protect generator and transformer from over flux condition especially it shall be below the safe v/f limit of transformer. This shall be concerned that the new gas turbines are supposed to start up in to dead bus or blackout restoration. This limiter shall co-ordinate with generator transformer v/f protection function and protection relay.

The limiter shall be activated after an adjustable delay time.

#### 3.2.8.9.6 Stator Inductive current limit

There shall be a stator inductive current limiter to prevent the generator current being exceeded beyond the rated induction current capacity of the generator and shall coordinate with over excitation limit.

### 3.2.8.10 Monitoring functions

Following continues monitoring facilities shall be required.

1. PQ Monitoring
2. Rotor earth fault monitoring
3. V/f monitoring
4. Rotor temperature monitoring
5. Excitation Transformer Winding Temperature
6. Stator overcurrent monitoring
7. Stator overvoltage Monitoring.
8. Measurements Monitoring
9. Monitoring of the monitored Components
10. Ripple Monitoring
11. Converter Fault Monitoring
12. Auxiliaries Ready Monitoring
13. Power Supply Monitoring
14. Converter Temperature Monitoring

### 3.2.8.11 Excitation transformer

1. The excitation transformer shall be of three winding step-down dry type transformer with convection cooling.

2 The contractor shall decide the transformer VA rating and Basic Insulation Level (BIL) to continuously supply 1.05 times rated field current and also to supply adequate power during (field forcing) ceiling conditions at least for 10s.

3 The contactor shall provide the design calculations for the excitation capacity to the employer along with the offer.

4 Transformer shall withstand harmonic currents which created by the fully controlled thyristor bridge (especially in $5^{th}$ and $7^{th}$ harmonics).

### 3.2.8.12 Thyristor converter

The full control three phase (six thyristors and separate triggering for each thyristor) converter shall consist of one fully redundant thyristor bridges with 100% capacity. Converter shall able to provide continuous over voltage sufficient to drive the continuous 1.05 time of rate field current, defined field forcing and ability to smooth transfer (without any interruption) from faulty converter to redundant converter. Separate force cooling systems shall provide running and redundant thyristor bridge.

Each of them shall be rated to work in all operating conditions including field-forcing, conditions of induced over voltages due stator side maximum faults and transient conditions. The rectifier bridges in service shall be activated by the pulse generators and amplifiers of the excitation control units.

The repetitive peak reverses voltage and the peak off state voltage of the thyristor shall satisfy a voltage security factor of at least 3 times the maximum peak of secondary voltage of the excitation transformer.

The design of the ventilation equipment must be such that it avoids the entrance of foreign objects into the thyristor bridge, which can damage the bridge. The supply of the fan(s) must be taken from a dry type transformer with relevant supply voltages of fans, connected to the excitation transformer or for test purposes from the force supply provided from the auxiliary services AC network. The operation of the fan(s) shall be in Manual mode for testing purposes and in Automatic mode when the unit is operating.

The operating condition of temperature detection sensors (RTD) and operation condition of thyristor cooling fans shall include to AVR control logics as protection aspects.

**3.2.8.13 Field Circuit breaker**

1. Field Circuit Breaker (FCB) shall be located in d.c circuitry.
2. Ability to disconnect rotor winding from excitation system at maximum possible field currents.
3. The contractor shall guarantee that FCB open (trip) time and the closing time are within the stipulated standards and shall comply with rotor thermal capability and maximum possible field current. (Refer IEEE Std C50.13 -2005)
4. Opening and Closing of FCB shall be coordinated with AVR control, Generator control and Generator protection.
5. Polarity reversing link for slip rings shall provide to equalize the abrasion of slip rings

**3.2.8.14 Field Discharge / De–excitation**

1. There shall be a Field suppression circuit consisting of Field discharge circuit breaker non-linear discharge resistors or linear resistor with CROWBAR Thyristor (crowbar protection) and related power electronic devises.
2. The field discharge resistor shall be sized to field breaker arc voltage and maximum possible field voltage and shall be capable of absorbing energy due to induced ac field current created by generator terminal short circuit faults and ceiling currents at any operation condition.
3. Inverter mode operation of Converter shall support to field discharge in normal operation.
4. Field discharge circuit breaker shall comply ANSI/IEEE C37.18-1979.

### 3.2.8.15 Protection

The excitation system shall have protection means to supervise and ensures that the system is maintained inside its design operating conditions, and protects it in case of failures, with trigger and signaling in the local and remote alarm panels/units. The operation of all protection, as well as related alarms, will be stored in the excitation system event logger and the same shall be displayed in HMI PC as well.

#### 3.2.8.15.1 Annunciator Action

Annunciation shall be considered within the excitation system in addition to the Gas Turbine Local Control HMI PC and operator HMI PCs in Central Control Room to alert operators to potential problems or to aid in the determination of conditions that may have caused the excitation system to trip, minimizing equipment troubleshooting time. In addition to annunciation of those protective actions, annunciation shall provide loss of control power supplies, loss of regulator sensing, high temperatures within the excitation cubicle and failure of thyristors and fuses. Although several of these functions may be grouped together for annunciating to operators in a remote location, independent annunciation or local diagnostic display should identify individual faults locally.

#### 3.2.8.15.2 Regulation Channel Protection

It shall have protection that monitors the correct operation of the devices that comprise the voltage regulator (AVR unit). When a transfer occurs from the automatic channel to a manual channel by the operation of some protection, a signaling indication that the transfer was automatic shall be provided. For the case of manual transfers by the operator, the before mentioned signaling shall not be provided.

#### 3.2.8.15.3 Protection for Field Overcurrent.

This protection shall be operated when the detected field current in DC exceeds the allowed limits by the rotor and cannot be controlled by the proper devices of the Automatic/Manual channels.

#### 3.2.8.15.4 Protection of the Rectifier Bridge

The rectifier bridges shall have systems that monitors and protects when the generator is online. If a failure of the rectifier bridge occurs, the failing bridge must be blocked and maintain the rest of operation by smooth transferring to the redundant systems equipped.

- **Protection for Thyristor Overcurrent**

  This protection shall protect against excessive current conditions and can affect the operation of the thyristors. It should be done through ultra-fast fuses installed in each thyristor, provided with contacts for alarm and signaling for the protection circuit for failure of thyristor. The operation of this protection shall block the failed bridge and maintain the rest of the rectifier bridge operating.

- **Protection for Thyristor Overheating**

  The excitation unit shall have temperature sensors for each thyristor bridge. The operation of this protection shall block the failed bridge and activate transfer to the standby rectifier bridge. If this is not available it should trigger an excitation system failure.

- **Protection for Over Heating of Overvoltage in Field Winding**

  This protection shall limit the overvoltage in the thyristors produced by any internal or external condition that generates overvoltage in the field winding that exceeds the capacity of the excitation system components.

- **Protection against High rate of change of voltage**

  Protection shall be provided against high dv/dt by using parallel RC (snubber) circuit for each thyristor.

- **Protection for Failure of Trigger in Thyristor Gate**

  This protection shall supervise the continuity of the trigger pulses of the thyristors in an adequate form. The operation of this protection shall send a transfer to the redundant excitation control unit that has its own independent pulse generator.

- **Protection for Cooling System Failure**

  The operation of this protection shall send a block to the affected bridge and an alarm to the control panel and unit operation consoles installed at local control cubicle ad central control room. In case of standby bridge failure, a stop sequence must be initiated.

### 3.2.8.15.5 Protection for Field Winding

**Protection for Ground fault of Rotor or Field Winding**

The detection device for a ground failure in the field winding shall measure the insulation (capacitance/resistance) of the field winding to ground and shall cover and protect 100% the of rotor winding which should operate based on the injection principal.

### 3.2.8.15.6 Other Protections

It shall contain the protection functions and but not limited to followings.

- **Protection for Long Time in Forced Excitation**

  This protection shall provide to maintain the integrity of the excitation system and shall operate when the initial excitation exceeds the time established for a normal sequence, this time should be defined by the manufacturer.

- **Protection for Overvoltage**

  The excitation system shall withstand, without damage, any faults or abnormal operation of the synchronous machine. Faults on the synchronous machine ac terminals will induce a large positive current into the field (adding to the normal field current) which will have a dc and an ac component at the machine frequency. The peak of the ac component of the induced fault current will be additive for one of the rectifiers and provisions must be made for this overload duty. IEEE C37.18-1979 (ANSI) should be followed for selecting the magnitude and time duration of the induced currents for design purposes.

Protective devices such as non-linear resistors or thyristor crowbar circuits with linear resistors shall be sized to limit the voltage to acceptable levels for both the semiconductor bridge and the generator field winding while having adequate thermal capacity to carry the field current, which must flow to limit the voltage.

### 3.2.8.16 Field Flashing (Initial Excitation)

1. The field flashing shall be provided to enable the initial excitation when the generator is at 95% of rated speed and Excitation ON command is activated and total operation shall control by AVR control.
2. The energy for the field flashing shall be derived from the AC auxiliary station supply or from DC station battery supply.
3. Field shall consist with field flash breaker, reverse blocking diodes and series resistor for current limiting.

### 3.2.8.17 Power Supply of AVR Unit

There shall be redundant power supply systems of inputs from station AC auxiliary supply three phase, 400 V, 50 Hz: voltage deviation +15 to -15% of rated voltage, frequency deviation – 4 ~ +4% of rated frequency and from station DC supply with -20% ~ +20% of rated voltage. In case of a failure of one source or a failure of one power module, the operations of control electronics shall not be interrupted and appropriate alarms shall be brought up indicating the source /power module which has failed.

### 3.2.8.18 Human Machine Interface

A local control panel shall be provided in excitation panel for the local control and supervision of the excitation system.

**This local control panel shall have at least the following features.**

1. LCD screen with a visual user interface including push buttons, status signals, reference value setting indications, etc. Control is to be by a touch panel.

2. The password control for at least 3 user levels. (such as Engineer, Supervisor and Operator)

3. Status Indication and facility for the local control of:

    Field Breaker ON/OFF
    Controlling increase /decrease signals
    Selection of automatic mode; generator terminal voltage control, power factor control or reactive power control and manual mode selection.
    Changing of settings and parameters of voltage regulator with password protection.

4. Display of measuring values and process signals such as field current, field voltage, generator voltage, power factor, generator active and reactive power, frequency, generator current, firing angle etc. shall be displayed simultaneously.

5. Display of Alarms in clear text with facility for visual indication for alarm occurrence, acknowledgement and reset after alarm clearance.

6. The display shall be scrollable with the scroll or page keys.
7. The contents of the Event Logger with at least 50 faults including the plant GPS real-time stamp shall be displayed.
8. Shall display transient trending and slow trending.

#### 3.2.8.19 Data logging

All the critical data logging shall be provided to record various parameters that are measured within the excitation system and plant historian with GPS time tagged to facilitate trouble shooting of possible faults. The data are stored in records that can be retrieved and reviewed that represent the operating data at time of an event. The operating data are triggered to save the information into a record and time stamp to read into a viewing program when retrieved. Sequence of events can be recorded to define specific activity during the operation of the excitation system.

#### 3.2.8.20 Software and firmware

The contractor shall provide one set of programming software in English language for the excitation system in CD form. In case of a spare programmable logic controllers (PLC) are supplied with the system, contractor shall provide the programming software in CD for the spare PLC.

The contractor shall also provide all the fully licensed software and drivers in CD form for the OPC server, Modbus, HMI in excitation panel, and any communication devices.

The contractor shall provide the full application programs for the project (configured for the excitation systems) with passwords to the Employer in CD form. There shall be sufficient facility to modify the application program, i.e., additional Application Function Blocks can be implemented into the control sequence, by Adding, Moving or Removing of the Function Blocks.

This software shall facilitate UP/DOWN loading of parameters and uploading of the stored data (Data and Fault Logger).

All above software shall be pre-installed in a Notebook computer dedicated for the excitation systems and tested at manufacturer’s work, before dispatching. The contractor shall guarantee the performance of the software installed and supplied in CD form.

The programming/communication cords/cables for above work shall also be provided.

#### 3.2.8.21 Spares

The supplier shall be responsible for ensuring the continued availability of spare parts required for maintenance of the excitation system for a period of not less than 10 years from the date of commissioning and shall guarantee it. The supplier shall also provide the manufacturer/supplier's recommended spare part list.

a). Client requested spare parts are as follows;

- Complete AVR module

- Power rectifier bridge
- Field breaker
- Excitation transformer
- Auxiliary devises
- Firing circuit Module
- Power supply (DC-DC, AC-DC)
- Analogue input instruments (CT, VT)
- Sensing devises (Hole effect transducers, current shunt, speed pickups)
- Protection module for Rotor earth fault
- Communication modules/ports, remote control unit

b). Laptop computer (minimum configuration: Reputed brand, core i7, CPU speed>2.7 GHz) installed with licensed Software (with software CD or DVD) for AVR configuration, Calibration, Monitoring, Uploading, Re-commissioning

c). Special tools (Rotor Gap measurement etc.)

### 3.2.8.22 Installation and Commissioning

1). Facility to be provided for factory inspection.

2). All conditions of installation must be complied with IEEE standard which relevant to excitation.

3). Commissioning of all hard wire routing and providing final **AS BUILT** drawings and five (05) nos of copies.

4). Commissioning, functional test and tuning all functions in Table 02 and Table 03 in this specification. (PSS function shall be checked on line).

5). If any problematic issue, deviation found in commissioning it must be corrected and should continue the commissioning.

6). Providing comprehensive commissioning document.

7). Witness team shall be nominated by the Employer and the final acceptance shall be given by Witness team.

8). If any incomplete part of commissioning process, it is considered as condition of project incompletion.

**Equipment Test**

Tests and performance inspection - All tests shall cover IEEE 421-2-2014

The following routine factory tests are suggested for the excitation system prior to shipment:

**Table 2 – Equipment Routine and Type tests shall be carried out by the Vendor (Refer IEEE Std 421.4™ - 2004)**

| **Equipment** | **Tests** | |
|---|---|---|
| | **Routine test** | **Type tests** |
| Excitation control equipment | a) Visual examination to verify major component or subassembly identity, location, and mounting conformance to manufacturer's drawings.<br>b) Dielectric tests specified in IEEE Std 421.3-2016.<br>c) Verification of proper electrical and mechanical operation of all control functions of the excitation system.<br>d) Verification of input–output characteristics of each excitation control element. | a) Input–output characteristics of each excitation control element over specified ranges of supply voltage, frequency, and operating temperature. Verify gain, linearity, maximum and minimum outputs, and stability to be within tolerance.<br><br>b) Time constants of all excitation system elements by frequency response testing techniques described in IEEE Std 421.2-2014. |

| **Equipment** | **Routine test** | **Type tests** |
|---|---|---|
| Excitation control equipment | e) Digital testing, protocol verification of interface to the excitation system related to control, communication, and so on. | |
| Excitation transformer | a) Winding resistance<br>b) Ratio<br>c) Polarity and phase relationships<br>d) No-load loss (if applicable)<br>e) Magnetizing current at rated voltage<br>f) High potential test in accordance with IEEE Std 421.3-2016<br>g) Induced potential | a) Impedance, load loss, and regulation<br>b) Temperature rise, i.e., heat run<br>c) Impulse test(s) |
| Rectifier assemblies | a)Continuity of rectifier fuses.<br><br>b) Polarity and phase relationships.<br><br>c) High potential test in accordance with IEEE Std 421.3-2016. | a) Rated current, watt losses is sometimes required at rated voltage.<br>b) Temperature rise, i.e., heat run.<br>c) Burn-in, 48 hours unless otherwise specified (designate if voltage and/or current burn-in is required).<br>d) Verify current balance. |
| Routine tests of other components | All other electrical parts, i.e., bus ducts, rheostats, and similar devices, should be tested individually in accordance with the applicable IEEE standards. Transient immunity and radiated interference testing of electronic control equipment shall be carried out in the Vendor's premises prior to shipping in accordance with the specifications quoted earlier. | |

**Table 3- Commissioning test shall be carried out at site by the Vendor**
**(Refer IEEE Std 421.4 - 2014 )**

| **Function/Operation mode/Devices to be checked** | **Detail function** |
|---|---|
| Tests with synchronous machine not running | a) Verify external wiring to be in accordance with contract drawings.<br><br>b) Verify operation of all relays, contactors, circuit breakers, and voltage adjusters.<br><br>c) Verify operation of manual control means and regulator power amplifiers using station supply and simulated load per manufacturer's instruction books.<br><br>d) Verify operation of all excitation system control and protective devices using simulated input signals and station power supply per manufacturer's instruction books |
| Tests with synchronous machine running at rated speed and off-line | a) Energize machine with excitation system in the manual control mode.<br>b) Verify operation of excitation control elements using machine voltage signal per manufacturer's Instruction books.<br><br>c) Verify satisfactory transfer of excitation control from manual to automatic mode and transfer between redundant voltage regulators.<br><br>d) While in automatic control mode, check stability and adjust the excitation system stabilizer for satisfactory performance per IEEE Std 421.2-2014.<br><br>e) Perform functional tests of each of the protection features associated with the excitation system, e.g., conduction failure where possible, field ground detector, PT fuses failure, and loss-of-cooling.<br><br>f) Perform functional and dynamic test of applicable excitation limiters, e.g., field current, volts/Hertz, and so on, in accordance with IEEE Std 421.2-2014.<br><br>g) Shall perform tests of redundant power supply transfer, rectifier bridges, or other redundancy. |

| Function/Operation mode/Devices to be checked | Detail function |
|---|---|
| Tests with synchronous machine running at rated speed and off-line | h) Test trip excitation system by simulating a trip condition, for example, loss-of-cooling.<br><br>i) Phase rotation of transformer to generator to verify wiring.<br><br>j) Verify field flash.<br><br>k) Verify small-signal transient response (step and/or frequency response), and excitation system voltage time response, ceiling field voltage and response ratio according to guidelines given in IEEE Std 421.2-2014. |
| Tests with synchronous machine connected to power system | a) Verify that polarity and phase relationships of machine terminal voltage and current signals to the excitation system are in accordance with the contract drawings and the manufacturer's instruction books.<br><br>b) Verify satisfactory transfer of excitation control from the manual to automatic control mode and vice versa.<br><br>c) Verify settings and operation of compensators, online limiters, for example, under excitation limiters, and protective devices using machine terminal current and voltage signals per applicable IEEE standards. Test settings per 12.7.2 (Refer IEEE Std 421.4- 2014) may be used if power system conditions preclude testing with final in-service setting. Where feasible, verify final setting and operation of all excitation control and protection elements with machine operating in normal and worst-case system configurations.<br><br>d) Verify settings and operation of power system stabilizers, where applicable, per instructions in manufacturer's instruction books and guidelines given in IEEE Std 421.2-2014 or alternatively in accordance with the client test procedure.<br><br>e) PSS must be commissioned in site conditions. This shall involve applying simulated inputs to the exciter and measuring the response of the PSS at various points throughout the algorithm. |

#### 3.2.8.23 Environmental and enclosure considerations

##### 3.2.8.23.1 Environment condition

The boards and cabinets of the excitation system and the equipment contained shall be designed to operate at an environment temperature in the interior of 0 to 50°C and relative humidity of 10 to 98% without condensation. All the equipment shall be designed to operate in a corrosive and vibration environment.

##### 3.2.8.23.2 Disposal

Human and environment safe method shall be stated in technical proposal to disposal of electronic devise.

##### 3.2.8.23.3 Enclosure

Specifics should be mentioned as to the ease of access and removal of particular equipment items within the enclosure. If the enclosure has access to all sides, doors shall be on all sides for ease of maintenance. Shall include dust filters and rodent-proof screened louvers. Additional considerations shall comply as follows: (Refer IEEE Std 421.4™ - 2014)

- User-mounted monitoring instruments for operation, testing, and adjustment
- User mounted pushbuttons and switches for manual/automatic controls
- Terminals/connectors
- Wiring/wire marking
- Insulation flammability
- Dangerous materials, i.e., asbestos, PVC, and so on
- Nameplates
- Fire protection
- Heaters/thermostats
- Doors/panels/accessibility
- Handles/locks/latches
- Cable entry location, sealing methods
- Mounting and anchoring
- Breaker interlocks
- Grounding
- Personnel protection
- Circuit isolation/barriers
- Interior lighting/receptacles/communication
- Noise level: Audible
- Electromagnetic interference
- Radio frequency interference
- Telephone influence factor

#### 3.2.8.24 Warranty

The Vendor shall provide warranty on all equipment against defects in design, material, and workmanship, Software for a period of one (1) year after installation and final acceptance. The Vendor shall provide warranty that the excitation performance shall meet all specified requirements providing that it is maintained by the Buyer according to the Vendor's recommended maintenance practices.

The Vendor shall provide a separate price for additional warranty coverage on a yearly basis to a maximum of five (05) years from the completion of acceptance tests on the unit.

#### 3.2.8.25 AVR Training

Vendor shall provide training and it shall cover following areas.

1). Operation and Maintenance
2). Trouble shooting and fault-finding exciter module and software
3). AVR module, AVR card replacement and software up loading
4). Parameter changing, tuning, limiter functional tests

#### 3.2.8.26 Applicable Standards

The excitation system shall comply with the following international standards and regulations or equivalents:

**<u>General Excitation System Standards</u>**

| | | |
|---|---|---|
| 1). | IEEE C37.18-1979 | - IEEE Standard Enclosed Field Discharge Circuit Breakers for Rotating Electric Machine. |
| 2). | IEEE Std 421.4™ - 2014 | - IEEE Guide for the Preparation of Excitation System Specifications. |
| 3). | IEEE Std 421.1™ - 2007 | - IEEE Standard Definitions for Excitation Systems for Synchronous Machines. |
| 4). | IEEE Std 421.5™ - 2016 | - IEEE Recommended Practice for Excitation System Models for Power System Stability Studies. |
| 5). | IEEE Std 421.3-2016 | - IEEE Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines. |
| 6). | IEEE Std C50.1-2005 | - IEEE Standard for Cylindrical-Rotor 50 Hz and 60 Hz Synchronous Generators Rated 10 MVA and Above. |
| 7). | IEEE 421.2 -2014 | - Guide for Identification of Dynamic Performance |

| | | |
|---|---|---|
| 8). | IEC 60 034-16-1 (1991) | - Excitation Systems for Synchronous Machines Definitions |
| 9). | IEC TR 60034-16-2:1991 | - Excitation Systems for Synchronous Machines Models for power system studies |
| 10). | IEC 60 034-16-3 (1996) | - Excitation systems for synchronous machines-Dynamic Performance |
| 11). | IEC 60 146-1-1 (1991) | - Semiconductor converters |
| 12). | IEC 60 185 | - Current transformer |
| 13). | IEC 60 726 (1982) | - Dry type power transformers |
| 14). | IEC 60 664-1 (2002) | - Insulation co-ordination |
| 15). | IEC/EN 60 439 (1999) | - Low voltage switchgear and control gear Assemblies |
| 16). | EN 50 178 (1997) | - Installation of electronic devices in heavy-current plants. |
| 17). | IEEE 762-2006 | - Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability and Productivity. |

## 3.3 Three Phase Power Transformers

### 3.3.1 Oil-filled Power Transformers

#### 3.3.1.1 Scope

This section covers the supply, delivery, erection, installation and commissioning of Generator Transformer, Step Down Auxiliary Transformers and associated equipment necessary to complete the Plant. The number, size and rating of the transformers required are as shown in the Schedule of Transformers in this specification.

The transformers shall have the ratings, ratio, vector group, tap-changing facilities, type of cooling and other details as defined herein although the primary and secondary voltage may be varied to suit the Contractor; standard generator and auxiliary system voltages subject to the approval by the Employer.

The transformers shall be 3 phase oil immersed type suitable for outdoor installation. Each item or function which is obviously necessary for the proper completion of the work, it's 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.

#### 3.3.1.2 Grid Parameters

| | | |
|---|---|---|
| (a) | Nominal voltage | 132kV |
| (b) | System highest voltage | 145kV |
| (c) | System frequency | 50 Hz |
| (d) | Number of phases | 03 |
| (e) | Method of earthing | Star point directly earthed |
| (f) | System fault level | 40kA (1 second) |

#### 3.3.1.3 Service Conditions

The service conditions for transformers are as specified in clause 3.4. The transformers shall be three phase oil immersed type suitable for outdoor installation. They shall be rated at the normal service conditions stipulated in clause 4.2 of IEC 60076-1 and shall conform to technical specifications given in this document.

#### 3.3.1.4 Applicable Standards

The equipment and components supplied shall be in accordance with the latest editions of the standards specified below and amendments thereof.

| | | |
|---|---|---|
| 1 | IEC60076-1:2011 | Power transformers - Part 1: General |
| 2 | IEC 60076-2:2011 | Power transformers- Part 2: Temperature rise for liquid-immersed transformers |
| 3 | IEC 60076-3:2013 | Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air |
| 4 | IEC 60076-5:2006 | Power transformers - Part 5: Ability to withstand short circuit |
| 5 | IEC 60076-6:2007 | Power transformers - Part 6: Reactors |
| 6 | IEC 60076-7:2005 | Power transformers - Part 7: Loading guide for oil-immersed power transformers |
| 7 | IEC 60076-10:2016 | Power transformers - Part 10: Determination of sound levels |
| 8 | IEC 60137:2017 | Insulated bushings for alternating voltages above 1 000 V |
| 9 | IEC 60156:1995 | Insulating liquids - Determination of the breakdown voltage at power frequency - Test method |
| 10 | IEC 60214-1:2014 | Tap-changers - Part 1: Performance requirements and test methods |
| 11 | IEC 60214-2:2004 | Tap-changers - Part 2: Application guide |

| | | |
|---|---|---|
| 12 | IEC 60296:2012 | Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear |
| 13 | IEC 60616:1978 | Terminal and tapping markings for power transformers |
| 14 | IEC 60815:2008 | Selection and dimensioning of high-voltage insulators intended for use in polluted conditions |
| 15 | IEC 60076-10:2016 | Power transformers - Part 10: Determination of sound levels |
| 16 | IEC 60616: 1978 | Terminal and tapping markings for power transformers. |
| 17 | IEC 60270:2000 | High-voltage test techniques - Partial discharge measurements |
| 18 | IEC 60296:2012 RLV | Fluids for electro-technical applications – Unused mineral insulating oils for transformers and switchgear |
| 19 | IEC 60529:1989 | Degrees of Protection Provided by Enclosures |
| 20 | IEC 61869-1:2007 | Instrument transformers - Part 1: General requirements |
| 21 | IEC 61869-2:2012 | Instrument transformers - Part 2: Additional requirements for current transformers |
| 22 | IEC 61869-3:2011 | Instrument transformers - Part 3: Additional requirements for inductive voltage transformers |
| 23 | IEC 60422:2013 | Mineral insulating oils in electrical equipment Supervision and maintenance guidance |
| 24 | IEC 60422:2013 | Mineral insulating oils in electrical equipment - Supervision and maintenance guidance |
| 25 | IEEE C37.90.1(2012) Surge | Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus |
| 26 | IEC60529:1989+AMD1:1999+ AMD2:2013 CSV | Degrees of protection provided by enclosures (IP Code) |
| 27 | BS EN 50288-7:2005 | Multi-element metallic cables used in analogue and digital communication and control. Sectional specification for instrumentation and control cables |
| 28 | BS EN ISO 1461:2009 | Hot dip galvanized coatings on fabricated iron and steel articles |
| 29 | BS 2562:1979 | Specification for cable boxes for transformers and reactors |
| 30 | BS EN 10025:2009 | Hot rolled products of structural steels. |
| 31 | BS 5493:1997 | Code of practice for protective coating of iron and steel structures against corrosion |

| | | |
|---|---|---|
| 32 | NEMA TR 1-2013 | Transformers, Step Voltage Regulators and Reactors |
| 33 | EN13011 | Transportation Services - Goods transport chains - System for declaration of performance conditions |
| 34 | ISO 12944:2007 | Corrosion protection of steel structures by protective paint systems |
| 35 | ISO 14001 | Environmental systems – requirements, with guidance for use |
| 36 | ISO 9001: 2008 | Quality management systems – requirements |
| 37 | IEEE C57.93 | Guide for installation and maintenance of liquid immersed power transformers |
| 38 | IEC62155 | Insulators Ceramic or Glass Hollow pressurized and unpressurized Voltages greater than 1000 V A.C |
| 39 | BS EN 10025 | Specification for weldable structural steels |
| 40 | BS 61 | Specification for threads for light gauge copper tubes and fittings |

### 3.3.1.5 Technical Requirements

Generator Transformer

| ***Description*** | ***Primary side*** | ***Secondary side*** |
|---|---|---|
| Nominal voltage | 11~15kV* | 132 kV |
| System highest voltage | 12/17.5kV** | 145 kV |
| Rated fault current | To be indicated by the bidder | 40 kA |
| Lightning impulse withstand voltage (peak) | 75/95kV** | 650 kV |
| One-minute power frequency withstand voltage | 28/38kV** | 275 kV |
| Tap Changer | On load tapping (Secondary side) +10% to -10% at 1.25% steps | |
| Insulator creepage distance (Unified specific creepage distance) | 43.3mm/kV | 43.3mm/kV |

Step Down Auxiliary Transformer

| | ***Primary side*** | ***Secondary side*** |
|---|---|---|
| Nominal voltage | 11~15kV* | 6.6 kV |
| System highest voltage | 12/17.6kV** | 7.2 kV |
| Rated fault current | To be indicated by the bidder | To be indicated by the bidder |
| Lightning impulse withstand voltage (peak) | 75/95kV** | 60 kV |
| One-minute power frequency withstand voltage | 28/38kV** | 20 kV |
| Off load tapping (Secondary side) | +5% to -5% at 2.5% steps | |
| Insulator creepage distance | 43.3mm/kV | 43.3mm/kV |

* the primary/secondary voltage may be varied to suit the Generator Manufacturer

** to be decided to suit Generating Voltage as per IEC 60076-3

#### 3.3.1.5.1 Performance Characteristics

| | |
|---|---|
| Vector group | YNd11 or YNd1 |
| System frequency | 50Hz |
| Cooling type | ONAN/ONAF (70%) |
| Average winding temperature rise (by resistance measurement) at steady state continuous MCR at normal ambient (25°C to +40°C) under normal service condition. | 55 K |
| Top oil temperature rise at normal ambient (25°C to +40°C) under normal service condition. | 50 K |
| Minimum short circuit impedance voltage at $75^0$C | 7%. (Minimum value shall be complied with Table 1 of IEC 60076-5) |
| Duration of thermal Withstandability of short circuit current (Under three phase faults) | 2s (as per IEC 60076-5) |
| No load loss and load loss (corrected at 75ºC) shall be indicated by the bidder in the schedule of particulars. Such indicated values (which will be guaranteed by the bidder) will be considered for the evaluation. | |

#### 3.3.1.5.2 Continuous Maximum Rating

Transformers shall have the continuous maximum rating as stated in the Guaranteed Technical Particulars 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 Guaranteed Technical Particulars. To allow for high atmospheric temperatures, the allowable temperature rise shall be reduced as stated in this Specification.

"Transformer and its components shall be able to carry loading beyond rated power under some circumstances with complying the current and temperature limits defined in the Table 04 of IEC60076-7:2005 "

The overload capability curve shall be given together with calculated winding, top oil and hot spot temperatures at 1.1pu to 1.8 pu loads in 0.1pu steps

#### 3.3.1.5.3 Connections

Transformer windings shall be connected in accordance with the IEC 60076 group symbol specified in the Guaranteed Technical Particulars. 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.

#### 3.3.1.5.4 Evaluation of Losses

The Bidder shall state in the Technical Particulars and Guarantees (Form 18A - Performance guarantees on generator Step- Up transformers of Volume 1), 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.

Step-up transformers will be assessed on the basis of considering the cost of total guaranteed losses of transformers based on following evaluation rates:

| Sri Lanka Rupees per kW of guaranteed loss | | | |
|---|---|---|---|
| Power Transformer | No load loss | Load loss at CMR and nominal tap position | Auxiliary loss at (CMR) |
| Rupees/kW | 2,000,000.00 | 359,000.00 | 350,000.00 |

The acceptance of transformers yielding component losses higher than the guaranteed values shall be governed by either of the following: -

- 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.

- 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 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.

#### 3.3.1.5.5 Impedance

The value of impedance measured on principal and extreme tappings shall be as stated in the Schedule. Minimum value at principal tapping shall be complied with Table 1 of IEC 60076-5.

As per IEC 600076-1 For transformers with tapings exceeding a voltage variation of 5 % from the principal tapping, impedance values shall be measured for the principal tapping and the extreme tapping(s) exceeding 5 %.

It is preferred that the equivalent zero sequence impedance of the transformer, when viewed from the HV terminals is not less than the positive sequence impedance between HV and generator side terminals at normal ratio normal rating. The value shall be stated in Guaranteed Technical Particulars on the basis of system short circuit levels stated in Guaranteed Technical Particulars.

#### 3.3.1.5.6 Noise

The transformer noise levels shall be measured as a type test and in accordance with IEC 60076-10. Maximum value of sound power level shall be accordance with NEMA TR1:2013 standard on this regards. 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 to reduce the noise level, for insertion between the transformer and its foundation.

#### 3.3.1.5.7 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 there from.

#### 3.3.1.5.8 Frequency Variation

The generator transformer (Unit Transformer) shall be capable of continuous operation at rated output at any frequency variation between ±5% of normal 50Hz and ±10% of rated voltage at any tap. The design voltage shall be +10% of the nominal voltage with a simultaneous drop of frequency of 5% of nominal 50Hz (47.5 Hz). Within these prescribed range of values of voltage and frequency the transformer shall be capable of continuous service without damage under the condition of over fluxing.

#### 3.3.1.5.9 Voltage Variation

Generator Transformer shall be able to withstand 1.4 times the rated voltage for 5 Sec at the LV terminals to which the generator is directly connected (during load rejection conditions).

The over excitation curve (% over excitation Vs Time) relevant to the design of the offered transformer shall be provided to prove that transformer is able to withstand 1.4 times the rated voltage for 5 Sec.

### 3.3.1.6 Cooling and Cooling Plant

#### 3.3.1.6.1 General

The types of cooling shall be as stated in the Guaranteed Technical Particulars and the letters relating to the method of oil circulating and cooling used in this Specification and Guaranteed Technical Particulars 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 Guaranteed Technical Particulars, after which the cooling equipment is to come into operation and the Transformer will operate as an ONAF unit. OFAN or OFAF shall not be allowed

Transformers shall be fitted with tank mounted radiators. They shall be capable of remaining at the operation of full load for 30 minutes in the event of failure of blowers associated with both coolers without the calculated winding hot spot temperature exceeding 140$^0$C.

Failure of one fan in each group of blowers shall not reduce the continuous maximum rating of the transformer.

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 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 standards.

#### 3.3.1.6.2 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.

#### 3.3.1.6.3 Cooler Banks

Each cooler bank shall be provided with:-

- A valve at each point of connection to the tank.
- A valve at each point of connection of radiators.
- Loose blanking plates to permit the blanking off of the main oil connection to the top.
- A 50mm filter valve at the top of each cooler bank.
- A 50mm drain valve at lowest point of interconnecting oil pipes.
- A thermometer pocket, fitted with captive screw cap, in the inlet and in the outlet oil pipes.

- Air release and drain plugs on each radiator.
- The omission of any, or the provision of alternative arrangements to the above requirements, will not be accepted unless approved in writing by the Employer before manufacture.
- An approved expansion piece shall be provided in each oil pipe connection between the transformer and each oil cooler bank.

#### 3.3.1.6.4 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.

#### 3.3.1.6.5 Oil Pipes and Flanges

All oil piping shall be of approved material with machined flagged joints. Copper pipe work is to comply with BS.61. Dimensions of steel pipes shall be in accordance with BS EN 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.

#### 3.3.1.6.6 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 IEC60529.

#### 3.3.1.6.7 Cooler Control

All the motors in cooling system shall be three phase, 50 Hz. 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.

The control arrangements are to be designed to prevent the starting of motors totalling 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 65 (as applicable).

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 $75^0$C hot spot temperature) and the second group at a higher temperature. (i.e., at $85^0$C hot spot temperature). The winding temperature shall give the starting signal for the fans and the oil temperature shall give the stopping signals.

#### 3.3.1.6.8 Overloading

Transformer and its components shall be able to carry loading beyond rated power under some circumstances with complying the current and temperature limits defined in the Table 04 of IEC60076-7:2005.

The overload capability curve shall be given together with calculated winding, top oil and hot spot temperatures at 1.1pu to 1.8 pu loads in 0.1pu steps.

### 3.3.1.7 Magnetic Circuit and Windings

#### 3.3.1.7.1 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 2.5kVrms 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.

#### 3.3.1.7.2 Flux Density

The core shall be constructed from cold rolled grain oriented electrical steel sheets. The design shall be such that there will be no adverse effects due to the 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 shall not exceed 16,000 lines per square cm (i.e., 1.60 Tesla) at the rated voltage. The flux density of the CRGO electrical steel of the core shall not exceed the value 1.9T at over excitation condition of Voltage and frequency limits. Combination of the main flux and increased leakage flux should not cause restrictions on possible over excitation conditions up to 1.9T of the CRGO electrical steel. The minimum flux density at magnetizing force of 800 A/m shall be 1.9 T. Data sheet of the CRGO electrical steel shall be provided with the bid including DC magnetizing curve. No load current at 110% of rated voltage shall not exceed 2.5 times the no load current at rated voltage.

#### 3.3.1.7.3 Windings

All windings shall have copper conductors. Transformer 132kV star connected windings may have graded insulation as defined in IEC 60076 and MV 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 Guaranteed Technical Particulars.

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 split by spacers, the clamping arrangements shall ensure that equal pressures are applied to all columns of spacers.

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.

#### 3.3.1.7.4 Internal Earthing

**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.

**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.

By connection through vertically tie rods to the top structure;

By direct metal to metal contact with the tank base maintained by the weight of the core and windings;

By connection to the top structure of the same side of the core as the main earth connection to the Tank.

**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 in 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 0.25mm are to be bridged with tinned copper strips so inserted as to maintain electrical continuity.

**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.

**Size of Earthing Connections** - Main earthing connections shall have a cross-sectional area of not less than 80 sqmm, but connections inserted between laminations may have cross-sectional areas reduced to 20sqmm. when in close thermal contact with the core.

### 3.3.1.8 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 | - | Non-inhibited class 1 |
| Required Standard | - | IEC 60296/ BS 148 |

Offered transformer oil shall meet general specifications specified in table 2 of IEC 60296.

### 3.3.1.9 Tanks and Ancillary Equipment

#### 3.3.1.9.1 Transformer Tank

The transformer shall be enclosed in a suitable stiffened welded steel tank 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 Employer, but, detachable under bases must not be used unless specifically approved by the Employer. 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 Employer.

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.

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.

#### 3.3.1.9.2 Conservator Tanks, Breathers and Air Dryers

The 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. 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 diaphragm type air cell to prevent direct contact of oil with air.

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 tank shall also be provided with a cleaning door, filling cap, drain valve with captive cap, vent valve, air cell breather, liquid level gauge 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 minimum maintenance type silica gel breather and a magnetic type oil level indicator. The breather shall be made out of Aluminum with glass view and shall capable of removing the silica gel content for drying. All breathers shall be mounted at a height of approximately 1400 mm above ground level. dried

The pipe work between the conservator and the transformer tank shall comply with the requirements of clause 6.3.1.13.5 and a valve shall be provided at the conservator to cut off the oil supply to the tank.

### 3.3.1.9.3 Valves and Location

All valves up to and including 75 mm bore shall be made of gunmetal.

The transformer shall be fitted with the following valves as a minimum requirement: -

<u>Main Tank</u>

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 50mm 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.

d). Two oil sampling valves at the top and bottom of the tank. These valves shall be accessible from ground level and shall also be provided with an approved oil sampling device.

e). A valve fitted with a blanking plate and located on the tank cover in line with the bottom sampling valve should be provided for attaching a vacuum gauge, a pressure gauge or an oil level indicator when vacuum filling.

<u>Conservator</u>

f). One valve between the conservator and gas actuated relay for the main tank and, where appropriate, for the tap change diverter switch tank.

g). One drain valve for oil conservator tank so arranged that the tank could be completely drained of all oil.

h). One pressure balancing valve arrangement system for rubber diaphragm in the event of oil filling or draining

<u>Tap Changer Selector Switch</u>

I). 50mm filter and 50mm drain valve where selector switches are contained in a separate tank.

j). 50mm oil sampling valve for OLTC.

Diverter Switch

k). One 50mm drain valve to be fitted to tank. An approved oil sampling device shall also be provided.

Forced Air Oil Coolers

l). 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 Employer before manufacture.

#### 3.3.1.9.4 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.

#### 3.3.1.9.5 Pressure Relief Device

An approved pressure relief device preferably with spring loaded mechanism, of sufficient size for the rapid release of excess pressure that may be generated in the tank shall be fixed. It shall be designed to operate at a preset safety limit and agreed by CEB. The device withstand temperature range shall be indicated in the schedule of technical particulars. In the event that the device is a spring-operated valve type, it shall be provided with one set of signaling contacts (please refer to Schedule A Guaranteed Technical Particulars of the contacts).

The relief device is to be mounted on the tank cover and is to be provided with a skirt to project at least 25mm into the tank to prevent gas accumulation. The pressure release device should have visual indicator.

The device should prevent the ingress of moisture or oil flow from the transformer after the operation of the device to relieve an internally generated pressure.

Number of pressure relief devices (one or more) and their installation points shall be decided depending on the volume of oil contained in the transformer. Number and positions shall be agreed by CEB.

#### 3.3.1.9.6 Earthing Terminals

Two bare steel contact surfaces having two 14 mm diameter holes on 45 mm centres shall be located one on either side and near to the bottom of the Transformer to facilitate connection to the local earthing system.

#### 3.3.1.9.7 Rating, Diagram and Valve Plates

The following plates, or an approved combined plate, shall be fixed to the 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 stainless steel or other approved material capable for continuous outdoor service and withstanding the climatic conditions of at site.

### 3.3.1.10 Voltage Control

**3.3.1.10.1** General

Transformer 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 6.3.1.5.

Winding taps as called for in the Guaranteed Technical Particulars shall be provided on the high voltage winding. But, where stated in the Guaranteed Technical Particulars, in the case of on-load tap selectors.

All terminals shall be clearly and permanently marked with numbers corresponding to the cables connected thereto.

#### 3.3.1.10.2 On Load Tap Changer (OLTC)

**a. General**

On-load tap changers shall comply with IEC60214 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, Germany is in wide use on the Employer's transformers for standardization purposes. On-load tap changer type “Vacutap” of Maschinenfabrik Reinhausen is preferred under this project. Tap changers shall be mounted from the cover into the transformer tank.

Tap changers shall be in-tank type mounted from the cover into the transformer tank. Diverter switch shall be in separate compartment where diverter switch oil will not be mixed with oil in main tank. 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 current making and breaking are accomplished by the same contacts within a tank separate from the transformer.

**b. 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.

**c. Lcocal 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 be supplied at Local Control Cubicle supplied for the gas turbine unit.

The following operating conditions are to apply to the on-load tap selector controls: -

- 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.
- It must not be possible to operate the electric drive when the manual operating gear is in use.
- 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.

- All electrical control switches and local manual operating gear shall be clearly labelled in an approved manner to indicate the direction of tap changing.

**d. Indicators**

Apparatus of an approved type shall be provided on the 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.

**e. Automatic Voltage Control**

Automatic Voltage Control (AVR) of OLTC shall be suitable to control the voltage of auxiliary busbars (as per the typical Single Line Diagram) installed at the LV side of the Generator Transformer, while Gas Turbines are in system restoration mode and standby mode. Proper coordination between each Transformer AVR and Generator AVR shall be ensured while maintaining permissible voltage levels at each bus bar.

In addition to the methods of voltage control, the following alternative method 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.

It must not be possible to operate any tap changer remotely though HMI PCs at Local Control Cubicle and Central Control Room 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.

**f. 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. 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.

**g. Supervisory Control Requirements**

Transformer tap change supervisory control will be affected from the Central Control Room (CCR). 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 labeled "Local" and "Remote".

**Controls**

Tap change raise/lower by direct operation of tap changer.

**Indications and Alarms:**

- Tap changer in Progress
- Tap changer out of step
- Tap lower

- Tap raise
- Tap Position
- VT fail
- Tap changer fail

### 3.3.1.11 Bushing Insulators and Terminals

#### 3.3.1.11.1 General

Transformer is to be provided bushing and terminals for phase and neutral terminals as required in the Technical Particulars & Guarantees (Schedule 3 of Volume 4).

All bushings shall comply with IEC.60137 and the minimum creepage distance for outdoor bushings shall be as specified in the Guaranteed Technical Particulars.

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 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 generating voltage (11~15 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.

#### 3.3.1.11.2 Porcelain

Hollow porcelain shall meet the test requirements of IEC.60231and 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.

**3.3.1.11.3 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 Employer 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.

**3.3.1.11.4 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 clearances from phase to earth and phase to phase must not be less than those stated in the standards. 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 galvanised in accordance with the specification and all bolt threads are to be greased before erection.

**3.3.1.11.5 Phase locations of HV, LV bushings**

During the designing stage, the required locations for L1, L2, L3 (R, Y, B) phases in HV and LV side shall be obtained from the Employer.

### 3.3.1.12 Cables and Terminations

#### 3.3.1.12.1 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 is to occur and no permanent deformation to take place in the structure.

#### 3.3.1.12.2 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.

#### 3.3.1.12.3 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.

### 3.3.1.13 Temperature and Alarm Devices

#### 3.3.1.13.1 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 HVand LV winding temperatures.

#### 3.3.1.13.2 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 employer. The sensors shall be able to be completely immersed in hot transformer oil and they shall withstand exposure to hot kerosene vapour 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 lightening impulse withstand, switching impulse withstand, AC voltage withstand and partial discharge measurement.

Temperature range of the system shall be -80ºC to +250ºC with an accuracy of ± 1ºC. Signal conditioner shall meet IEEE C37.90.1-2002, IEC 60255-27 and IEC 61000-4-2 emissivity and EMI immunity tests on all inputs and outputs and it shall have a failsafe 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.

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.

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 entire system shall be capable to be integrated into a complete transformer monitoring system.

The temperature device shall have separate contacts fitted with it for the following purposes:

- Control of the cooling plant motors.
- Winding temperature high alarm.
- Winding temperature trip.

- Oil temperature high alarm
- Oil temperature trip.

The continuous measured oil and winding temperature trend curve shall be plotted and to shall be saved in the Plant Historian System via DCS to monitor past temperature trend curves 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.

#### 3.3.1.13.3 Dial Type Temperature Indicators

In addition to the winding temperature trip and alarm devices the transformer shall be provided with an approved oil temperature instrument with a dial type indicator and a pointer to register the highest temperature reached. 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 $60^{0}$C and $120^{0}$C and reopen when the temperature has fallen by not more than $10^{0}$C. The alarm contacts shall be adjustable to close between $50^{0}$C and $100^{0}$C and reopen when the temperature has fallen by not more than $10^{0}$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.

Vacuum pressure gauge with scale such that at maximum operating pressure or vacuum the pointer will be indicating at least 60 % of total positive or negative range.

### 3.3.1.13.4 Gas and Oil Actuated Relay

The 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 unauthorised 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.

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 tied 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: -

- If the two conservators are connected to the transformer by a common oil pipe one relay shall be installed in the common pipe.
- 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.

#### 3.3.1.13.5 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 SCADA system and/or power plant annunciator alarms.

Contacts shall be furnished for the following:

Trip Alarm:

Buchholz trip
Winding Temperature trip
Oil Temperature trip
Tap Change Oil Surge trip
Tap change oil level trip
Oil level low trip
Pressure relief valve trip
Tap change pressure relief trip

Non Trip Alarm:

Heater AC supply fail
Winding temperature alarm
Oil temperature alarm
Transformer – pressure alarm
Low oil level
Oil level high
Marshalling kiosk supply 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)
Buchholz Alarm

#### 3.3.1.13.6 Condition Report During the Manufacturing of Transformers

The detailed condition report about its manufacturing stage shall be submitted and the purchaser 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 purchaser shall be permitted, at his option, to personally inspect such damages and/or test failures.

### 3.3.1.14 Additional Requirements

#### 3.3.1.14.1 Manufacturing Experience

The bidder shall ensure that, each transformer offered is manufactured by a manufacturer with a minimum of fifteen (15) years successful experience in manufacturing comparable equipment, in rated voltage and capacity. In addition, minimum of ten years (10) experience shall be in manufacturing for orders from outside the country of the manufacturer.

If the offered equipment is manufactured under license, the manufacturing experience of equipment manufactured by the parent company shall not be counted as manufacturing experience of the licensee equipment.

In addition the Bidder shall submit a reference list of two or more transformers of same or similar design and rating manufactured and supplied by the manufacturer for orders from outside the country of the manufacture. Offered transformer will only be accepted if transformers identical/similar in design have a minimum of five years (5) field experience.

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

#### 3.3.1.14.2 Radio Interference

When operated at voltage even up to 10% in excess of the normal system rating, transformers shall be substantially free from partial discharges (i.e. corona discharges in either internal or external insulation) which are likely to cause interference with radio or telephone communication.

#### 3.3.1.14.3 Drawings, Maintenance Manual

**a. Drawings**

**Required drawings – Part I**

Five (5) copies of each of the drawings specified below shall be provided.

i). Outline drawings including the following information:

- a). Un-tanking 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.

**Required drawings – Part II**

i). Five (5) paper copies and CADD files in AutoCAD 2017 (or Higher Version) of each of the drawings specified below shall be provided.

ii). Certified test data for all testings

iii). 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.

iv). Five (5) colour 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.

v). 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.

### 3.3.1.14.4 Transportation and Packing

**a. Impact Recorder**

When prepared for shipment the transformer shall be fitted with impact recorder which shall remain in situ until the transformer is delivered to site. 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.

The impact recorder shall be switched off in the presence of the Employer 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 inspected with the employer at the site (Kelanitissa Power Station) 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, 32 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 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 synchronised.

**b. 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.

Manufacturer shall provide maximum allowable readings for the safe transportation filled in following table in advance.

| Axis | Outside tank | Inside tank | Duration | Comments |
|---|---|---|---|---|
| | Max g-forces used for the design | | (cont. or msec) | |
| Longitudinal | | | | |
| Vertical | | | | |
| Lateral | | | | |

In the event that the transformer is found to have been subjected to excessive shock/impact beyond the guaranteed value or the impact recorder has been damaged in transit, may be liable for rejection of the Transformer and the acceptance of transformer shall be entirely at the discretion of the Employer.

Mounting location shall be confirmed with the employer before mounting the impact recorder and recording of events shall be started just after mounting the impact recorder.

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.

**c. Transportation without Oil**

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.

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 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.

The dew point of the dry gas should be measured and recorded to ensure it is below -40 0C. The dew point should be checked again within 24 hours of the oil having been removed and the transformer dry gas 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 insulation is higher than 0.5%, the manufacturer must dry the transformer.

The maximum acceptable dew point shall also be indicated on the shipping tag. The dew point of the shipping gas shall be recorded along with the pressure and temperature of the shipping gas at the time of the dew point measurement. This information shall be recorded on the test report, the shipping documents and on a tag at the location of the dew point measurement.

**d. 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 by 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.

CEB considers seriously the moisture content in cellulose insulation and, hence vapour pressure drying (or approved drying method) and workmanship thereafter shall be maintained at an 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.

**e. 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 lts drums and filtered by use of the plant described in the preceding paragraph into a mobile storage tank supplied by Contractor prior to transfer again via filter plant into the transformer.

### 3.3.1.14.5 Corrosion Protection

All the paint work of transformer steel works shall be suitable for atmospheric corrosivity category C5M as defined in ISO 12944-2:1998. The durability class of the paint system shall be "high (H)" (i.e. more than 15 years) as per ISO 12944.

The manufacturer shall submit for CEB'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. All galvanized and non-galvanized steel surfaces shall be covered in paint specifications as per recommendations of ISO 12944.

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 manufacturer 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 CEB 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. Surface preparation of un-galvanized surfaces shall achieve Sa 2.5 as per ISO 8501-1 before painting.

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 outdoor 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

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.

**3.3.1.15 Quality Assurance**

The manufacturer shall possess ISO 9001:2015 Quality Assurance Certification for the manufacture of transformers for the plant where the manufacture of power transformers is done. Bidders shall furnish a copy of the ISO certificate certified as true copy of the original by the manufacturer, along with the offer.

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.

The manufacturer is responsible for any sub-suppliers setting up and executing their own quality assurance systems.

If the manufacturer is having ISO 14001 Environmental Management Certification, a copy of certificate can also be furnished.

### 3.3.1.16 Inspection and Testing

#### 3.3.1.16.1 Testing

The transformer 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 transformer 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.

Type tests, Ability to withstand short circuit and Acceptance tests shall be as follows.

The following test shall be performed in the presence of the Employer.

<u>Routine Tests</u>

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).
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
m). Measurement of d.c. insulation resistance between each winding to earth and between windings.
n). Measurement of dissipation factor (tan δ) of the insulation system capacitances.
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).
q). Measurement of frequency response (Frequency Response Analysis or FRA). The test procedure shall be agreed between manufacturer and purchaser.

**Note:**

Tests e, g, i, k, l, m, n, o and q shall be performed after temperature rise test.

<u>Type Tests</u>

Type test shall be according to the IEC 60076, part 1, clause 11.1.3.

<u>Special test</u>

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 δ) 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). (If short circuit test report for sample transformer is available and the Contractor can demonstrate the suitability of new transformer design, by the calculation referring to the test report, the short-circuit test can be waived under approval of the Employers).
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). Check of external coating (ISO 2178 and ISO 2409 or as specified).
m). Measurement of dissolved gasses in dielectric liquid.
n). Mechanical test or assessment of tank for suitability for transport (to customer specification).
o). 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.
p). Measurement of the harmonics of the on-load current
q). Insulating test of oil and Measurement of dielectric strength of oil
r). Dielectric Frequency Response Analysis and estimation of moisture in cellulose insulation.
s). Oil Tests before and after temperature rise tests (Breakdown voltage, Interfacial tension & Moisture in Oil)
t). Calculation of efficiency and voltage regulation.
u). Oil pressure test for radiators.
v). Calibration and Current Injection test on the winding (hot spot) temperature indicators based on results of the temperature rise test.
w). Functional Tests
- Check & simulation (all status, alarm & tripping) of control wiring
- Control sequence and operation tests for cooling fans, oil pumps etc
- Tests for mechanical relays and devices

x). Dimensional Check
y). HV bushing tan □/capacitance measurement.

**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.
- It is important to perform core/frame insulation and SFRA tests as last tests at Factory Acceptance Testing. No other electrical test is allowed after SFRA at factory

**SFRA at Factory**

The SFRA shall be carried at factory for end-to-end open, end-to-end short circuit, capacitive inter-winding and inductive inter-winding for both high voltage and low voltage windings for the frequency range at least from 20Hz to 1MHz (Number of data point in SFRA plot shall not be less than 200 points per decade). The test files performed in the factory shall be provided to CEB in one of the formats of .fra / .tfra / .xfra / .sfra / .pax. The transformer shall be properly demagnetized using an acceptable demagnetization test kit before performing SFRA. The transformer shall be on the tap-position with the highest number of effective turns in circuit at the time of conducting SFRA.

The connection arrangement should be clearly specified for each and every test. That should be witnessed and confirmed by the FAT engineer and his/ her responsibility is to obtained photos for future reference.

### 3.3.1.16.2 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,

- 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.

- All the Routine Tests specified under special test 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.
- Ability to Withstand Short Circuit General

At detailed design stage, manufacturer shall submit evaluation of thermal and dynamic withstandability of short circuit as per this specification within 4 weeks from contract award.

Following documents, drawings and calculations shall be submitted with this evaluation as per IEC 60076-5 Annex A.

**<u>Documents required</u>**

- 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.

**<u>Calculation of EM Forces (Clause :A.3.2 (d))</u>**

- Radial inward or outward force on each physical winding
- Maximum axial compression force on each physical winding (Fc)
- 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)

**<u>Calculation of Stresses (Clause: A.3.2 (e))</u>**

- Mean hoop tensile stress on outer windings (σ*t)
- Mean hoop compressive stress on disc-, helical-, single-layer-type inner windings (σ*c)12
- 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 those documents to engineer at Employers' premises or manufacturers' premises.

**3.3.1.16.3 Inspection**

The selected Bidder shall make necessary arrangements for inspection of the equipment by an Employer appointed by the Employer and also to carry out in his presence necessary Acceptance / sample tests of the materials and equipment, offered.

**3.3.1.16.4 Site Acceptance Tests**

Prior to removal from the transporter at site, following tests to the transformer windings 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
  a) all windings to earth
  b) between windings
  c) current transformer windings to earth

d) between current transformer windings
e) control cabling
f) auxiliary power cabling
g) between core and tank
h) between core and core clamp

- Check of protective earthing connections of

a) bushing turrets
b) on load tap changer and motor drive
c) cubicles
d) control cabling
e) auxiliary power cabling
f) coolers, pipes and bridging of flanges

- Current transformer polarity check
- Control equipment circuit check
- Oil tests

a) oil level check
b) dielectric withstand test
c) 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:

a). conservator oil level
b). dehydrating breather
c). valves
d). cubicles
e). touch up painting
f). cubicle heaters
g). de-aeration of the gas and oil actuated relay
h). oil leaks
i). tank protective earthing
j). neutral earthing
k). line and bus connections
l). air clearances

- fingerprint tests (Um>72 kV)

a). Determination of capacitances windings-to-earth and between windings (Um >72.5 kV)
b). Measurement of dissipation factor (tan δ) of the insulation system

c). capacitances (Um >72.5 kV)
d). frequency response analysis (FRA)
e). Insulation dielectric response (PDC, RVM or FDS etc)
f). low voltage no-load magnetisation current measurement
g). low voltage impedance measurement

**SFRA at Site**

The requirements mentioned in the 1.30.1are applicable to the SFRA testing at site too. Additionally, SFRA shall be carried as first electrical test at site after assembling and oil filling, by using the same test instrument used for SFRA testing at factory.

#### 3.3.1.16.5 Trail 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.

### 3.3.1.17 Documents to be Submitted

All final drawings shall be sent to CEB for approval.

The following documents shall be submitted along with the transformer. Four (4) paper copies and CAD files in AutoCad Version 2017 or higher of each of the drawings specified below shall be provided

#### 3.3.1.17.1 Instruction Manual

The instruction manual shall include all necessary final design details of the transformer, including properly documented disassembling procedures of transformer with illustrations, exact information for all auxiliary equipment, such as thermometers, gauges, relays and alarm set-points, and tap changing equipment actually supplied on the transformer. It will not be considered sufficient to include only "typical" device manual. Instruction books shall include copies of all final drawings.

The comprehensive installation, operating and maintenance instructions shall also be included to the instruction manual. Certified test data for all testing shall also be included.

Four (4) colour photographs of the core and coil assemblies shall be taken immediately prior to tanking at such angles as to provide comprehensive details of design and construction information for record and shall be incorporated to in each copy of the instruction manual.

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 manual.

### 3.3.1.17.2 Required Drawings

- Outline drawings including the following information:
- Un-tanking dimensions.
- Center of gravity, shipping and completely assembled, in three dimensions.
- Exact bushing terminal locations named as per the existing system, accessory equipment locations, weights and dimensions.
- Identification of all components or accessories which will be shipped separately or disassembled due to shipping restrictions.
- Base detail required for foundation designing.
- Core and winding assembly
- HV & LV connecting leads
- Disassembling drawings
- Off load tap changer drawings
- Complete set of Gasket dimensional drawings,
- Schematics and wiring diagram, which shall include auxiliary power requirements and fuse and breaker sizes.
- Bushing detail drawings
- Tap Changer detail drawings

### 3.3.1.18 Spare Parts and Tools

**a. Mandatory Spares**

The following spare parts shall be provided and included in the schedule 2, Mandatory Spares in volume 5:

a). 03 nos. of complete set of oil level indicators.

b). Additional 10% of total volume of transformer oil supplied in 200 Liter drums.

c). 02 nos. of HV bushing with necessary spares (Gaskets, seals bushing oil etc;)

d). 03 nos. of LV bushing with necessary spares (Gaskets, seals etc;)

e). One neutral bushing with necessary spares (Gaskets, seals etc;).

f). 03 nos. of dial type thermometers for oil temperature indications & 03 nos. of dial type thermometers for winding temperature indications.

g). 03 nos. of Complete Radiator Fans with motor

h). 01 nos. of Buchholz relays

i). 03 nos. of Complete set of Gaskets

j). 03 nos. of maintenance free dehydrating silica gel breathers

k). 01 no. of equipment kit for operation of Buchholz relay

Note: - Comprehensive method statement shall be provided along with above spares for replacing any gasket and replacing any bushing.

**b. Recommended Spares**

Any other recommended spares for the smooth operation of transformers for ten (10) years period shall be listed separately.

**c. Mandatory Tools**

Any other mandatory tools required for the smooth operation of transformers for shall be listed separately and include in Schedule 2, Mandatory Spare Parts of Volume 5.

#### 3.3.1.19 Galvanizing

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 1999 or equivalent approved by CEB.

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 CEB.

If particularly specified for protection during transport and erection. 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 CEB.

**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. Prior to the painting, 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. 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/CEB. 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 manufacturer.

#### 3.3.1.20 Design Review

The selected bidder with the **consultation of manufacturer's design engineers and experts** (if manufacturer is not the bidder) 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. A general description of the core design & material
    b. Geometry and cross section data
    c. Special issues of the core design

- Windings
    a. Winding arrangement & material
    b. Cross section and number of turns
    c. Insulation design

- Thermal design
    a. Losses
    b. Cooling
    c. Temperature
- Short circuit withstand capability as per IEC 60076-5
    a. Thermal ability to withstand short circuit
    b. 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
    a. Design & Drawings
    b. Fabrication
    c. Testing
    d. Surface Preparation and Painting
- Ancillary Equipment
    a. HV, LV & Neutral Bushings
    b. Bushing/Internal Current Transformers
    c. Buchcholz Relay
    d. Pressure Relief Device
    e. Valves
    f. Breather
    g. Offline Tap Changer
    h. Control Cabinet and External Cabling
    i. Cooling fans/oil pumps
    j. On-line Monitoring Equipment
- Testing at factory
- Transportation
    a. Design for Transport
    b. Transportation Route and Preparedness
    c. Transportation Shipping Impact Withstand

d. Marking of Center of Gravity
e. Transportation monitoring management of transformer
    - Type/Location of Impact Recorder
f. Transportation of transformer accessories, components removed from the transformer
g. Acceptance criteria for receiving transformer
h. Transformer Unloading at site

- Commissioning Testing at Site

  The bidder shall bear all the costs incurred to bidder for this design review.

### 3.3.2 Dry type transformer

This section covers the supply, delivery, erection, installation and commissioning of Unit Auxiliary Transformers and associated equipment necessary to complete the works.

The transformers shall have the ratings, ratio, vector group, tap-changing facilities, type of cooling and other details as defined herein although the primary and secondary voltage may be varied to suit the Contractor; standard generator and auxiliary system voltages subject to the approval by the Employer.

There shall be dedicated Unit Auxiliary Transformer for each gas turbine. Unit Auxiliary Transformer shall be rated to accommodate the auxiliary loads of additional gas turbine in continuous basis in an event of unavailability of Unit Auxiliary Transformer of that gas turbine.

The bidder shall ensure that, each transformer offered is manufactured by a manufacturer with a minimum of fifteen (15) years successful experience in manufacturing comparable equipment, in rated voltage and capacity. In addition, minimum of ten years (10) experience shall be in manufacturing for orders from outside the country of the manufacturer.

If the offered equipment is manufactured under license, the manufacturing experience of equipment manufactured by the parent company shall not be counted as manufacturing experience of the licensee equipment.

In addition the Bidder shall submit a reference list of two or more transformers of same or similar design and rating manufactured and supplied by the manufacturer for orders from outside the country of the manufacture. Offered transformer will only be accepted if transformers identical/similar in design have a minimum of five years (5) field experience.

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

### 3.3.2.1 Technical Requirements Unit Auxiliary Transformer

| | *Primary side* | *Secondary side* |
|---|---|---|
| Nominal voltage | 6 kV* | 400 V |
| System highest voltage | 6.6 kV* | 415 V |
| Rated fault current | To be indicated by the | To be indicated by the bidder |
| Lightning impulse withstand voltage (peak) | 95 kV | - |
| One minute power frequency withstand voltage | 28 kV | - |
| Off load tapping (high voltage side) | +5% to -5% at 2.5% steps | |
| Insulator creepage distance | 43.3mm/kV | 43.3mm/kV |

* the primary and secondary voltage may be varied to suit the medium voltage level.

### 3.3.2.2 Applicable Standards

The equipment and the components supplied shall be in accordance with the latest edition of the standards specified below and amendments thereof.

- IEC 60076-11 Dry type power transformers
- IEC 60076-12. Loading guide for dry type power transformers
- IEC 60076-1 Power transformers
- IEC 600137 Insulating bushing for alternating voltages above 1 kV
- IEC 600551 Determination of transformer and reactor sound levels
- IEC 600616 Terminal and tapping markings for power Transformers
- IEC 600722 Guide to the lightning impulse and switching impulse testing of power transformers and reactors
- IEC 600815 Guide for the selection of insulators in respect of polluted conditions
- BS 2562 Cable boxes for transformers and reactors
- BS 5493 Protective coating of iron and steel structures against corrosion

### 3.3.2.3 Basic Features

The transformers shall be of cast resin dry type and suitable for indoor applications with a suitable enclosure. The transformer shall be designed so that they can deliver continuously its rated current under steady loading conditions without exceeding the temperature rise which shall be fully rated at ambient temperature of 40 $^0$C in an enclosure.

### 3.3.2.4 Transformer Construction

#### 3.3.2.4.1 The Core

The core shall be constructed of the best quality, low loss, cold rolled, grain oriented steel laminations insulated on both sides. Laminations shall be “step lap” overlapped to minimize core losses and noise. The assembled core shall be braced in suitable steel frames that make up the base-frame and lifting facilities for complete transformer. The entire core assembly shall be covered with a resin-based lacquer for corrosion protection before the coils are mounted.

The transformer core shall be of three limbs stacked core type. The core/coil assembly shall be mounted on the cover plate so that the assembly could be removed using the suitably placed lugs provided on the cover plate.

Construction features shall permit local repairs to be easily carried out in the event of equipment failure.

#### 3.3.2.4.2 Transformer Enclosure

The transformer enclosure shall be made of heavy-gauge steel and of robust construction. An enclosure with protection degree IP23 or higher which proposed by manufacturer to suit the location of installation, which provide safety barriers. Connections for equipment grounding conductors and supply-side bonding jumpers shall be made at a terminal bar that is mounted inside the transformer enclosure.

#### 3.3.2.4.3 Windings

All the windings shall be of high conductivity conductors of best quality. The transformer shall have separate high voltage and low voltage windings. The insulation system of the windings shall consist of approved materials for assigned temperature class. The insulation level of the windings shall comply the IEC standards.

HV windings shall be vacuum cast with aluminum/copper disk foil as conductor material and 155ºC (class F) insulation system temperature.

Winding design shall be adequate to allow for full encapsulation with filled resin under vacuum. The resin system shall be two components epoxy filled with a mixture of inorganic fillers improving its thermal, mechanical and fire behavior properties. The casting process shall be arranged in production process to assure the total elimination of air bubbles that could create partial discharges.

The surface of the encapsulated winding shall be smooth and completely closed and impervious to moisture and common industrial contaminants.

The LV windings will be of non-encapsulated design with Copper foil wound together with epoxy resin and thermally cured in an oven to achieve thermal, mechanical and moisture penetration properties that are comparable, for LV coils, with those of cast windings.

Both edges of windings shall be sealed (top and bottom), to prevent the entry of dust or moisture inside the coil.

**3.3.2.4.4 Sound Levels**

Audible sound emits by the transformer due to the core vibration shall be limited to K factor 1~9 as specified in NEMA ST-20.

**3.3.2.4.5 HV/LV connections**

The LV connections will be made from above onto bars located at the top of the coils on the opposite side to the HV connections.

The transformer shall be capable of withstanding, on any tapping, for two seconds (IEC value = 2 s), without damage, under service conditions, the thermal and mechanical effects of a short – circuit at the terminals of any winding.

**3.3.2.4.6 Thermal insulation class**

The insulation system temperature for HV and LV winding will be 155ºC (class F) .The average winding temperature rise for both HV (at rated tapping position) and LV windings at full load shall not exceed 115 ºC. (At an ambient temperature of 40 °C).

**3.3.2.4.7 Off load tappings**

The transformer shall be provided with tapping links on the HV windings. Their position can be selected whilst the transformer is off circuit. Taping selection shall be by means of bolted links. The tapping range shall be:

- Plus 2.5% and 5%
- Minus 2.5% and 5%

Tapings with connection cables are not accepted.

**3.3.2.4.8 HV and LV windings assembly**

The high and low voltage coils of each phase shall be supported and clamped by lower and upper supporting blocks, each having rubber expansion blocks for thermal expansion.The position of the LV terminals shall be either at the opposite side of the HV terminals at the top. The neutral bar terminal, if any, shall be at the same side as the LV phase terminal.

The design of the complete assembly should be in a way that if necessary, an exchange of separate high and low voltage coils can be done.

#### 3.3.2.4.9 Finishing

The procedure being stated shall be applicable to the metallic parts of the transformer and enclosure. Enclosure shall be made out of rust free sheet steel. Painting shall be powder coating (epoxy polyester powder) with 70µm average thickness

#### 3.3.2.4.10 Accessories

The transformers shall be equipped with following the accessories deemed necessary for proper operation by the manufacturer plus the ones specified in the specification.

- Lifting eyes or lifting lugs.
- HV and LV terminals
- Earthing terminals
- Pulling holes on the under base
- Winding temperature control system:
- The transformer will be equipped with a thermal protection device. It will consist of sensors and temperature control unit. The sensors will be supplied assembled and wired to the terminal block fixed on the upper part of the transformer. The temperature device provided shall have two numbers of potential free contacts for trip/alarm. In order to avoid any malfunction due to magnetic interferences, the temperature device will not be assembled in the transformer, but it will be packed for its transport with the transformer.
- Transformer shall have a rating plate of weatherproof stainless steel material placed in a clear position. Nameplate information as called for by IEC standards shall be provided.

### 3.3.2.5 Bushings

All bushings shall be of porcelain clad, of the highest quality and comply with IEC 60137. Creepage distance of the bushing insulator shall be 290mm or sufficiently higher for transformer up to 15kV. They shall be sealed in a manner to prevent ingress of moisture and to facilitate removal. The neutral bushings and stems shall be identical to those provided for phase terminations. Bushing palms shall be made of brass and be suitable for the bolting of conductor compression lugs.

The palms shall be suitably dimensioned, to suit the bushing rod and the holes spaced sufficiently apart to enable tightening of bolts using standard spanners and to prevent overlap of lugs.

### 3.3.2.6 Terminal Leads

Outgoing leads shall be brought out through bushings, the leads shall be such that the core and coils could be removed with the least possible interference with these leads, and they shall be specially supported inside the transformer to withstand the effects of vibration and short circuits.

The leads shall be so fixed that they do not break at the connection and would not twist and touch each other in case the bushing is turned accidentally.

### 3.3.2.7 Earthing Connections

Earthing connections shall be provided with connection facilities for 50mm2 copper stranded conductor. Three bolts of M12 size shall be located on either side of the tank base (two) and on the cover plate (one).

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. The bottom main core clamping structure shall be connected to the enclosure by copper cable.

### 3.3.2.8 Off Load Tap Changer

Voltage tappings shall be provided on the high voltage side of each transformer. Tapping step shall be ±2.5%. Number of tappings shall be as stipulated in the Clause 6.3b.3 – Technical Requirements.

The tappings shall be selected by an "off load" tapping switch with an external hand wheel with provision for locking on to a selected tapping. The voltage operating positions, together with tap change positions shall be clearly and indelibly marked.

### 3.3.2.9 Terminal Marking

All transformers shall have the primary and secondary terminal markings plainly and indelibly marked on the transformer adjacent to the relevant terminal. These markings shall be 25mm in height.

### 3.3.2.10 Radio Interference

When operated at voltage even up to 10% in excess of the normal system rating, transformers shall be substantially free from partial discharges (i.e. corona discharges in either internal or external insulation) which are likely to cause interference with radio or telephone communication.

### 3.3.2.11 Spare Parts and Tools

The supplier shall specify the spare parts required for proper and continuous functioning of the transformers. The supplier shall also specify if any special tools are required for the maintenance of transformers other than those conventional for transformers. A schedule of prices and quantities of spare parts and special tools shall be given by the bidder in Schedule 3, Special tools of Volume 5.

### 3.3.2.12 Outline Drawings, Maintenance Manual and Packing

Outline drawings and other necessary drawings baring an effect on customers' installation shall be provided with the transformer and a comprehensive maintenance manual shall also provided.

### 3.3.2.13 Quality Assurance

The manufacturer shall posses ISO 9001 Quality Assurance Certification for the transformers for the plant where the manufacture of distribution transformers is done. Bidders shall furnish a copy of the ISO certificate, certified as “true copy” of the original by the manufacturer, along with the offer.

### 3.3.2.14 Type Tests Certificates

The following Certificates of Type tests as per IEC 60076 by an internationally recognised independent testing authority shall be furnished with the offer

- Lightning Impulse withstand voltage test
- One minute wet power frequency withstand voltage test
- Temperature-rise test
- Acoustic sound level measurements
- Short-circuit tests

### 3.3.2.15 Inspection and Testing

#### 3.3.2.15.1 Inspection

The selected Bidder shall make necessary arrangements for inspection of the equipment by an Employer appointed by the Ceylon Electricity Board and also to carry out in his presence necessary Acceptance / sample tests of the materials and equipment, offered.

#### 3.3.2.15.2 Acceptance /Sample Tests

The following Acceptance/Sample tests conforming to IEC 60076 shall be witnessed by the Employer. Extra copies of these Test Certificates shall also be supplied with the equipment.

- Measurement of winding resistance
- Measurement of voltage ratio and check of voltage vector relationship
- Measurement of impedance voltage, short-circuit impedance and load loss
- Measurement of no-load loss and current
- Dielectric routine tests
- Pressure test at 0.25 bar above atmospheric

#### 3.3.2.15.3 Testing

Routine tests

- Measurement of windings resistances
- Transformation ratio measurement and connection checking
- Load loss and short-circuit impedance measurements

- No load loss and current measurements
- Separate source voltage-withstand test
- Induced over voltage withstand test
- Partial discharges measurements

Type Tests

- Temperature rise test
- Lightning impulse test
- Special tests (Always performed under customer request)
- Noise level test
- Measuring zero-sequence impedance
- Measuring insulation resistance
- Measuring of harmonics of the no-load current
- Measuring of the parallel capacity of windings and tag δ
- Anti-corrosion protection measurement
- Short circuit test

These tests are carried out in accordance with the relative IEC and/or IEEE standards.

## 3.4 Medium Voltage metal enclosed switchgear and control gear

This part of specification shall be applied only if an intermediate voltage level of 6kV is used depending upon the starting means of gas turbines. This section covers supply, installation and commissioning of medium voltage switchgear and control gear of 6 kV with associated equipment necessary to complete the works. The number, size and rating of the switchgear required are shown in the Schedule at the end of this Section. The 6kV switchgear will be used to supply auxiliary power requirement.

The manufacturer shall have a minimum of fifteen (15) years experience in manufacturing similar type of switchgear and control gear. Evidence shall be provided to prove that the manufacturer has minimum of five (05) years experience for the offered model in the export market for similar applications.

The minimum requirements are detailed herein according to Single Line Diagrams, Appendix E2 but the Contractor shall be responsible for ensuring that the equipment supplied meet the ratings and other requirements of his particular plant design.

### 3.4.1 General

All metal enclosed switchgear and control gear shall be prefabricated switchgear and control gear suitable for indoor and outdoor installation and shall comply IEC 62271. All major components contained in metal-enclosed switchgear and control gear shall be designed and tested in accordance with their various relevant standards.

The switchgear assembly shall consist of free standing, vertical enclosure containing circuit breaker compartments and circuit breakers, primary bus system, ground bus system, auxiliary compartments and transformers, protection and control devices, control bus (as required) and connection provisions for primary, ground, and control circuits. The basic structure will be of modular construction.

Metal enclosed switchgear and control gear shall be designed so that normal service, inspection and maintenance operations, determination of the energized or de-energized state of the main circuit, including the usual checking of phase sequence, earthing of connected cables, locating of cable faults, voltage tests on connected cables or other apparatus and the elimination of dangerous electrostatic charges, can be carried out safely.

The short circuit current ratings applicable to the earthing circuit depend upon the type of system neutral earthing for which it is intended. All medium voltage equipment shall include fully rated earthing facilities to provide safe maintenance access. To ensure personnel protection during maintenance work, all parts of the main circuit to which access is required or provided shall be capable of being earthed prior to becoming accessible.

MV switchgear installed indoors shall have ingress protection of IP 41; outdoor equipment shall be of IP 65. All enclosures containing electrical equipment shall be provided with thermostatically controlled anti-condensation heaters arranged to operate at low voltage ac. Ventilating openings, vermin proof vent outlets, Inspection windows, Partition or shutter being part of the enclosure, Covers and doors of Enclosures and Compartments shall be complied to relevant sections of IEC 62271.

A steel cabinet with doors and locks equipped with a complete set of spanners to fit every nut and bolt on the circuit breakers along with any special tools or maintenance equipment necessary shall be provided.

Requirements for gases in gases in switchgear and control gear shall be as per IEC 62271-100. Quantity, quality and density of SF6 to be used in switchgear and control gear shall comply 60376. Parts of high voltage switchgear and control gear housing compressed gas shall comply with requirements laid down in the relevant IEC standards.

Equipment shall be designed so as to minimize corona or other electrical discharge and radio interference.

A key cabinet capable of accommodating all padlocks and keys for the switchboard and padlocks of an approval type for all padlocking positions shall be provided for each switchboard.

### 3.4.2 Systems and Fault Levels

The switchgear shall be suitable for indoor operation on 3 phase 50Hz system having 6kV nominal voltage and rated voltage shall be 6.6 kV. The system highest voltage is 10 per cent in except under load throw-off conditions where higher values may occur. All necessary Fault level calculations related 6kV auxiliary system shall be done at the design stage and shall be forwarded for Employer’s approval.

All current carrying equipment shall be capable of withstanding these currents for a period of three seconds unless otherwise specified.

### 3.4.3 Circuit breakers

Circuit-breakers installed in metal enclosed switchgear shall be AC three-pole, SF6 or Vacuum type, designed for indoor or outdoor installation and for operation at frequency of 50 Hz on systems having voltages above and to their auxiliary equipment 1000V. All such circuit breakers shall be designed and constructed according to the IEC 62271-100. This sub section does not specify the Generator circuit-breakers installed between generator and step- up transformer and it is separately specified in section 6.5 of this specification.

Rated Voltage, Rated Insulation Level, Rated Normal current, Temperature rise, Rated short-time withstand current, Rated peak-withstand Current, rated supply voltage of closing and opening devices and auxiliary circuits, rated pressure of compressed gas supply (if any) for insulation shall be determined appropriately as per the standards IEC 62271-100.

A circuit-breaker, including its operating devices, shall be capable of completing its rated operating sequence in accordance with the relevant provisions for the whole range of ambient temperatures within its temperature class as defined in IEC 62271-100.

Medium voltage circuit breakers shall be fully withdrawable for isolation and maintenance purposes and shall be lockable in the isolated position. Suitable circuit breaker handling equipment shall be provided where necessary. Withdrawal shall not expose live parts.

#### 3.4.3.1 Operating Mechanism

Each of switchgear equipment shall be provided with a mechanical indicating device visible externally from the front of the switchboard. It shall be positively driven in both directions to show whether the circuit breaker is in the "OPEN" or "CLOSED" position and shall be operative when the circuit breaker is in the "SERVICE", "ISOLATED" or "EARTHED" modes. Lamp indication in place of a mechanical indicator will not be accepted but red green lamps shall be provided on each panel to provide an additional external indication of the switch position.

Closing mechanisms shall be motor charged spring assisted types with 110V d.c. release solenoid operating mechanisms would be acceptable for all types of circuit-breakers. A circuit breaker shall be able to perform 10,000 number of operations taking into account the program of maintenance schedule specified by the manufacturer.

The insulation of the solenoid coil shall be chosen to minimize the generation of flammable gases, should it overheat, and it shall be positioned in the switchgear to avoid risks of ignition of such gases by the operation of the main and auxiliary contacts.

It shall be possible to charge the mechanism spring with the circuit breaker in either the "OPEN" or "CLOSED" positions. It shall not be possible for the circuit breaker to close unless the spring is fully charged. A visual indicating device, preferable mechanical, shall be provided to indicate the state of the spring. The device shall indicate "SPRING CHARGED" when the spring is in a condition to close the circuit breaker and "SPRING FREE" when the spring is not in a condition to close the circuit breaker. If a charged spring is released when the circuit breaker is closed in the service position, than an alarm shall be initiated in the control room but a closed circuit breaker shall not open and such release shall not result in damage. For withdrawable circuit breakers, the spring latching mechanisms shall be arranged, such that the springs are discharged as the circuit breaker is withdrawn.

The mechanism shall be fitted with local manual spring release, preferably a pushbutton, shrouded to prevent inadvertent operation and provided with means for padlocking as well as an electrical release solenoid suitable for operation from the 110V d.c. supply.

230V a.c. motors shall be used for charging the spring mechanism. Recharging of the mechanism operating spring shall be commenced immediately and automatically upon completion of each circuit breaker closure. An alarm shall be initiated in the Control Rooms if the spring fails to recharge. An emergency hand operated charging device shall be supplied by the contractor.

### 3.4.4 Disconnectors and earth switches

For maintenance or other purposes, circuit breakers, contactors and main circuit fuses shall be connected to the busbars through disconnectors of agreed design, as appropriate. The isolating devices shall be arranged for operation while the busbars are live and while no current is passing. All disconnectors and earth switches shall be designed as per IEC 62271- 102.

Isolators shall be capable of carrying continuously the rated load current of the circuit and the fault current for the time specified. On-load isolators shall be capable of making a current equivalent to the specified prospective fault current as limited by the cut-off characteristics of the largest fuse with which it may be associated.

### 3.4.5 Auxiliary switches

All necessary auxiliary switches and mechanisms for indication, protection, control, interlocking, supervisory and other functions shall be supplied with each circuit breaker, contactor, isolating device and earthing device. All auxiliary switches including spares shall be wired up to a terminal board on the fixed portion of the switchgear.

### 3.4.6 Control & wiring

Switchgear shall normally be controlled through operator station (Human Machine Interface computer - HMI PC) located in the Local Control Cubicle. However, local control at the switchgear shall be provided for maintenance purposes. Lockable rotary Local/Remote selector switches is preferred for the purpose. Further controlling and monitoring functions shall be extended to HMI workstations located in Central Control Room (CCR) for centralized control and monitoring of the power plant from CCR.

Control devices, control buses, local control, instrument cables and wiring on the equipment shall be installed at the factory. Low voltage cables shall be enclosed in grounded metal flexible conduit when routed through a high voltage compartment. Control wiring shall be neatly bundled and tie wrapped where applicable. Wiring shall be protected from rubbing against door flanges or other parts of the enclosure.

Control wire shall be minimum 1mm2 diameter, stranded, extra flexible, 600V flame retardant, grey color and UL-listed wire except where larger sizes are needed for current carrying requirements. Current transformers shall be provided with a minimum 2.5 mm2 diameter subject to the burden limitations. The conductors shall be stranded copper for fixed wiring and extra flexible stranded copper for hinge wiring. The conductors shall be flameproof 600V, 90°C normal operating temperature, the wires shall be neatly bundled and tie wrapped.

The assembled control equipment and wiring connections shall be insulated for 600V and shall be subjected to a one (01) minute test of 1500V AC at the factory after fabrication and assembly is complete.

Terminal blocks shall be provided for terminating all power and control wiring. Terminal blocks shall be rated at 600V, strap screw terminals with white marking strips showing terminal numbers.

Terminal blocks shall be conveniently located for external connection without accessing the high voltage compartments and shall be marked appropriately. A wire label at both ends will identify each internal connecting wire.

### 3.4.7 Interlocks and shutters

Interlocks between different components of the equipment shall be provided for reasons of protection and for convenience of operation. The following provisions are mandatory for main circuits. Switchgear mechanisms shall be provided with means of locking in the isolated and earthed positions.

The withdrawal or engagement of a circuit breaker, switch or contactor shall be prevented unless it is in the open position. The operation of a circuit breaker, switch or contactor shall be prevented unless it is only in the service, disconnected, removed, test or earthing position, comply to relevant sections of IEC 62271. The interlock shall prevent the closing of the circuit breaker, switch or contactor in the service position unless any auxiliary circuits associated with the automatic opening of these devices are connected.

Metal enclosed switchgear and control gear provided with disconnectors Interlocks shall be provided to prevent operation of disconnectors under conditions other than those for which they are intended as stipulated in IEC 62271.

The contractor shall give all necessary information on the character and function of interlocks.

Earthing switches having a rated short circuit making capacity less than the rated peak withstand current of the main circuit should be interlocked with the associated disconnectors. Apparatus installed in main circuits, the incorrect operation of which can cause damage or which are used for securing isolating distances during maintenance work, shall be provided with locking facilities (for example, provision for padlocks).

If non-mechanical interlocks are provided, the design shall be such that no improper situations can occur in case of lack of auxiliary supply. However, for emergency control, the manufacturer may provide additional means for manual operation without interlocking facilities. In such case, the manufacturer shall clearly identify this facility and define the procedures for operation.

### 3.4.8 Trapped key Isolation system

Trapped key interlocking isolation system shall be installed and commissioned using locks and keys for sequential control of equipment and machinery to ensure safe operation. Trapped key interlocks shall ensure the safe access to potentially live or dangerous plant or equipment related to 132kV system, medium voltage system, generators, transformers etc.

### 3.4.9 Insulation Levels and Clearances

Rated short duration power frequency withstand voltage and Rated lightning impulse withstand voltage of switchgear and control gear shall comply with IEC 62271-1.

The equipment shall be able to withstand the specified insulation level at Site conditions.

### 3.4.10 Temperature Rise

The temperature rise of any part of the switchgear and control gear at an ambient air temperature shall not exceed the temperature-rise limits specified in IEC 62271-1 under the conditions specified in the test clauses.

Each current carrying component of the switchgear and control gear supplied shall be capable of continuous operation at the specified nominal ratings without exceeding the maximum temperature without assistance from any forced cooled ventilation or air conditioning plant. The permissible overload rating for the switchgear operating under emergency conditions, shall be stated in the Schedule of Technical Particulars together with the duration and ambient temperature for which it applies.

### 3.4.11 Circuit Breaker Control

The 6kV switchgear and control gear shall be equipped with facilities for automatic control and remote control from the Central Control Room (CCR) via a lockable local/remote control selector switch on each circuit breaker panel. Selection of either control position shall prevent manual control from the other position but shall not prevent operation of automatic protection devices.

### 3.4.12 Isolating Facilities

Facilities shall be provided on both the busbar and circuit sides to permit isolation of circuit breakers for maintenance purposes.

Mechanical indicators, externally visible at the front of the cubicle whether or not the front door is closed, shall be provided to show whether the circuit breaker is in the service or isolated condition and to show the position of earthing switches and disconnectors.

Padlocking facilities shall be fitted to enable earthing switches and disconnectors to be locked in the “on”, “off” and “earthed” positions.

Facilities shall be provided for high voltage tests on cables and busbars and for primary injection of current transformers.

Where windows are provided for observation of the position of isolators and earthing switches, these shall comply with IEC 62271.

### 3.4.13 Earthing Facilities

Means shall be provided to earth incoming and outgoing circuits, and busbars. These facilities shall permit, as a minimum, the simultaneous earthing of any one busbar and any two circuits. At least two panels on each section of busbar shall have facilities for carrying out busbar earthing.

The earths shall be made either through circuit breakers or by the use of earth switches with fault making capacity, which have the same make and short time current ratings as the circuit breakers. The means of earthing shall form an integral part of design of the switchboard

It shall not be possible to select an integral earthing position unless the associated circuit breaker is in the open position. When the circuit breaker is being used for earthing, a facility shall be provided to prevent the circuit breaker from being opened by mechanical or electrical means during closure or when closed. Similar facilities shall be provided on mobile earthing devices. It shall be impossible to return a circuit breaker to the service position without the electrical trip circuit being restored to normal.

The operating mechanism of each earthing switch shall be a manual device designed so that the closing speed of the switch is independent of the operator. It shall not be possible to have the switch in a partially open or closed position and it shall not be possible for a switch to close and open immediately afterwards.

On generator circuits, the earthing switch shall be interlock with the field suppression switch that it is not possible to earth an excited generator.

The 6 kV, system shall be earthed through a low resistance type earthing. All neutral points of secondary side (6 kV) of three station service transformers shall be earthed through three separate grid type earthing resistors to limit earth fault current to 400A, each. (refer annexure… “6kV Medium voltage single line diagram for protection scope”).The resistor shall be rated to carry this current at least for 60 seconds. The applicable standards shall be IEEE 665, IEEE 80, IEEE C62.92.1-2000, IEEE C62.92.2-1989 and IEEE C62.92.3-1993. The contractor shall take every precaution to design station earth mesh, to maintain touch voltages and step voltages, as defined in other parts of this document.

### 3.4.14 Earthing of Metal Parts

All metal parts including any relays, instruments, etc. mounted on the switchboard, shall be connected to a copper earth bar which runs along the full length of the switchgear panel.

The cross section of the bar shall not be less than 300sq.mm and shall be sufficient to carry the rated short time withstand current of the switchgear for the time accepted in clause 6.4.2.

The frame and tank of the withdrawable circuit breakers shall be connected to the earth bar through a substantial plug type contact arranged to make and maintain contact whenever the circuit breaker is in the service or an earth position. Reliance upon connection via the carriage wheels is not acceptable. Similar earthing facilities shall be provided for withdrawable voltage transformers.

The earthing contacts of all earthing switches and the earthing connections for any earthing devices shall be connected directly to the earth bar.

### 3.4.15 Trip Circuit Supervision

Supervision shall be provided on each circuit breaker cubicle, by means of a continuously active monitoring circuit connected into the trip circuits, when the circuit breaker is in the "SERVICE" position. This monitoring circuit shall detect failure of the trip supply, or a break in the tripping circuit whether the circuit breaker is "OPEN" or "CLOSED". In the event of any trip circuit failure, a flag relay and amber light shall operate at the circuit breaker panel and a remote alarm shall operate in the control room. The rating of components associated with the trip circuit supervision scheme shall be such that failure of any item does not result in tripping of the associated circuit-breaker.

### 3.4.16 Busbars and Connections

Busbars and connections shall comply with the requirements of BS159, or other approved international standard, and shall be continuously rated for the site conditions and currents specified. Busbars and current carrying parts shall be manufactured from hard drawn high conductivity copper. Where specifically approved by the employer, aluminums busbars and connections may be used and full details of procedures adopted for aluminum/copper interfaces shall be submitted.

The peak asymmetric fault current rating of the busbars and connections shall be equal to, or greater than, the make rating of the circuit breakers. Either insulated or uninsulated busbars are acceptable subject to approval in respect of clearances in air and evidence of dielectric tests applicable to the whole installation. Taping is not acceptable. Any insulating material used shall be capable of withstanding the heating effects of the rated short time withstand current without permanent deformation or deterioration and shall comply with IEC 60085 on thermal stability and IEC 60466 or latest version on flammability.

Busbars and connections shall be adequately supported against short circuit forces and provision shall be made to allow for thermal expansion of the conductors due to normal load currents and short circuit currents. Full details of procedures used for busbar joints shall be submitted.

Busbars shall be contained in a separate metal enclosed compartment within the general casing of the switchgear.

All calculation related to bus bars such as continues current ratings, short circuit levels etc. shall be submitted to the Employer for approval by the contractor prior to fabrication.

### 3.4.17 Cable Terminations

Provision shall be made in accordance with clause 6.15.14 for terminating cable of the types specified.

Cable terminating boxes and glands shall be of a type approved by the manufacturer of the cable. For single core cables insulated island layer glands shall be provided with a test link connected between the island layer and earth. Where busbar frame earth leakage protection is specified then an island layer gland shall be provided in all cases.

Each panel of switchgear shall have separate terminal chambers for the receipt of main and multicore cables.

### 3.4.18 Current Transformers

All current transformers supplied shall be suitable for the duty specified under the protection and metering functions and comply with the requirements of IEC 61869.

Current transformers, including primary winding conductors, shall have a short time current rating and duration not less than that corresponding to the design short circuit level of the associated switchgear.

Current Transformers shall have a maximum continuous primary current rating not less than the primary equipment rating of the circuit in which they are installed. The secondary winding of each current transformer shall be earthed at one point only.

Magnetization curves shall be provided for each type and rating of current transformer.

Approval of the employer shall be obtained for all the CT ratings.

The contractor shall ensure that the capacity of the CTs are adequate for the operation of the associated protective devices and instrument being supplied. All CT calculations related to CT selection shall be produced for employers' approval at the design stage.

Each current transformer shall be individually labeled and serial plates are to be provided for lifting to the outside of current transformer chambers, etc. 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 from each ratio. These connections shall be shown on the appropriate schematic and connection diagram.

### 3.4.19 Voltage Transformers

Voltage transformers shall be suitable for the duty specified under the protection and metering functions and comply with the requirements of IEC 60044-2. They shall be either three phase or single-phase units with a secondary phase-to-phase voltage of 110V when the rated nominal voltage is applied to the primary winding. The transformer shall have an accuracy class suitable for the duty specified. All calculations related to VT selection shall be produced for employers' approval at the design stage.

Where necessary to meet protection and metering requirements, voltage transformers with two separate secondary winding or open delta tertiary windings shall be provided.

The primary windings shall be connected to the busbar of feeder side of the circuit breaker, as specified, through replaceable fuses of adequate breaking capacity with current limiting features. HRC type secondary fuses shall be provided. The fuses shall be so placed as not to be accessible to unauthorized persons. The voltage transformer fuses shall be supervised by V.T. fuse failure relays.

The primary and secondary winding fuses shall be designed according to IEC60282.

Voltage transformers shall have facilities to permit them to be safely isolated either by withdrawal or by use of a lockable isolating switch, with the associated circuit breaker closed in the service position.

Connections to the voltage transformer primary fuses shall be capable of carrying the circuit breaker rated short-time withstand current. The voltage transformer connection shall be capable of carrying a current of 200A continuously so that primary injection testing may be carried out, unless other approved means are provided for primary injection testing.

Voltage transformers of the withdrawable type shall utilize plug-in contacts. Provision shall be made for looking the voltage transformer in the service or withdrawn position. Shutters shall be fitted to the spouts which shall open and shut automatically by the insertion or withdrawal of the voltage transformer. The secondary winding earth connection shall be made before the primary connections are made. The spout shutters shall be painted YELLOW or RED depending on whether they are connected to the circuit side or the busbar side of the circuit-breaker.

The secondary windings of voltage transformers shall be suitably insulated to allow for earthing at either and (line or star point). VTs shall be arranged such that they cannot be back energized, from the secondary circuits, when the primary connections are dead.

A voltage transformer shall be provided on each section of the bus-bars. The busbar connected voltage transformers, shall be connected to supply "running" voltmeter and frequency meter indication, instrumentation and metering circuits as relevant.

### 3.4.20 Accessories

The switchgear and control gear shall be supplied with all necessary fuses, terminals, small wiring, voltage selection relays, auxiliary switches and/or relays, mechanical indicators, earthing, locks, locking facilities, and keys, cable boxes and terminations for power and control cables, oil, foundation channels and bolts, main and circuit labels, locks and keys. Special consideration must be made for dust exclusion. Anti-condensation heaters are required.
Keys and locks shall be contained in suitable wall mounted key cabinets, mounted on the switch room wall.

All special tools and appliances necessary for installation, operation, testing and maintenance shall be provided contained in suitable wall mounted tool cabinets of mild steel construction, mounted on the switch room wall.

All accessories such as relays, fuses, MCBs, terminal blocks, auxiliary switches, mechanical indicators, earth links, CTs, VTs etc. shall be adequately labeled in concise manner. All such labels shall be engraved with black lettering on a white background.

### 3.4.21 Testing of Switchgear and control gear

Components contained in metal enclosed switchgear and control gear shall comply with and be tested in accordance with IEC 62271.

**Type tests**

The type tests shall be made on a representative functional unit. The performance of any particular arrangement may be substantiated by test data of comparable arrangements.

- Dielectric tests
- Measurement of the resistance of circuits
- Temperature rise tests
- Short time withstand current and peak withstand current tests
- Verification of the protection
- Tightness tests
- Electromagnetic compatibility tests (EMC)
- Additional tests on auxiliary and control circuits
- Verification of making and breaking capacities
- Mechanical operation tests
- Pressure withstand test for gas filled compartments
- Internal arcing test
- Miscellaneous provisions for making and breaking tests of circuit breakers
- Test circuits for short circuit making and breaking tests of circuit breakers

- Short circuit test
- Single phase and double earth fault tests of circuit breakers
- Out of phase making and breaking tests of circuit breakers

**Routine tests**

The routine tests shall be made on each transport unit and, whenever practicable, at the manufacturer's works to ensure that the product is in accordance with the equipment on which the type test has been carried out.

- Dielectric test on the main circuit
- Tests on auxiliary and control circuits
- Measurement of the resistance of the main circuit
- Tightness test
- Design and visual checks
- Partial discharge measurement
- Mechanical operation tests
- Pressure tests of gas filled compartments
- Tests of auxiliary electrical, pneumatic and hydraulic devices
- Tests after erection on site

## 3.5 Generator Circuit Breaker (GCB)

### 3.5.1 General

This Specification covers the design, manufacture, factory testing, delivery, installation and commissioning of 3 phase, 50 Hz arc proof, SF6 or Vacuum, Generator Circuit Breaker switchgear with control, monitoring and indication equipment incorporated, complete with all specified documentation.

- The manufacturer shall have a minimum of fifteen (15) year experience in manufacturing similar type of generator circuit breakers. Evidence shall be provided to prove that the Manufacturer has minimum of three (03) year experience for the offered model in the export market for similar application as Generator Circuit Breakers. Circuit Breakers with the operating mechanism of the offered type shall be suitable for tropical climate.
- The manufacturer shall have an established department that will serve the Employer in the supply of spares for at least ten (10) years after the commissioning of the equipment.
- The quality of design, manufacture and erection processes shall be assured in accordance with the ISO 9001 standard. ISO certificate shall be furnished with the offer.
- When selecting a generator circuit-breaker, due allowance shall be made for the likely future development of the system as a whole, so that the generator circuit-breaker shall be suitable not merely for immediate needs but also for the requirements of the future.
- The generator circuit breaker shall be suitable for synchronizing the generators, and shall

be capable of out of phase switching within standard synchronization limits.

- The Generator circuit breaker shall be SF6 or Vacuum type.
- The circuit breaker shall be with motor charged spring operated mechanism. It shall have facility for both local and remote operation.
- The Circuit Breaker shall be capable for three-pole operation. It shall be suitable for a minimum number of 10,000 mechanical C-O operations as a Generator Breaker. Permissible number of switching operation as a Generator circuit Breaker at rated breaking current shall be at least 10,000 operations before a major overhaul.
- The circuit breaker shall consist of a minimum number of assemblies except for interrupters and other parts subject to deterioration. Such parts shall be easily removable in small assemblies. Original and renewable parts shall be so manufactured that they can be assembled in the field without undue dismantling.

### 3.5.2 Environmental Condition

Environmental conditions to be considered in designing of the circuit breaker shall be as per the section 3.4.

### 3.5.3 Applicable Standards

- 62271-37-013-2015 - IEEE/IEC International Standard for High-voltage switchgear and control gear - Part 37-013: Alternating-current generator circuit-breakers
- IEC 62271 – 2 for High-voltage switchgear and control gear - insulation coordination.
- IEC 60529:1989 or latest - Degrees of protection provided by enclosures
- IEC 61936-1:2010 Power installations exceeding 1 kV a.c. - Common rules
-

### 3.5.4 GCB Switchgear

The design and construction of the switchgear shall guarantee 100% arc proof units and the quality of design manufacture and erection processes shall be assured in accordance with the ISO 9000 series standards. ISO certificate shall be furnished with the offer.

The supplied generator breaker switchgear shall be designed so that normal service,

inspection and maintenance operations, determination of the energized or de-energized state of the main circuit and the elimination of dangerous electrostatic charges, can be carried out safely.

Rated voltage of the Circuit breaker shall be matched with generating voltage of the plant in all operating conditions. (Rack in Rack out type Generator circuit breaker as per the clause 6.5.5 of this specification and shall be installed in the switch gear unit.)

The generator circuit breaker switchgear shall be a modular design built by placing standardized units side by side in a coordinated way. Each switchgear unit shall consist of the following main components:

a). Circuit breaker, as per the clause 5.5 of this specification.

b). Bus bars:

c). Isolating switch (Disconnector) transformer side

d). Earth switches generator side and transformer side

e). Auxiliary compartment with instruments and control cabling.

f). Duct for evacuation of the gases produced by an arc.

Means shall be provided to ensure the reliable operation of the shutters where applicable. Movement of the shutters shall be positively driven by the movement of the removable parts.

The switchgear shall be a standard design of the manufacturer and shall be simple to configure. Selection of instruments and other apparatus shall not require a dedicated solution. The functional units of the switchgear shall be guaranteed arc proof in accordance with IEC 60298.

The switchgear and control gear shall be designed so that normal service, Start up, Maintenance, Inspection, Operations, Determination of the energized or De energized state of the main circuit etc., shall be possible from the front side.

Inter-locking

The withdrawal or engagement of the Generator circuit breaker (from/to switchgear) shall be impossible unless it is in open position.

The operation of the Generator circuit breaker shall be impossible unless it is in the service, disconnected, removed, test or earthing position.

It shall be impossible to close the Generator Circuit Breaker in the service position unless it is connected to the auxiliary circuit.

It is required to incorporate a locking magnet to make automatic interlock logic without human intervention. Interlocking of the doors of circuit breaker compartment shall be decided by considering Circuit Breaker rack in rack out.

Switchgear unit shall be naturally ventilated through vermin proof louvers comprising a brass gauze screen attached to a frame and secured to the inside. In addition, thermostatically controlled heaters with a setting of at least 15°C to 40°C for continuous operation at the rated AC voltage 230V, 50Hz shall be provided in series with a single pole switch mounted within the switchgear unit. A 230V, 13A socket outlet shall be provided in the unit.

Motors and their electrically operated ancillary equipment installed within the switchgear unit shall operate satisfactorily at all supply voltages between 85% and 110% of rated single-phase voltage of 230V, 50Hz and shall be suitable for continuous operation under ambient conditions, specified.

Vent outlets shall be arranged in such a way that gas or vapour escaping under pressure shall not endanger the operator. It is preferable to have such exhaust duct positioned above the switchgear unit and runs along its whole length. (In such a design each compartment shall be fitted with a flap positioned on top of it to allow the gases generated due to a fault inside the compartment to pass into the duct.)

Access doors of Switchgear unit shall be provided with "glass windows" where necessary to view instruments without opening the cubicle. The arrangement of equipment within the unit shall be such that access for maintenance or removal of any item shall be possible with minimum disturbance to associated apparatus. The switchgear panel front instruments and manual controls shall be visible through glass windows of panel.

An Earthing bus bar made of electrolytic copper conductor shall be provided for extending the whole length of the metal clad switchgear and control gear. Ratings of the earthing bus bar shall be designed to ensure maximum safety of the personnel and equipment.

Degree of protection shall be according to IEC 60298. Degree of protection on the external housing shall be IP4X and inside the panel shall be IP 2X.

An approved schematic diagram of the parts of the control system local to the Switchgear unit , identifying various components within the unit and necessary instructions, shall be affixed to the inside of the access door. The diagram shall be marked on durable non- fading material suitable for specified site conditions.

Labels, written in English language shall be provided for all instrument relays, control switches push buttons, indicating lights, etc. Relays shall be clearly labeled according to their function and their equipment. Labels shall be preferably on a white background with black engraved letters.

Clearly Legible name plate consists of the following shall be attached to the switch gear unit,

I. Manufacturer's Name or trade mark
II. Type designation and serial number
III. Rated Characteristics
IV. Year of manufacture

### 3.5.5 Generator Circuit Breaker Design

The Generator Circuit Breaker shall be suitable for indoor or outdoor depending upon the requirement of installation setup of gas turbine. T he principal function of the generator circuit-breaker is to carry generator rated load current and provide a means for interruption of short-circuit current from the generator as well as from the power system. However, the generator circuit-breaker can be used for load, transformer excitation, or out-of-phase current switching. In some cases, these switching requirements may be the determining factor in the selection of a generator circuit-breaker rather than short-circuit current interruption requirements. Following design and construction aspects of the generator circuit breaker shall meet requirement a specified in relevant clauses of IEEE/IEC 62271-37-013:2015.

a. Requirement for Liquids/gases
b. Earthing arrangements
c. Auxiliary and control arrangements
d. Stored energy operation

e. Operation of shunt closing/opening operations, capacitor operation of shunt releases, requirement for multiple releases and limits
f. Requirement for low/high pressure interlocking devices
g. Nameplates of circuit breaker and accessories
h. Interlocking devices
i. Position indicators
j. Degree of protection provided by enclosures
k. Creepage distances for outdoor insulators
l. Gas and vacuum tightness
m. Liquid tightness
n. Fire hazard
o. Electromagnetic compatibility (EMC)
p. X-ray emission
q. Requirements for simultaneity of poles during single closing and single opening operations
r. Pressure limits of fluids for operation
s. Vent outlets
t. Warning labels

A generator circuit-breaker, including its operating devices, shall be capable of completing its rated short-circuit operating sequence in accordance with the relevant provisions of 5.6 to 5.9 and 5.103 for the applicable range(s) of ambient temperatures as defined in Clause 2 of IEC 62271-1:2007. Generator circuit-breakers provided with heaters shall be designed to permit an opening operation at the assigned minimum ambient temperature when the heaters are not operational for a minimum time of 2 h.

### 3.5.6 Operating duty and performance of Generator Circuit Breaker

Bidder shall furnish type test certificates issued by a recognized authority for short circuit testing and the operation of the circuit breaker at duties corresponding to the rated breaking capacities. The test duty shall not be less onerous than the requirements of IEC / IEEE standard.

Circuit breaker must be capable of coping up with interrupting duties produced by out of phase conditions due to lack of synchronism between generator and power system at the instant of operation of the generator circuit breaker. Out of phase capability of the Generator circuit breakers shall be in accordance with the relevant standards. This rating shall be indicated on the nameplate of the circuit breaker.

**Excitation current switching capability**: Circuit breaker shall be capable of coping up with the interrupting duties produced by the highest magnetizing current of Generator transformer and the switching of line charging currents at any voltage up to rated maximum voltage at power frequency without causing an over voltage and exceeding the voltage levels specified. This capability shall be proved by a test in accordance with IEC / IEEE or by a calculation.

Normal method of generator circuit breaker operation shall be by spring-operated mechanism for both opening and closing operations. Provision shall be made for the prevention of a spring charging motor turning the manual-charging handle if inadvertently energized during the manual charging operation.

The design of the operating mechanism shall be to ensure positive opening of the circuit breaker whether the tripping signal is received in the fully closed or any partially closed position. Closing the circuit breaker into a standing trip signal or opening the circuit breaker into a standing close signal shall not cause any damage to the circuit breaker.

For the purpose of inspection, testing, adjustment and other maintenance work, means shall be provided to permit local operation of the circuit breaker. If the maintenance procedure requires slow operation of the breaker, the design of the circuit breaker and the operating mechanism shall permit such operations.

Each part of the operating mechanism shall be of substantial construction, utilizing such material, where necessary to prevent sticking due to rust or corrosion. The overall design 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.

The CB shall be fitted with anti-pumping devices and operation counters. The operation counter shall operate only during the closing cycle of the circuit breaker operation. All Pressure gauges, counters etc. shall be easily readable.

Single closing and two tripping coils (Trip 1 and Trip 2) shall be provided suitable for Plant DC system.

Voltage ranges: 75-110% for tripping
85-110% for closing

Trip circuit failure protection and close coil protection against breaker failure to close shall be provided.

Power closing mechanism shall be recharged automatically for further operations as soon as the circuit breaker has completed a closing operation. The design of the closing mechanism 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 close and two trip operations, without recharging for spring operating mechanism.

If the circuit breaker closing 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. Means shall be provided to prevent over charging of the springs.

Access for operating cubicle for inspection, Testing and maintenance shall be provided from the front.

Motors and their electrically operated ancillary equipment for charging spring shall operate satisfactorily at all supply voltages between 85% and 110% of rated voltage 230V, 50Hz, and shall be suitable for continuous operation under ambient conditions, specified. Motors shall be provided with adequate protection.

### 3.5.7 Enclosure of the circuit breaker and switchgear unit

Circuit breaker and switchgear unit operating mechanism, auxiliary switches and associated relays, control switches, control cable terminations, and other ancillary equipment shall be accommodated in cubicles or compartments.

The cubicle for circuit Breaker and switchgear unit shall be of rigid construction. All fastenings shall be integral with the panel or door. Doors and panels shall be rigid and fitted with sealing material suitable for the climatic conditions specified.

Circuit breaker control position selector and circuit breaker operating control switches shall be installed in the circuit breaker cubicle. Circuit breaker control from this position will be used under maintenance and emergency conditions only.

The covers and doors which are parts of the enclosure shall be metallic, and when they are closed they shall provide the degree of protection specified for the enclosure.

Circuit breaker enclosure ventilating openings and vent outlets shall be so arranged or shielded that the same degree of protection as that specified for the enclosure is obtained. Ventilating openings and vent outlets shall be arranged in such a way that gas or vapour escaping under pressure does not endanger the operator.

The circuit breaker enclosure shall be fitted with compact fluorescent light fitting; the light switch shall be controlled by the enclosure door.

The circuit breaker enclosure shall be fitted with a thermostat-controlled heater. The space heater shall be suitable for 230+10% -15%VAC power supply.

The enclosure door shall be fitted with padlocking facilities.

### 3.5.8 Generator Circuit Breaker Controls, Indications, Alarms

**Controls**

The following circuit breaker controls shall be provided.

<u>Local Controls:</u>

i). Local/Remote Selector Switch. The local/remote control switch shall be in either local or remote position.

ii). Circuit Breaker Open/Close Control Switch with spring return to the centre-neutral position. Circuit Breaker close signal shall be interlocked with the circuit breaker position and the position of the Local/Remote Selector Switch.

**Indications**

The following circuit breaker indications shall be provided:

<u>Local Indications:</u>

i). Circuit Breaker - Local control mode;

ii). Circuit Breaker - Remote control mode;

iii). Circuit Breaker –Center neutral

position:

iv). Circuit Breaker Open;

v). Circuit Breaker Closed;

vi). Closing Spring Charged;

vii). Circuit Breaker in Service Position (if applicable);

viii). Circuit Breaker in Test Position (if applicable);

<u>Remote Indications:</u>

i). Circuit Breaker on Local control mode;

ii). Circuit Breaker on Remote control mode;

iii). Circuit Breaker –Center neutral position:

iv). Circuit Breaker Open;

v). Circuit Breaker Closed;

vi). Closing Spring Charged;

vii). Circuit Breaker in Service Position (if applicable);

viii). Circuit Breaker in Test Position (if applicable);

ix). Circuit Breaker rack out/rack in

The following circuit breaker alarms shall be provided at both local control room and central control room:

i). Circuit Breaker Main trip coil FAIL;

ii). Circuit Breaker Duplicate trip coil FAIL;

iii). Closing spring FAIL to charge;

iv). SF6 gas density LOW Stage 1 (warning); If applicable

v). SF6 gas density LOW Stage 2 (breaker operation blocked); If applicable

vi). Circuit Breaker not correctly rack-In

**Control & Auxiliary Circuits**

Circuits shall be separated on a control, trip, indication, alarm, etc. basis as appropriate and shall be arranged to facilitate external connections and to provide appropriate isolating points for circuit checking and fault finding.

The functional identification of all connections in control, indication, alarm circuits and device numbers shall be in accordance with relevant IEC/IEEE standards. Both ends of each wire shall carry wire numbers as shown on the wiring diagram or in the wiring/connection table. Wires associated with tripping circuits shall be provided with red ferrules marked "TRIP".

Wires shall not be jointed or teed between terminal points and shall not be clamped directly under screws.

### 3.5.9 Testing of the Generator Circuit Breaker

Testing of Generator Circuit Breaker and associated Switchgear unit with the Generator circuit breaker shall be done according to the latest standards specified in clause 3.5.3.

**Type Tests**

Type tests are made to determine the adequacy of the design of a particular type, style, or model of the generator circuit-breaker to meet its assigned ratings and to operate satisfactorily under the specified service conditions. Type tests are expected to made only on representative generator circuit-breakers of basically the same design, i.e., the same interrupters operating at the same contact speeds, and having at least the same dielectric strength.

Relevant Type Test certificates as per standards IEEE/IEC 62271-37-013-2015of the design of a particular type, style, or model of the offered generator circuit-breaker shall be provided in the detailed design stage. .

**Routine Tests**

Routine tests shall be made on the complete generator circuit-breaker at the factory. However, when generator circuit-breakers are assembled and shipped as separate units, the routine tests shall be performed on site.

i). Dielectric test on the main circuit

ii). Test on auxiliary and control circuits

iii). Measurement of the resistance of the main circuit

iv). Tightness test

v). Design and visual checks

vi). Mechanical operation tests

### 3.5.10 Maintenance

The Generator Breaker Switchgear shall be so designed and manufactured that, besides periodic inspection of pressure, leakage, measurement of time - motion characteristics, the maintenance shall be very simple and minimum. Contact parts and the arc controls devices, which are subjected to erosion, shall be easily accessible, simple to dismantle, and to inspect. Any special tools, racking out trucks and consumable required for maintenance shall be listed and furnished with the offer.

Three copies of operating and maintenance manuals together with all relevant drawings and circuit diagrams shall be supplied.

Operating and Maintenance manual shall include all necessary instructions for operation and maintenance including the following,

a). A general description of the equipment with particular attention to the technical description of its characteristics and operation so that the user has an adequate understanding of the main principles involved

b). A description of the safety features of the equipment and the operation of the interlocks and padlocking features.

c). As relevant, a description of the action to be taken to manipulate the equipment for operation, isolation, earthing, maintenance and testing.

d). Recommended extent and frequency of maintenance considering switching operations, total number of operation and time in service, environmental conditions, and measurement and diagnostic tests.

e). Recommended place for the maintenance work (Indoor, outer door, in factory, on site) and procedure for inspection, diagnostic tests, examination and overhaul.

f). Comprehensive drawings of the details of the switchgear and control gear which are important for maintenance including overhauling, with clear identification (part number and description) of assemblies, sub-assemblies and significant parts.

g). Description of special equipment or tools required for the maintenance work.

h). Description of Safety precautions to be observed during the maintenance work.

i). Limits of values and tolerances which when exceeded should be corrected by the maintenance staff. At least the limits and tolerances of the following shall be given: (i) Pressure, (ii) density levels, (iv) Operating times, (v) Resistance of the main circuit, (vi) Quantities and quality of liquid or gas, (vii) Manufacturers references of liquid or gas, (viii) Permissible torques of all nuts and bolts, (ix) Important dimensions

j). List of special tools, lifting and access equipment.

k). Description of tests after maintenance work.

l). How to proceed with the equipment at the end of its operating life, taking into consideration environmental requirements.

m). It is mandatory that the maintenance manual shall include a list of all the components (not sub-assemblies) and order number for each of such components. If any manufacturer does not offer individual spares such offers are liable to be rejected.

## 3.6 Protection system for Generator, Generator Transformer, Station Service Transformer, 132kV Cable and Black start Diesel Generator

### 3.6.1 Scope of the Protection system

This sub section specifies the total protection requirement for the plant including generators, Medium Voltage system, transformers, and 132 kV system. The protection panels, consist of relays and associated equipment shall be installed in the Local Control Cubicle.

The new protection systems shall isolate faults as quickly as possible to limit damages and to maintain healthy and steady operational condition. The scheme shall provide a high degree of selectivity and discrimination between faulty and healthy circuits. All devices shall remain inoperative for faults outside the protected area and transient conditions. They shall be insensitive to mechanical shocks, vibration etc. Each protective scheme shall be designed so that it does not cause incorrect tripping of a circuit breaker if a fault occurs outside the zone of protection covered by the scheme.

Protection system offered shall be a standard product of the manufacturer and shall be of numerical type. Combinations using static and numerical relays will not be accepted.

Protection schemes shall generally be arranged in redundant relays in order to have redundant protection functions for generator, main transformer and 132kV cable system while rest of the protection system shall not be duplicated. The total protection system shall be according to the main/back-up protection principle.

The protection system shall cover all the generators, generator transformers, excitation transformers, auxiliary station service transformers, medium voltage bus bar, 132kV cables and black start diesel generators.

The design of the protection system shall be as Appendix E4 “Protection scope for Generator, Generator T/F and Station Service T/F”, Appendix E5 “Protection scope for Emergency Generator” and Appendix E6 “Trip Scheme for 132kV Circuit Breakers of Kelanitissa New Gas Turbines”. However single line diagrams for the proposed system to cover the full scope of the Plant shall be submitted with the Technical Bid. The rated secondary current of all the current transformers shall be taken as 1A. The CT capacity, protection class and the CT ratios shall be decided by the contractor with due consideration to the DC saturation and maximum through fault current effects and other requirements set out in this bid document. The number of protection CT cores in each CT, shall be decided so that the redundant protection functions are fed from the different CT cores.

The documentation regarding the total protection calculations including the settings and the CT sizing shall be submitted for approval of CEB during the design stage. The three-phase fault level at 132kV bus bar shall be as per the system parameters given under clause 6.3.1.2.

Adequate test facilities shall be provided in the relay panel to enable the protection equipment to be tested whilst the primary circuit is on load, without having to disturb any wiring.

Adequate facilities shall be provided to isolate all dc and ac incoming and outgoing circuits so that work may be carried out on the equipment with complete safety to personnel and without loss of security in the operation of the generating station.

All test equipment required for commissioning and routine testing of the offered protection equipment shall be provided.

The contractor shall design and submit for approval of CEB, his tripping schemes for all type of faults and emergency trips of the total power plant, including 132kV cable faults. The trip circuit supervision feature shall be included for the generator circuit breaker trip coils.

The protection system including protection relays and trip relays, in the station side shall be operated from the station battery supply of 110Vdc, +10% to -15% and the protection relays proposed in the existing 132kV gas insulated substation(GIS) shall be operated from the GIS battery supply of 110Vdc.

As implementation of the plant consists of connection to existing 132kV GIS bays, it shall be the total responsibility of contractor to implement interfacing of control and protection systems to the existing 132kV bay system , in a manner that the trip signals/commands , breaker failure protection signals , trip circuit supervisions, breaker/ isolator status feedback signals and interlock systems are functional, effectively and efficiently , to the satisfaction and approval of the CEB, as specified in this document and shown in the Appendices. The contractor shall calculate the sizing of the existing CTs, before incorporating these into his protection system.

The contractor shall provide contacts of ratings as specified in the clause 6.6.2.7, 6.6.6.1 and shown in Appendix E6 “Trip Scheme for 132kV Circuit Breakers of Kelanitissa New Gas Turbines”, for trip and control commands to 132kV bay control system. These contacts shall be wetted from the DC power supplies of proposed station side in order to avoid the mixing of the power supplies. Similarly, he shall obtain all binary inputs from the existing 132kV GIS, such as status signals of existing GIS breaker position, earth switch position, isolator positions and master trip relay contacts, by installing isolating relays in the GIS side and obtaining the contacts of these and by wetting these contacts from the station side power supply.

In this manner all the signals, namely status and commands, between the Proposed station and existing 132kV GIS shall be power from the station battery supply of 110Vdc, +10% to -15% , so that for occurrence of any earth fault in these cables, the responsibility shall be on the station side. The two locks out relays and cable protection relays, in 132kV GIS, shall be provided in a separate panel as specified in the "remote station ", in Appendix E6 "Trip Scheme for 132kV Circuit Breakers of Kelanitissa New Gas Turbines".

### 3.6.2 General requirement

#### 3.6.2.1 Requirements for manufacturers of protection equipment:

The protection relay manufacturer shall have minimum 20 years of successful experience in design and supply of protection systems for applications of similar voltage and capacity ratings, comparable to generating capacity of 35MW or higher. In addition, they shall have a minimum of fifteen (15) years' experience in manufacturing for orders from outside the country of the manufacturer.

If the equipment is manufactured under a license, the service experience of equipment manufactured by the parent company shall not be counted as service experience of the licensee equipment manufacturer. The bidder shall provide adequate evidence of compliance to the above requirement to the satisfaction of CEB.

The bidder shall have successful experience, in supplying at least five (5) projects (at least 3 outside the country of manufacture) of protection systems outside the country of the manufacturer in power stations of 45MVA (single unit) or higher capacity, during last five (5) years.

These experiences have to be substantiated by means of reference installations being in service under similar environmental conditions in Sri Lanka or neighboring countries. In order to assess the manufacturers experience with similar projects, the bidder is required to submit the following with his bid.

- o Manufacturer's data sheet.
- o Manufacturer's production capability.
- o Manufacturer's experts who will be nominated for this project.
- o Manufacturer's training experience.
- o Reference list of projects executed.
- o Catalogues and brochures of equipment and devices offered
- o Reference list of customers, utilities with projects of similar or higher capacity, including postal addresses, contact telephone numbers, email address, web address etc.
- o Local office and technical capability
- Guarantee for availability of spares during the life time of the equipment

### 3.6.2.2 Design features

The design of the Protection equipment shall be as per Appendix E4 "Protection scope for Generator, Generator T/F and Station Service T/F" and Appendix E6 "Trip Scheme for 132kV Circuit Breakers of Kelanitissa New Gas Turbines" where the protection functions are distributed in unit /stand-alone modules, namely relays A, B, C, D, E, F, G, H and I with the possibility to add input/output cards and fiber optic communication interface if necessary. The desired level of redundancy shall be as follows;

- Generator protection system relays A shall be redundant with relay B.
- Main transformer protection system relays C and D shall be redundant each other by judiciously distributing the protection functions between these units and as per the Appendix E4 "Protection scope for Generator, Generator T/F and Station Service T/F".
- Cable protection system relays F and G ( and H & I) shall be redundant each other with the protection functions as per the Appendix E4 "Protection scope for Generator, Generator T/F and Station Service T/F"
- The system offered shall incorporate the protective functions specified, a variable programmable (software) tripping logic (matrix), supervision, signaling and testing facilities, measuring as well as memory functions, fault recording and event recording. LED indications shall be provided in each relay and the status of the DC power supplies shall be permanently indicated.

The protective functions shall be accommodated in a software library and shall be selectable and programmable.

### 3.6.2.3 Redundancy

Hardware and software shall fulfill requirements specified in clause 6.6.1 of this document and Appendix E4, Appendix E5 and Appendix E6.

### 3.6.2.4 Tripping Concept

Depending on the circumstances the tripping logic requirements may change. It is the bidder's discretion to implement the tripping concept to match the requirements of tripping schemes specified in this bid document.

In case, the bidder wishes to implement programmable software trip matrix inside the protection relays, then each tripping scheme (tripping matrix) shall be built inside the numerical protection relays with their binary output relays operating to trip redundant master trip relays to operate the trip coils 1 and 2 of generator circuit breaker. The number of redundant master trip relays shall vary as per the bidder's trip schemes. The master relays shall be of heavy duty type suitable for flush mounting and having robust operating coils of sufficiently high value to operate in conjunction with series trip flags, with contact ratings as specified in clause 6.6.2.7 below. The trip relay contacts shall be suitably rated to perform the required duty and the relay operating time shall not exceed 10ms from the initiation of the trip relay operating coil. The contractor shall also design the trip pulse time of the trip outputs such that the, contact breaking occurs after the operation of breaker auxiliary contact.

The master trip relays shall be high speed, rugged, bi- stable (mechanically latching), lock out type, with both hand and electrical reset facility. The all contacts shall be single throw, double break type. Both set and reset coils shall have coil cut off contacts.

The software trip matrix shall also accept signals from external functions such as temperature devices, Buchholz etc.

In case the bidder wishes to implement trip matrices externally to the protection relays, then the bidder shall implement this by means of Master trip relays.

For the tripping of existing 132kV GIS bay breaker, the contactor shall provide, redundant master trip relays in the station side and in the existing GIS side , such that station side master trip relays shall drive GIS side master trip relays, subjected to power supply requirements set out in the clause 6.6.1.1 "Scope of the Protection system "and as shown in the annexure "Trip Scheme for 132kV circuit breaker, Generator/Generator Transformer, Station service transformer and 132kV cable" . Theses trip signals shall be hard wired.

### 3.6.2.5 Setting, Control and User Program

The bidder shall provide fully licensed and type tested at manufacturer's site version of relay setting and configuration, event and disturbance handling and monitoring software (User Interface Program), with the offer. This software shall be installed in the standard notebook computer which also shall be offered. There shall be additional copy of all these software on CD/DVD format.

All numerical protection relays shall be provided with an integral man machine interface. Using the local interface it shall be possible to read, relay indications.

The protection system shall be configured and set with a standard notebook computer through a user interface program (software). It shall be connected to the system via a RJ45 (Ethernet), fiber optic or other suitable interface. The required suitable connection leads complete with end connections (about 3m in length) shall be supplied. All relays shall be IEC61850 compatible. The software shall be in English.

User interface program shall be user friendly, menu-driven and the following operations shall be permitted:

- Addition or deletion of a protection function.
- Setting of function parameters and system parameters

- Ability to edit parameters offline i.e. without establishing a connection to the protection equipment.
- Editing of trip matrix
- isplay of actual measured and derived values (U, I, P, Q, f, etc.)
- (The measurement function of the relay shall be accessible locally or remotely and shall displayed on the relay display.)
- Display of events
- Disturbance record
- Testing of relay functions
- Facility to add self-explanatory texts with a minimum of coding.

Since the security of the protection functionality is utmost important, the remote controlling via coupling modules and interfacing with higher order control systems shall be limited to monitoring, alarms and annunciation handling, event and disturbance handling, subjected to user authority levels. The setting and configuration of relays from remote control systems/SCADA shall be inhibited. Communication with remote equipment shall be compatible with IEC61850.

The protection settings shall first be defined and stored in the computer prior to downloading to the protection system. An unexpected mal operation in the Man-Machine Communication (MMC) shall not influence the protection behavior in any form. It shall be possible to upgrade/expand the MMC software.

The MMC program shall enable all protection functions to be set within their predetermined ranges without permitting inadmissible settings. It shall also enable protection functions to be freely assigned to input channels of adequate measuring values.

All software shall be provided with instruction manuals and shall be in English language. It shall be possible to ensure protection against changes by the unauthorized personnel.

The user interface program shall be such that references to the manual shall be kept to a minimum. It shall also offer facilities including:

- Ability to create, edit and check parameters, off-line i.e. without establishing a connection to the protection equipment.
- Ability to save and read parameters
- Ability to download parameters sets through the MMC to the relay
- Facility to add self-explanatory texts with a minimum of coding.

Changes in parameters, measured values, signals and events should be with access security. Functions- specific parameters such as:

Input channels, pickup values, time delay, definitions of characteristics shall be selectable and menu driven on a computer.

**Displaying on PC**

The following displays shall be provided at HMI PCs for settings, measuring or diagnostic reasons:

Display of measured values (U, I, P, f, angle) according to selected protection function
Display of events
Display of general system data for configuration status
Display of binary inputs and outputs
Display of output signals
Display of diagnostic status

**Event Recording, Disturbance recording**

There shall be built in event and disturbance recorders with following features;

- Event recording: the occurrence and disappearance of each event for all protection functions.
- Disturbance recorder for recording all analog waveforms, binary inputs and binary outputs for a programmable trigger input. It shall be possible to download and save the Disturbance records in a common format, as specified in IEEE Std C37.111-2013, to an external device (i.e. A notebook computer). Fully licensed software shall be provided to view and analyze such disturbance records after downloading to notebook computer.

**3.6.2.6 Adaptive Relaying**

Adaptive relaying facility shall be available. Relays shall permit independent sets of settings of protection configurations to be defined by the user. Only one of these sets of parameters (Setting Group) can be active at any one time when the protection is in operation.

Provisions shall be made for switching between sets of parameters either by relays own intelligence or by a signal from outside.

**3.6.2.7 Output Contacts**

Maximum Contact ratings of all outputs (Including Master and Intermediate tripping relays) shall be 125Vdc. The maximum continuous DC current capacity of the protection relay output contacts shall not be not less than 8A and short time ratings shall be 1 second capacity of 10A and 0.2 seconds making capacity of 30A and breaking capacity for DC

current at 125 Vdc, for circuits with L/R =40ms, shall not be less than 0.35 A as per the IEC 60255-1 orIEC61810-2. All protection relays shall be provided with an adequate number of contacts.

The maximum continuous current capacity of Master trip relays (and intermediate relays) shall not be less than 30A, short time ratings shall be 1 second capacity of 60A and breaking capacity (DC) shall not be less than 8A.

### 3.6.3 Testing and Monitoring

#### 3.6.3.1 Self-monitoring

A continuous self-monitoring and diagnostic feature shall be incorporated to ensure high reliability of both protection functions and the internal power supply.

Self-monitoring functions shall be divided into three parts.

- Power on diagnostics;
- Continuous self-monitoring of the hardware;
- Hardware shall be monitored while the system is being initialized after switching on and afterwards during normal operation.
- Cyclically performed test routines by the software.

In addition, supply voltages, clock frequency, processing inputs of Computer, MMC or carrier communication links etc. shall be monitored.

Upon occurrence of a hardware failure the self-monitoring shall carryout the following.

- o An alarm signal shall be transmitted
- o Despite detection of a faulty component the system shall maintain the protection external to the faulty component dependent area
- o Block tripping of the faulty component dependent area
- o Diagnostics shall be stored in the nonvolatile memory and displayed on the LCD display of the relay

#### 3.6.3.2 Software Tests

To prevent disruption to normal operation the test function shall be protected against accessibility (password etc.).

The test function is mainly for the purpose of commissioning and for testing during long shutdowns. The software test function shall also include:

- o The protection functions.
- o The tripping and signaling outputs
- o The signaling inputs

### 3.6.4 Backup power supply

Backup DC power supply to the protection relays shall be provided and guaranteed for 48 hours in an event of auxiliary supply failure with the plant DC distribution explained in Clause 3.10.6.

### 3.6.5 Guarantee for spare parts

The manufacturer shall give with the offer the Cost of mandatory spare parts of following and include the cost in Schedule 2, Mandatory Spare Parts of Volume 5;

- One unit/ stand along module (relay A or B) for Generator protection system.
- One unit/ stand along modules (relay C or D) for main transformer protection system, subjected to the condition that manufacturer offers total firmware of all protection functions, for the CEB to have full independency of replacing either C or D, with the offered spare, without intervention of manufacturer, if not manufacturer shall offer two separate units for relays C and D.
- Two units/ stand along module (relay F G, H and I) for cable protection system,
- One unit/ stand along module (relay E) for auxiliary transformer protection system.
- One miniature circuit breaker (if any) for each offered.
- In case there are manufacturer specific units/equipment such as communication modules (add on) etc., then he shall offer one such unit for each offered.
- Additional mandatory software (if any)

Manufacturer shall provide a breakdown of cost of mandatory spare parts in a separate list. The cost of the mandatory spare parts shall be taken for the evaluation. In addition to this, manufacturer shall attach a separate sheet containing manufacturer recommended spare parts (if any), with the total cost and cost breakdown. However, this shall not be taken for the evaluation.

Supply of spare parts for at least 10 years shall be guaranteed by the manufacturer in a duly signed letter.



### 3.6.6 Configuration and general data

#### 3.6.6.1 Inputs and Outputs

**Analog inputs**

The rated current of current channels shall be 1A. The current channels shall be rated to receive the rated current of current transformers and have sufficient capacity (VA) and 1 second rating. The current channels shall match with the CT capacity, protection class and Accuracy Limiting Factor (ALF) so that the correct and reliable operation of the protection functions are guaranteed.

The rated voltage of voltage channels shall be 110Vac. The voltage channels shall be rated to the rated voltage of the voltage transformers (PT) and continuous thermal rating shall not be less than 300Vac. The VA rating shall not be greater than 0.25VA.

**Binary Inputs**

Binary inputs for each protection function shall be available for blocking or signaling purposes. The blocking of any protection function shall be facilitated via the binary output of another external or internal protection function. Maximum permissible input voltage shall not be less than 150Vdc and Minimum operating voltage shall be 88Vdc.

### 3.6.7 Indications and Signaling

#### 3.6.7.1 Visual Signals

Separate LED's shall be provided on the relay or relay panel board for the indication of alarm and trip of each protection function. Furthermore, it shall be possible to latch them.

Visual signalization for "DC power supply ON" or "Loss of DC supply" shall be provided, for each individual protection unit.

#### 3.6.7.2 Signaling

Auxiliary relays for internal alarm and trip signaling as well as for external inputs shall be available.

#### 3.6.7.3 Signaling Contacts

Used for alarm and other auxiliary signaling. The contact rating shall be not less than 125V d.c and 0.35A and L/R=40ms.

#### 3.6.7.4 Time Synchronizing

The protection system offered shall 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. It is preferable this facility is incorporated using the common station time synchronization module. This time synchronizing format shall be a standard version available in the market.

### 3.6.8 Protection Functions

The basic requirement of protection functionality is as per the Appendix E4 and Appendix E5. However the contractor may provide additional protection functionality depending on the system requirement (e.g. Split phase differential protection depending on the requirement of generator winding arrangement). Provision of contractor's protection scope in a single line diagram, with the offer is mandatory.

**Required protection functions for Generators:**

- Over/Under Voltage
- Generator Differential
- Loss of Excitation
- Reverse Power
- 95% stator earth fault

- 100% Stator earth fault
- Rotor earth fault
- Over/Under frequency
- Under Impedance
- Stator thermal Over load
- Negative phase sequence
- Voltage Restraint Over current
- Pole Slip protection
- Loss of potential
- Excitation Transformer Over current
- In advertent energization
- Beaker failure Protection

**Required protection functions for 11~15/132kV Unit (Generator) Transformers:**

- Transformer Differential (2 winding)
- Transformer Block Differential (3 winding)
- Over fluxing
- HV and MV side Over current
- HV Side Restricted Earth fault
- Transformer HV side Neutral Over Current
- MV Bus Earth Fault
- Breaker failure Protection initiation output

**Required protection functions for the 11~15/6kV Step Down Auxiliary Transformer:**

- Transformer Differential
- HV side Over current function
- 6kV Bus Frame earth leakage protection
- LV side Restricted earth fault function
- LV side over current and earth fault function

**Required protection functions for the Unit Starter Motor:**

- Over Current Protection

**Required protection functions for the black start generator:**

- Over/under voltage function
- Voltage restrain over current function
- Earth fault function
- Under /over frequency function
- Reverse power function

**Required protection functions for 132kV cable:**

- Cable differential protection
- Cable Over Current at 132kV GIS
- Breaker failure protection initiation output

**Other functions required for operation:**

- Logic function
- Breaker failure protection
- V/T fuse failure protection
- Trip circuit supervision

### 3.6.8.1 Generator Over Voltage Protection function (59)

Separately adjustable two stage three phase over voltage function with a reset ratio higher than 95% shall be provided with the generator protection equipment. The first stage shall have a built-in time delay adjustment, whereas the second stage shall be instantaneous. The first stage will be used to lower the excitation/alarm and the second stage to trip the machine. It shall be possible to program both definite as well as IDMT type.

### 3.6.8.2 Under Voltage (27)

A two separately adjustable stage three phase under voltage function with a reset ratio of 105% shall be provided with the generator protection equipment. The first stage shall have a built-in time delay adjustment, whereas the second stage shall be instantaneous. The first stage will be used to increase the excitation and the second stage to trip the machine.

This shall consist of DC component filter, harmonic filter and three phase voltage measurement.

### 3.6.8.3 Under Impedance (21)

The protection shall comprise two stage three-phase impedance function that must detect two and three-phase short circuits, within a set distance from the point of installation. The time lag must be independent of the grading of the distance protection system. The impedance function shall be of three zones, direction selectable Mho characteristic with ability of offset selection.

Furthermore, as the short circuit currents for faults at the generator terminals can be of very low values, the generator back-up protection must be able to operate, even if the fault current shall drop to10% to 30% of rated value in 10 seconds. The reset ratio shall be 105%.

### 3.6.8.4 Over Flux (24)

This function shall provide protection against over excitation of the generator transformer, which may be caused by over voltage and/or under frequency. The function shall measure the

V/Hz ratio, and if the same exceeds the pick-up value, a tripping command shall be initiated after a preset time delay. The function shall have two settings, which governs the maximum and minimum trip time. The V/Hz setting curve in between shall be user settable. There shall be a separate setting of definite time type for the alarm level.

**3.6.8.5 Under Excitation (40)**

To detect the loss of excitation and slipping phenomena, capacitive minimum reactance function with an offset mho characteristic shall be used. The offers giving function (40) that does not rely on this impedance-based characteristic is not acceptable.

This function shall be provided with a time element to distinguish the loss of excitation condition from power swings. The characteristic shall contain operating points for various levels on an under-excited machine up to point Xd (unsaturated synchronous reactance) for complete loss of excitation.

The other side of the circle diameter shall be given by half of the transient reactance X'd.

**3.6.8.6 Generator Differential (87G)**

The differential protection function shall be of low impedance type with biased characteristic of proven high stability for the most severe through-fault currents. The function shall be inrush proof and based on three phase measurement with suppression of DC current and harmonic components.

The basic setting shall define the pickup value of the differential protection for internal faults. The pickup ratio shall govern the stability of the differential protection for external faults. Stability for external faults shall be achieved without any reduction in the pickup sensitivity for relatively low internal fault currents of the order of the rated current. The reset ratio shall be higher than 95%.The minimum settable differential setting shall be 5% of generator rated current. There shall be a differential setting of unrestraint nature which shall have adjustable setting range of 1- 50% of generator rated current.

**3.6.8.7 Negative Phase Sequence (46)**

This function shall be of two tripping stages, where one stage can be set to cover the generators continuous negative sequence current capability by a definite time function. This value shall be adjustable from 1% to 20% of generator rated current. The second stage shall cover the generator's short time negative sequence capability governed by;

$$\left(\frac{I_2}{I_{rated}}\right)^2 \times t = k$$

Where $I_2$=negative sequence current (A) , $I_{rated}$ = generator rated current

The value of K shall be adjustable between 1 to 20 sec .

The function shall have a starting stage to initiate an annunciation prior to tripping. The pickup current and operating time shall be separately adjustable with programmable inverse characteristic if necessary. Three phase measurement shall be carried out. There shall be a stage alarm stage of definite time characteristic.

#### 3.6.8.8 95% Stator Earth Fault Protection (59N)

For earth faults within about 95% of the stator winding, a sensitive voltage function shall be provided. This protection for detection of the neutral displacement shall be equipped with a filter to eliminate all harmonics and must therefore be insensitive to phenomena other than ground faults in the stator windings. The voltage and time settings shall be independently adjustable. The stator earth fault function shall be fed from secondary resistor of the earthing transformer in the generator neutral.

#### 3.6.8.9 100% Earth Fault (64G)

In order to cover the remaining 5...15% of the winding, and also to provide backup for the 95% protection, an additional 100% stator earth fault protection shall be provided. For 100% stator earth fault protection, only the principles based on the injection principle are acceptable.

#### 3.6.8.10 Generator Reverse/over Power Protection (32)

This function must be able to monitor the actual reverse power of the machine. A sensitive measurement of the reverse power shall be provided. There shall be two Reverse power protection functions and one protection function is mainly intended for the protection of the prime mover while the other function shall be used for control purpose. The reverse power protection function shall be provided with the possibility of angle correction and also to facilitate usage of the function as active power and shall be adjustable in the range of 5% to -5% of rated power in steps of 0.1% of rated power. The over power protection shall be provided to facilitate over active power detection with an adjustable range from 80% to 115% of rated active power.

#### 3.6.8.11 Stator Thermal Overload Protection (49S)

To protect the generator against overloading a single pole thermal relay having a thermal replica with adjustable heating and cooling rate shall be provided. This relay must match the machine characteristics, with an inverse time dependent response according to the standard ASA-C50 P.13 (American standard requirements for cylindrical rotor synchronous generators).

The winding temperature must be simulated and follow rapid changes in load. The replica element shall be designed on a digital basis. This function shall allow usage of all built-in reserves of the machine. This function shall have two stages for the tripping and the alarm purposes.

### 3.6.8.12 Pole Slipping Protection (78)

The impedance-based function shall be capable of detecting a power swing which can lead to instability in addition to being able to detect an actual pole slip. Also by varying the size of the lens characteristic it shall be possible to ensure that a trip command is given to the circuit breakers in such a way that separation of the poles occurs at a controlled angle at any time.

### 3.6.8.13 Under Frequency Protection (81U)

This function shall have at least 2 separately adjustable frequency stages and also independent time delay setting. It shall operate on a digital basis whereby the frequency setting shall be adjustable in steps of 0.01 Hz. The setting shall be in the range of 50 to 40Hz. At lower voltages, the function is expected to block. Under frequency protection shall also be used as supervision and control element for load shedding.

### 3.6.8.14 Over Frequency Protection (81O)

There shall be 2 stage over frequency detection functions. Time delay shall be provided. Setting shall be in the range of 50 to 75 Hz in steps of 0.01Hz.

### 3.6.8.15 Rotor Earth Fault Protection (64E)

Relay shall have 100% rotor earth fault detection which is applicable to static excitation systems proposed under clause 6.2.8 for rotor earth fault protection.

### 3.6.8.16 Voltage Balance Protection or Generator P.T. Fuse Failure (60)

A three phase or single-phase voltage comparison function shall be provided to detect an open circuit in any phase of the potential transformer. This function must prevent unnecessary tripping during failure of the P.T. circuit and give a corresponding annunciation and shall be able to program and link as a binary input to all voltage based functions, in order to block the functions to prevent unnecessary tripping. Different rated voltages of the main PTs shall be compensated with the aid of the reference values of the corresponding analogue channels.

Two signal types, pick up and starting, shall be available with adjustable delay and shall be provided for blocking.

### 3.6.8.17 Voltage Restraint Over Current (51V)

There shall be 4 stages over current function, with independent pickup settings, curve type selection (IDMT and/or Definite time) and time settings and the characteristics of which are modified continuously according to the voltage at the generator terminals.

### 3.6.8.18 Main transformer Differential (87T), Generator/main transformer Block Differential (87U) and Station Service Transformer Differential (87ST)

The differential protection functions shall be of low impedance type with biased characteristic of proven high stability for the most severe through-fault currents. The function shall be inrush proof, with second harmonic blocking with an adjustable range of 5 to 100% of fundamental and fifth harmonic blocking with an adjustable blocking range of 5 to 50% of fundamental and shall be based on three-phase measurement with suppression of DC current and harmonic components. The reset ratio shall be greater than 95%. The minimum differential setting shall be 10 % of transformer rated current. There shall be a differential setting of unrestraint nature which shall have adjustable setting range of 1- 50% of transformer rated current.

The basic setting shall define the pick-up value of the differential protection for internal faults. The pickup ratio shall govern the stability of the differential protection for external faults. Stability for external faults shall be achieved without any reduction in the pick-up sensitivity for relatively low internal fault currents of the order of the rated current.

The Transformer Differential protection functions shall incorporate software amplitude and vector group compensation for different CT ratios and transformer vector groups for up to three transformer windings. The transformer vector group displacement shall be matched for all known transformer connection groups (y= star, d= delta and Z=Zigzag), without the need of interposing transformers.

### 3.6.8.19 Generator Transformer HV Over current (50/51T)

The Transformer HV over current protection shall protect transformers against faults which produce over current, such as short circuits and earth faults. The measurement shall not respond to DC components and harmonics; the over current protection shall practically only react to the power frequency component. Both single and three-phase measurement shall be available. Three stages shall be provided for each measurement. One shall be instantaneous stage for clearing high current faults within a very short tripping time without delay and the second stage shall be for lower fault currents with adequate delay. The third stage shall be of IDMT type to discriminate with the line protection.

### 3.6.8.20 Generator Transformer HV side Restricted Earth Fault (REF) and Station Service Transformer LV side REF (87TN)

A single phase high impedance current operated function shall be provided for restricted earth fault protection for the high voltage side of the main transformer with grounded neutral point. The function shall remain stable for external faults, and shall be provided with a stabilizing resistor and necessary filters. The current function shall not be sensitive to high harmonics. In order to limit the voltage appearing across the secondary CT leads under internal fault conditions to a safe level, non-linear resistors shall be provided for connection across the high impedance input. The secondary wiring of the high impedance circuit shall match with the protection level of the nonlinear resistor.

### 3.6.8.21 MV Bus Earth Fault (64B)

The earth fault function shall protect 100% of the transformer delta windings against ground faults since each part of the delta connected winding will always have a potential difference to earth. The function also shall act as a backup to stator earth fault protection. It shall measure the neutral voltage displacement across the tertiary open delta winding of the generator VT and shall only consider the nominal frequency, filtering out any higher harmonics.

### 3.6.8.22 Generator Transformer HV side Neutral Over Current (50/51NT)

This function shall act as a backup to un-cleared line/bus earth fault protections. The generator transformer HV neutral is solidly grounded and the 51N earth fault over current setting shall be configured to approximately 25% of the transformer rated current with a time delay equal to that of the over current protection. The function shall have three stages similar to the 50/51T.

### 3.6.8.23 Logic Functions

Logic combination of binary input signals or of output signals of protection functions (trips) shall be provided to facilitate the realization of extended protection functions or specific signalization. There shall be AND, OR, XOR, ON delay TIMERs, OFF delay TIMERS, PULSE TIMERs etc. available for the realization of logic applications. The AND and OR gates shall be used in at least on 30 instances with a refresh rate of 1ms. The each timer shall be used at least on 10 instances and shall have a refresh rate of 1ms. The XOR block shall be used in 10 instances with a refresh rate of 1ms.

### 3.6.8.24 Spare Over Current and over/ under voltage functions

There shall be at least one additional over current function with four stages (in addition to the over current functions provided with the above functions) of three-phase and single phase measurements. This shall be programmed or both over current and earth fault protection functionality. If not supplier shall provide two separate function blocks for the each. The function shall be programmed for the inverse time characteristics in accordance with B.S. 142 providing different curves such as normal inverse, extremely inverse, very inverse and long-time inverse for over current /earth faults and definite time curves. The reset ratio of the function shall be greater than 95%.There shall be at least one additional over/under voltage function with two stages (in addition to the over current functions provided with the above functions) of three phase and single phase measurements).The hysteresis shall be adjustable from 0 to 100% of base voltage.

### 3.6.8.25 Breaker failure protection (BFP) for 52G and 152G breakers (50BF)

The breaker failure protection shall be applied for the both generator breaker (BFP1) and the 132kV existing GIS breaker (BFP2). There shall be voltage free contacts for each master trip relay of station protection system, in GIS side, for BFP2, which shall be an input to the existing bay controls and bus bar protection systems to ensure fast back-up tripping of upstream or surrounding breakers (existing GIS breakers) with the detection of failure of the breaker. The BFP1 shall initiate tripping of the existing 132 kV GIS breaker. The detection shall be realized through; both current detection and breaker auxiliary contact check methods. The reset time of the current detection shall be 1ms.The current measurement shall be three phase and 1out of 3 detection is necessary. The minimum current setting shall be 5% of the rated generator current for BFP1. In order to increase the security, it shall be possible to block the breaker auxiliary contact-based method for higher currents.

### 3.6.8.26 Inadvertent Energization Protection (50/27)

This function shall provide protection against accidental energization of generator at stand still.

### 3.6.8.27 Station Service Transformer HV side over current (50/51S)

This protection is to cater to any phase over current fault in the Station Service transformer and back up to LV side faults. This function shall have at least two definite time and one IDMT type stages. The reset ratio shall be greater than 95%.

### 3.6.8.28 6kV Bus Frame earth leakage protection (64BN)

This protection shall cater to any sensitive leakage current that could occur due to a failure in 6kV metal clad switchgear. This function shall be sensitive enough to detect 1 to 5% of maximum earth fault current and shall be stable enough, not to operate for any spurious noises that could arise in the frame earth.

### 3.6.8.29 Station Service Transformer LV side over current (50/51S)

This protection is to cater to any phase over current fault in the Station Service transformer LV side. This function shall have at least two definite time and one IDMT type stages. The reset ratio shall be greater than 95%.

### 3.6.8.30 Station Service Transformer LV side neutral over current (50/51S)

This function shall protection against LV side earth fault. Station Service transformer LV neutral is resistive grounded. The function shall have three stages similar to the 50/51T.

### 3.6.8.31 Unit Starter Motor Over Current Protection

This function shall protect against faults in the unit starter motor and shall be stable for motor starting current.

### 3.6.8.32 Black start Diesel Generator (6kV) Over/Under Voltage Protection

Separately adjustable two stage three phase over/under voltage function shall be provided with Black Start Diesel Generator protection equipment. The first stage shall have a built-in time delay adjustment, whereas the second stage shall be instantaneous. It shall be possible to program both definite as well as IDMT type.

### 3.6.8.33 Black start Diesel Generator (6kV) Voltage Restrained Overcurrent Protection

There shall be two stages over current function, with independent pick up settings, curve type selection (IDMT and/or Definite time) and time settings and the characteristics of which are modified continuously according to the voltage at the generator terminals.

This function shall be three phase and current input shall be from neutral side CTs in order to detect phase faults of the diesel generator windings in addition to detect external faults.

### 3.6.8.34 Black start Diesel Generator (6kV) Restricted Earth Fault Protection

A single-phase high impedance current operated function shall be provided for restricted earth fault protection for the generator winding with resistive grounded neutral point. The function shall remain stable for external faults, and shall be provided with a stabilizing resistor and necessary filters. The current function shall not be sensitive to high harmonics. In order to limit the voltage appearing across the secondary CT leads under internal fault conditions to a safe level, non-linear resistors shall be provided for connection across the high impedance input. The secondary wiring of the high impedance circuit shall match with the protection level of the nonlinear resistor.

### 3.6.8.35 Black start Diesel Generator (6kV) Neutral Overcurrent Protection

This function shall be a backup neutral/residual overcurrent function against earth fault. Black start Diesel Generator neutral is resistively grounded. The function shall have two stages.

### 3.6.8.36 Black start Diesel Generator (6kV) Under/Over frequency Protection

Both functions shall have at least two (02) separately adjustable frequency stages and also independent time delay setting. It shall operate on a digital basis whereby the frequency setting shall be adjustable in steps of 0.01 Hz. At lower voltages, the function is expected to block.

### 3.6.8.37 Black start Diesel Generator (6kV) Reverse Power Protection

This function shall detect any inadvertent operation that lead to reverse power operation.

### 3.6.8.38 Station Auxiliary Transformer (6/0.4kV) HV side Overcurrent Protection

This protection is to cater to any phase over current fault in the Station Auxiliary transformer HV side. This function shall have at least two definite time and one IDMT type stages. The reset ratio shall be greater than 95%.

### 3.6.8.39 Station Auxiliary Transformer (6/0.4kV) LV side Overcurrent Protection

This protection is to cater to any phase over current fault in the Station Auxiliary transformer LV side. This function shall have at least two definite time and one IDMT type stages. The reset ratio shall be greater than 95%. The setting of this protection shall be in coordination with Molded Case Circuit Breakers (MCCB) and Miniature Circuit Breakers (MCB) of 400V distribution sub system so as to maintain the safety of personal and equipment. These protection arrangements shall be in accordance with latest IEE wiring regulations.

### 3.6.8.40 Station Auxiliary Transformer (6/0.4kV) LV side Neutral Overcurrent Protection

This protection is to cater to any earth fault in the 400V side. This function shall have at least two definite time and one IDMT type stages. The reset ratio shall be greater than 95%. The setting of this protection shall be in coordination with Residual Current Circuit Breakers (RCCB) of 400V distribution sub system so as to maintain the safety of personal. These protection arrangements shall be in accordance with latest IEE wiring regulations.

### 3.6.8.41 Emergency Diesel Generator (400V) Over/Under Voltage Protection

Separately adjustable two stage three phase over/under voltage function shall be provided with Emergency Diesel Generator protection equipment. The first stage shall have a built-in time delay adjustment, whereas the second stage shall be instantaneous. It shall be possible to program both definite as well as IDMT type.

### 3.6.8.42 Emergency Diesel Generator (400V) Voltage Restraint Overcurrent Protection

There shall be two stages over current function, with independent pick up settings, curve type selection (IDMT and/or Definite time) and time settings and the characteristics of which are modified continuously according to the voltage at the generator terminals.

This function shall be three phase and current input shall be from neutral side CTs in order to detect phase faults of the emergency diesel generator windings in addition to detect external faults.

### 3.6.8.43 Emergency Diesel Generator (400V) Neutral Overcurrent Protection

This function shall be a backup neutral/residual overcurrent function against earth fault. Emergency Diesel Generator neutral is solidly grounded. The function shall have two stages.

### 3.6.8.44 Emergency Diesel Generator (400V) Under/Over frequency Protection

Both functions shall have at least two (02) separately adjustable frequency stages and also independent time delay setting. It shall operate on a digital basis whereby the frequency setting shall be adjustable in steps of 0.01 Hz. At lower voltages, the function is expected to block.

### 3.6.8.45 Emergency Diesel Generator (400V) Reverse Power Protection

This function shall detect any inadvertent operation that lead to reverse power operation.

### 3.6.8.46 Emergency Diesel Generator (400V) Loss of Excitation Protection

In case the generator is being synchronized to the 400V bus, provision of this protection is imperative. To detect the loss of excitation and slipping phenomena, capacitive minimum reactance function with an offset mho characteristic shall be used. The offers giving function (40) that does not rely on this impedance-based characteristic is not acceptable.

This function shall be provided with a time element to distinguish the loss of excitation condition from power swings. The characteristic shall contain operating points for various levels on an under excited machine up to point Xd (unsaturated synchronous reactance) for complete loss of excitation.

The other side of the circle diameter shall be given by half of the transient reactance X'd.

### 3.6.8.47 Emergency Diesel Generator (400V) Thermal Overload Protection (49S)

To protect the generator against overloading a single pole thermal relay having a thermal replica with adjustable heating and cooling rate shall be provided. This relay must match the machine characteristics, with an inverse time dependent response. The winding temperature must be simulated and follow rapid changes in load. The replica element shall be designed on a digital basis. This function shall allow usage of all built-in reserves of the machine. This function shall have two stages for the tripping and the alarm purposes.

### 3.6.8.48 Emergency Diesel Generator (400V) Under impedance Protection (21)

The protection shall comprise two stage three phase impedance function that must detect two and three phase short circuits, within a set distance from the point of installation. The impedance function shall be of direction selectable Mho characteristic with ability of offset selection.

Furthermore, as the short circuit currents for faults at the generator terminals can be of very low values, the generator back up protection must be able to operate, even if the fault current shall drop to10% to 30% of rated value in 10 seconds. The reset ratio shall be 105%.

### 3.6.8.49 132kV Cable Differential Protection

There shall be redundant three phase based cable differential protection functions for 132 kV cable between 132kV existing GIS bay and HV terminal of the main transformer. These functions shall detect phase to phase and three phase faults in the cable. This function shall be secure against power surges, out of step and emergency loading conditions.

This function shall be of low impedance type with biased characteristics of proven high stability for most severe through fault currents. This function shall be inrush proof and based on three phase measurements with suppression of DC and harmonic components. This function shall have a provision to compensate line charging current to provide to increased sensitivity.

This protection shall be arranged as master – master system and the communication between two (2) IEDs, installed at main transformer HV side and 132kV GIS side, shall be provided via an optic fiber cable.

The contractor shall use existing CTs in the 132kV GIS bays for this protection function. However, if he feels that the rating and sizing of these CTs are not adequate, then he shall install new CTs for this purpose. The sizing calculations for this purpose shall be submitted to CEB for approval.

#### 3.6.8.50 Cable Over Current Protection

This function shall be in redundant configuration and shall provide protection against phase faults on 132kV Cable and shall act as a backup protection for cable differential protection. This function shall be of inrush proof and three phase measurements with suppression of DC and harmonic components. This function shall have at least two (2) definite time stages and one (1) IDMT stage.

### 3.6.9 Applicable standard

The relays offered shall comply with following standards and be suitable for operation in tropical condition.

| **General standards for protection relays and electromagnetic relays** | |
|---|---|
| Electromechanical non –specified time<br>All –or- nothing relays<br>General requirement | IEC61810-1 |
| Electromechanical relays –reliability | IEC 61810-2 |
| Electromechanical All –or- nothing relays<br>Part 7: Test and Measurements | IEC 61810-7 |

| General standards for protection relays and electromagnetic relays | |
|---|---|
| Relays and relay systems associated with electrical power Apparatus<br>Operation temperature: 0 to 55°C<br>Storage temperature : 0 to 85°C<br>Humidity Level 95% max | ANSI/IEEE C37. 90 -2005 |
| Humidity Test | IEC 60068-2-78:2012<br>Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state |
| Measuring relays and protection equipment Part 1: Common requirements | IEC 60255-1 |
| Energizing quantities - Change of auxiliary energizing quantities | IEC 60255-11 |
| Electrical Relays<br>Part 23: Contact Performance | IEC 60255-23 |
| Measuring relays and protection equipment –<br>Part 27: Product safety requirements | IEC 60255-27 |
| Enclosure Protection | IEC 60529, IEC 60255-27 |
| Communication networks and systems in substations | IEC 61850-1 to -10 |
| Low-voltage switchgear and control gear assemblies - Part 2: Power switchgear and control gear assemblies | IEC 61439-2:2011 |
| **EMC standards** | |
| Surge withstand capability test | IEEE C37.90.1<br>2.5kV, Oscillatory<br>4.0kV, fast transient |
| Electrostatic discharge<br>Direct application<br>Indirect application | IEC 60255-22-2, class IV and IEC 61000-4-2, class IV<br>15kV air discharge<br>8kV contact discharge |
| Fast transient disturbance /burst | IEC60255-22-4, class A, 4kV<br>IEC 61000-4-4, Class IV |
| Surge immunity test | IEC 60255-22-5, or<br>IEC 61000-4-5 Installation Class 3,<br>1-2 kV, 1.2/50 µs, high energy |
| Power frequency immunity tests | IEC 60255-22-7, class A,150-300V |
| Power frequency magnetic field test | IEC 61000-4-8, class V,1000A/m, 3s and 100A/m continuous |
| Damped oscillatory magnetic field test | IEC 61000-4-10, class V, 100A/m |
| Radiated electromagnetic field disturbance | IEC 60255-22-3, 20V/m, 80-1000MHz<br>IEC 61000-4-3, 20V/m, 80-2500 MHz<br>Or IEEE C37.90.2 35/m , 25-1000MHz |
| Conducted electromagnetic field disturbance | IEC 60255-22-6, 10V 0.15-80MHz |

| | |
|---|---|
| **Electromagnetic emission tests;** | |
| Radiated emission | IEC60255-25, 30-1000MHz |
| Conducted emission | IEC60255-25, 0.15-30MHz |
| 1MHz Oscillatory burst disturbance or High frequency test | IEC 60255-22-1, class III 2.5kV, ANSI/IEEE C37.90.1-2012 |
| Ring wave immunity tests | IEC 61000-4-12, class IV 2-4kV |
| Mechanical tests | |
| Vibration | IEC 60255-21-1, class 2 |
| Shock and bump | IEC 60255-21-2, class 2 |
| Seismic | IEC 60255-21-3, class 2 |
| Insulation | |
| Dielectric test | IEC 60255-5 , IEEE C37.90, 2.0kV AC, 1min |
| Impulse voltage test | IEC 60255-5, IEEE C37.90, 5kV 1.2/50µs,0.5J |
| Insulation resistance | IEEE C37.90 , >100 MΩ at 500Vdc |

### 3.6.10 Electromagnetic compatibility (EMC)

| | |
|---|---|
| **Immunity,** | |
| 1MHz burst disturbance tests | IEC 255-22-1(1988), ANSI/IEEE C37, 90.1-1989 |
| Electromagnetic discharge tests | 6/8 kV(10 shots) Cl.3 |
| | EN 61000-4-2(1994), IEC 1000-4-2(1995) |
| Fast transient tests | (Burst) 2/4 kV Cl.4 EN 61000-4-4(1994) |
| | IEC 1000-4-4(1995) |
| Power frequency magnetic 1000 A/m 50/60Hz permanent field | |
| Field immunity test | EN 61000-4-8(1993), IEC 1000-4-8(1993) |
| Radio frequency | 0.15-80 MHz, 80% amplitude modulated |
| Interference test (RFI) | 10 V/m Cl.3 ENV 50140(1995) |
| | IEC 1000-4-3(1995) |
| | 900 MHz, pulse modulated 10 V/m Cl..3 |
| | ENV 50204(1995) |
| Emission | Cl.A EN 50081-2(1994) |
| (Industrial environment) | EN 55011(1992) |
| | CISPR 11(1990) |
| | EN 55022(1995) |
| | CISPR 22(1995) |
| Seismic Test | 5g, 30s, 1, 33Hz(1 Octave/min) |
| | IEC 255-21-3(1993) |
| | IEEE 344(1987) |
| Testing of cubicle | IEC 439 clause 5.2.35 |

### 3.6.11 Operation and maintenance

**3.6.11.1** Manuals

The operation and maintenance manuals shall be provided in three copies and shall contain following information to enable the Employer to maintain, dismantle, reassemble, adjust, test, commission and operate the system. The language shall be English.

a). Table of content
b). List of illustration
c). Introduction
Detailed description which shall contain a complete and accurate description of the system including:
- Range of features provided as standard.
- Range of optional features.
- Range of settings provided for all features, both standard and optional.
- Details of all of the operating time characteristics for the protection relay.
- Statement of performance under the reference conditions.
- Variation of performance with departure from reference conditions.
- Effects of interruptions to control circuit auxiliary power supply.
- Voltage transformer requirement.

d). Operating principle and characteristics
e). Operating instructions
f). Testing and adjustments
g). Maintenance instructions
h). As built drawings
Drawings /schematic diagrams shall include all components with their ferruling numbers.
i). List of spares, list of equipment and ordering information
j). Any other information required for the O & M of the system.

**3.6.11.2 Maintenance**

All cards or modules shall be field replaceable and interchangeable with other identical cards or modules. Sufficient information shall be provided for the user to decide definitely whether or not two similar modules are actually interchangeable.

## 3.7 Energy Metering Devices

### 3.7.1 Basic features

MWh and MVArh meters are to be provided in each generator to measure the energy generation at generator terminals (Gross Energy) and beyond the 132kV unit transformer (Net Energy). The metering schemes including relays, current transformers and voltage transformers are to give an overall accuracy corresponding to the commercial grade.

The Meter shall be capable of measuring and recording Import and Export active , reactive and apparent energy , power and power factor and the recorded/display units shall be kWh/MWh, kVArh/MVArh, maximum kVA/MVA demand, maximum kW/MW, maximum kVAr/MVAr, and power factor. The accuracy class of the meters shall be Class 0.2S for Active Energy (kWh/MWh) and Class 2 or better for reactive Energy (kVArh/MVArh).

a). The Meter shall operate with specified accuracy for power factors in the full range of all quadrants.

b). The Meter shall be of panel mounting type and shall have terminals at the backside of the meter. There shall be an external trim to hide the panel cutout.

c). The Meter shall be of the programmable type suitable for recording active/reactive energy consumption in kilowatt-hour (kWh), Megawatt-hour (MWh) or Gigawatt-hour (GWh) depending on the energy transferred and also the maximum demand in Kilovolt Ampere (kVA) or Megavolt Ampere (MVA) depending on the plant capacity.

d). The Meter shall be suitable for Time-of Day Metering (minimum of 6), Import-Export Metering. The meters shall have provisions to change the time of day tariff in the field and shall have facility to program for a minimum of six (06) time of day tariffs. The meter shall be programmable at site by CEB.

e). The Meter shall record the monthly consumption (generally every 30 or 31 days) along with the cumulative consumption of kWh, MWh or GWh separately and the maximum of average kVA/MVA demand over a demand integration period of fifteen (15) minutes to one (1) hour (defined by user) for generally every 30 or 31 days period. Facilities shall be provided to reset the maximum demand indication automatically as well as manually.

f). It shall be possible to program, download data and reset the maximum demand both locally and remotely through software running on, PC on Microsoft Windows 10 latest version.

g). The Meter shall record the consumption accurately irrespective of the phase sequence of supply.

h). The Meter shall operate normally when any two voltage leads are connected, even in the absence of neutral.

i). 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.

j). Flashing light indication shall be available on the front face of the meter which acts as an activity indicator. The meter shall also be provided with blinking LED which blinks and shall be analogous to the kWh/MWh/GWh metered, for calibration purposes. The number of pulses per kWh/MWh/GWh shall be indicated in the rating plate and facilities shall be provided to program the meter constant.

k). The meter shall directly display the following data as applicable at the time of reading (calling) when required;

Instantaneous Voltage – Volts (line/Phase)
Instantaneous Current – Amps (on three phase)
Current Transformers ratio and Voltage Transformer Ratio
Power factor – PF (on three phases)

l). The following table give range parameter that shall be fed to the meter as applicable.

| | |
|---|---|
| Operational Voltage (line –line) | 110 V |
| Voltage transformer ratio | 11000/110 V |
| 15000/110 V 132000/110 V | |
| Standard Rated Current | 1Amp/5Amp |
| Current transformer ratio | 100:1/5 Amp min |
| 5000:1/5 Amp max | |
| Frequency | 50Hz |

m). The Meter shall have facilities to store a minimum of twelve months data and to display the necessary data when required.

n). The Metering equipment shall be suitable for indoor use and conform to the degree of protection of IP51 as per IEC 60529.

### 3.7.2 Remote reading

Facilities shall be available to carry out following tasks for each of the meter by remote operation via HMI workstations in the Central Control Room and the Engineering Station.

i. To take the relevant meter readings for each meter separately
ii. To reset the maximum demand value of each meter
iii. To get error messages when the meter is faulty, and the date and time of occurrence of such event
iv. To download stored data from meter

### 3.7.3 Display of measured values

The Meters shall be provided with a clear Electronic Display and the dimensions of figures shall not be less than 4 mm (Height) and 4mm (Width). Minimum number of digits of the main charactors shall be 8 including a decimal point which can be adjustable by the user settings upto 3 decimal places.

The Meters 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) / Megawatt-hour (MWh), kilovar-hour (kVArh) / Megavar-hour (MVArh) and kVA / MVA based on the energy transferred for a unit period. The capacity of the display shall read actual primary measured value regardless of the CT or VT ratio.

### 3.7.4 Calibrating Output device

The Meters shall have a calibrating output device accessible from the front and capable of calibrating with the help of the universal reference standard meter.

### 3.7.5 Electromagnetic compatibility

**3.7.5.1** 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.

#### 3.7.5.2 Radio interference suppression

The Meters shall not generate, conduct or radiate noise which could interfere with other equipment in the control or protection systems of gas turbine and generator.

### 3.7.6 Manufacturing Experience

Offered meter shall be of proven and state of the art technology and shall be a standard product of the manufacturer's product line. Manufacturer shall have experience in manufacturing energy meters for commercial and industrial applications for at least ten years (10) years. In addition, minimum of five (5) years of experience shall be in manufacturing for contracts outside the country of the manufacturer. The supplier shall provide the documentary support to the manufacturer's proof of ability in above two cases.

### 3.7.7 Warranty

Manufacturer shall provide 5-year warranty from the date of commissioning of the meters to the employer. Manufacturer should forward the duly signed Warranty Certificate together with the letter of acceptance of the award

When the meters become defective within first two years of warranty they shall be replaced free of charge. The meters become defective after two years during the warranty period shall be repaired or replaced free of charge.

CEB shall not remove the meter cover for any purpose such that CEB has the right to claim under warranty in the event of any defect in the meter. Manufacturer shall honor the conditions in the warranty certificate accordingly.

### 3.7.8 Applicable standards

The equipment and components supplied shall be in accordance with the latest editions/amendments of the Standards specified below. Any offer not complying with reference to these standards, is considered as non responsive. However the CEB Specification shall supersede these standards in the event there is a discrepancy.

IEC 62052-11(2003) Electricity metering equipment (AC) General requirements, tests and test conditions- Part 11: Metering equipment

IEC 62053-22(2003) Electricity metering equipment ( AC) Particular requirements- Part 22: Static meters for active energy (classes 0.2 and 0.5)

IEC 62053-23 (2003) Electricity metering equipment (AC) particular requirements- Part 23

## 3.8 Synchronizing/ synchronizing check facility

Manual synchronizing facility, with synchronizing check feature, are required for all circuit breakers controlling generators, bus section, main step up transformer circuits, main LV supply feeders and Black Start Generator. Auto synchronizing facilities shall be required for all circuit breakers controlling generators. There shall also be three meters consisting of a double voltage meter to indicate the voltage at the both side of breaker terminals, a double frequency meter to indicate the frequency at the both side of the breaker and a rotating pointer type Synchroscope. The reed type Synchroscope are not acceptable.

The system provided under the contract shall be forwarded for the approval of the Employer and is to be such that the synchronizing circuit must be established before the circuit breaker can be closed. The contractor shall give due consideration to incorporate adequate interlocking facility when allowing of dead bus closing facility to certain breakers and also when black starting.

Synchronizing check relays shall check the magnitudes of voltage difference and frequency difference and then the phase difference before the closing command for the breakers are issued. The dead bus, check feature shall be provided and there shall be an external key switch to allow the dead bus closing.

The automatic synchronizing facilities shall be arranged to initiate closure of the associated breakers when the phase and the magnitude of the voltage difference and of frequency difference are within acceptable limits. There shall be the allowance for the inherent time delay between initiation of circuit breaker closure, and actual closure of the main circuit breaker contacts. The automatic synchronizing circuits shall be arranged such that they normally operate in conjunction with the synchronizing check interlock.

The automatic synchronizing window shall be within the synchro- check relay window. The contactor shall design and calculate the maximum voltage difference, maximum frequency difference, phase difference and the breaker lead time so that the safety of the generators breakers and other equipment are ensured and that there is no reactive power bump in the circuits involved. These calculations shall be submitted for the approval of the CEB. However the contractor shall ensure that the voltage difference window is ±10% or less phase angle difference is ±10° or less the frequency difference window is ± 0.1 Hz or less. These windows shall be later adjustable at will of Employer.

There shall be key switch for synchronizing start command. There shall be indications in the control room when the synchronizing of a generator is in progress and when there is a failure to synchronize condition.

## 3.9 Low voltage Switchgear

### 3.9.1 General constructional features

The switchgear, boards and all other equipment related hereto shall meet the General Technical Requirements, specified as follows.

Electrical switchboards shall be constructed of braced rolled steel sections, free standing and supporting structures for mounting of power and control cables. All steel work shall be made of min. 1.5 mm thick sheet steel. To avoid wobbling of doors, rear or side covers etc. they shall be adequately braced. The cubicles shall be of robust and rigid construction, of the self supporting floor mounted type. They shall be supplied complete with lifting lugs and eye bolts, with all required base frames, anchors, fixing materials, etc.

Service conditions, construction requirements, technical characteristics and verification requirements of all Low Voltage Switchboards and control gear assemblies shall comply IEC 61439.

Wherever the correct operation of circuit breakers, relays and other instruments makes it necessary, adequate vibration and shock absorbers shall be installed. All panels and cubicles shall be of standard dimensions, having a uniform appearance. The switchgear shall be of the indoor, completely enclosed (protection class IP 42), metal clad type with drawout mounted switching devices.

The construction shall be such that the various components of the switchgear are segregated electrically from each other, it shall be possible to gain access to the circuit breaker and to the cable box chamber in any cubicle without having to take the busbars out of service. Hinged doors and bolted panels shall be provided. The terminal blocks, relays and instruments shall be located so as to be safely accessible while the plant is in service. Suitable barriers shall be provided for access to live parts.

All instruments, relays, control and selector switches, indicating lamps, push buttons and trip levers shall be flush mounted and located at convenient heights on the front of the switchgear in a logical and clear manner. The layout of these panels is subject to the approval of Employer.

Cast resin insulators are permitted within individual cubicles but bushings entering or interconnecting different cubicles (busbars) shall be of absolute fire resistant type (porcelain). The design of cubicles shall facilitate a possible extension at either end. The cubicles shall have front access and – if not specified for erection at the wall- rear access for easy cable termination work and for maintenance and repair of the main and auxiliary equipment accommodated in the interior. Means shall be provided to limit the opening angle of doors to about 100°. Cubicles and panels shall be provided with interior lighting, controlled by door switches. Cubicles shall be complete with all locks, cable end boxes, colour coded busbars, internal wiring, terminal blocks and accessories.

Busbars shall be made of high conductivity electrolytic copper suitably protected against corrosion and rigidly supported on approved type of insulators. Busbars shall be suitably mounted in enclosed compartments running the full length of the distribution boards. Access to the busbars shall be possible only by removing bolted covers.

Opening the back or front door of any circuit breaker cubicle shall not expose the busbars. Busbar connections laying outside the busbar compartment shall be insulated or shrouded to eliminate hazardous accidental contact while working on other parts of the switchgear. Means shall be provided for expansion and contraction of the busbars resulting from temperature variations. All busbar joints and connections shall be smoothed and silver coated or tinned on the contact surfaces. If appropriated for the intended installation, contact surfaces can also be brightly polished and greased. All switchgear, busbars and connections shall be capable of withstanding all electrical, mechanical and thermal stresses they may be subjected to, under normal and fault conditions.

Clearance between live parts and to earth shall be in accordance with the relevant standards. Each cubicle shall be provided with devices for earthing the incoming cables, preferably each phase separately. Provision shall also made for earthing the busbars. Such earthing shall be interlocked with the incoming circuit breakers. Safety interlocks shall be provided to prevent earthing of live parts.

An earthing bar with a minimum cross section of 40x6 mm shall run the full length of the distribution boards. This bar shall be connected to the main earthing system, and all metallic parts not forming part of the live circuits and all instrument transformer terminals to be earthed shall be connected to it.

The finishing coat shall consist of lacquer of a colour agreed upon. The painting shall be scratch-proof and resistant to perspiration from the operator's hands. The painting shall be of such quality that damage of the paint during transport or erection can be easily repaired by the contractor on site.

Each cubicle/panel shall be equipped with a suitable mimic diagram. All panels/ cubicles shall have approximately 10% spare room for mounting of future auxiliary devices. Floor openings below cubicles shall be covered and sealed by the contractor after laying of cables, etc., so as to obtain fire proof and vermin proof installations. Where required gland plates with suitable glands shall be provided. Phase rotation and colour markings shall be employed throughout the plant.

### 3.9.2 Scope of work

This section covers the low voltage AC panels required for the power supply of all auxiliary facilities, installed in the power house. Adequate spare capacity shall be provided in low voltage switchgear for future expansions such as fuel oil treatment plant, additional pumps etc. The interconnection of these panels and detailed feeder arrangement shall be decided during detail design stage. Basic single line diagram of the 400V system indicating the 400V busbar and incoming bays is shown in the Appendix E2.

However, the scope of supply shall be as follows, but not limited to:

- One (1) number 400V main distribution board with two busbars or three busbars (depending on number of Gas Turbines) of incoming bays 1, 2 and 3 interconnected together with bus sections.
- Suitable numbers of 400V distribution boards for gas turbine auxiliaries with feeders from main distribution board.
- Adequate numbers of 400V distribution board for common auxiliary systems such as ventilation systems, lighting systems, workshops etc. with feeders from main distribution board.
- Adequate redundancies to energize the essential loads from alternative supply arrangements such as Emergency Diesel Generator (EDG) or outside distribution feeder.
- Each board, except the Main Unit and Main Common Distribution Boards shall be provided with 5% at least one, empty compartments of each outgoing feeder type completely wired as space. Such compartments shall be closed by steel panels/ doors.
- Each board, except the Main Unit and Main Common Distribution Boards shall contain 5% at last one, fully equipped spare outgoing feeder of each feeder type of each bus.

### 3.9.3 Main characteristics

The main characteristics for the low voltage panels shall be as follows.

| | | |
|---|---|---|
| Voltage class | : | 600V |
| Rated three phase AC voltage: | | 400V |
| Insulation level | : | 1000V |
| Rated frequency | : | 50Hz |
| Nominal power frequency withstand voltage not less than | : | 2 kV rms |
| Initial symmetrical short circuit current (I”k) | : | 25 kArms |

The switchgear must be capable of carrying the short time current and shall withstand the mechanical stresses of the peak short circuit current (Is) of 65 kA.

### 3.9.4 Mode of operation

Under normal operation conditions, each busbar (1,2 and 3) are fed in by the corresponding station transformers 1, 2 and 3. If one unit auxiliary transformer is not available, pre-selected 400V bus section breaker is closed to feed dedicated busbar of unavailable station transformer. Similarly, arrangement shall provide for other unit auxiliary transformers.

In case of a black start with the emergency diesel generator supply, the change over from the emergency diesel generator to the normal operation system has to be realized without any interruption. Additionally it must be possible to synchronize the emergency diesel generator on to the energized system, so that it can be loaded for test run purposes. It shall be possible to perform all above mentioned controls through the operator stations in the central control room.

### 3.9.5 Design features

The 400V AC main distribution boards shall be factory assembled, type tested and of modular type.

Type testing certificate must demonstrate the following;

- Adherence to upper temperature limit
- Electric strength
- Short circuit strength
- Flawless connection between parts of switch gear assembly and protective conductor by inspection or resistance measurement
- Short circuit strength of protective conducts
- Creepage distances and clearances
- Mechanical functioning
- IP protection class

The busbar system shall be protected against human contact. A subdivision into isolated switchgear, cable and busbar compartments for increased safety purposes is required. All outgoing feeders shall be of the draw out type, equipped with MCCBs. Each drawout unit shall have a door interlocked operating mechanism, which ensure that the compartment door of a withdrawable unit can only be opened when the master switch is open and that the unit itself can only be withdrawn in the off-circuit state.

Completely isolated busbar with arching barriers between sections to limit damages in case of arcs has to be provided. Each withdrawable unit shall be accommodated in its own compartment, which is closed off at the front by a door of the appropriate size with a cut out for the instrument panel. The instrumentation, protection relays, current and voltage transformers and synchronizing equipment shall also be provided.

Busbars and electrical connections between several pieces of apparatus forming an item of equipment shall be of electrolytic copper and they shall comply with IEC 60439-2. Busbars shall be protected against atmospheric corrosion by heat shrink sleeves.

A single failure shall not lead to a plant shut down. Double infeed shall be provided accordingly. The allocation of auxiliaries to different sections of each busbar and the interconnections between different boards shall be selected to achieve maximum plant availability and reliability.

Current ratings for standardized products refer to IEC conditions with 40°C ambient temperature. Such equipment, however, shall be selected with due regard to the environmental conditions at Site and cubicle design/ arrangement, i.e. if upon the increased ambient temperature, a deduction of the standard current rating becomes necessary such deduction shall be restricted to such an amount that a margin of 10% is still maintained ahead of the actual circuit requirement. In all such cases the Contractor shall state the permissible current ratings for both, IEC and site conditions.

The Contractor is obliged to submit a load evaluation for each individual switchboard and the entire plant.

The fault current requirements of the individual distribution boards and components shall be calculated by the contractor on basis of the design data of components under consideration of the maximum acceptable tolerances of components according to standards.

#### 3.9.5.1 Remote Indication and Control

All electrical measuring systems requiring remote indicators in the Local Control Cubicle and Central Control Room shall be equipped with transmitters, etc., as required.

All interfaces required for remote control facilities shall be provided.

#### 3.9.5.2 Interlocks

Electrical ON/ OFF interlocks of incoming feeders, transformer feeders, bus sectionalizers and coupling feeders shall be realized in the relevant boards. Electrical interlocks of motor and valve feeders involved in the main process functions of the plant shall be effected in relay cubicles, respectively by the control system

The basic interlocking principles for the power supply systems are listed below:

- All incoming feeders of a board or a section of such board shall be interlocked against each other and against the bus sectionalizer, so that each distribution board or section thereof shall be fed by one only power source at a time.

- Paralleling of infeeds of important boards being provided with two infeeds and/ or with bus sectionalizer shall be possible for a few seconds if synchronism is ensured. In such case one of the two relevant L.V. infeed circuit breakers shall be subsequently automatically tripped after a preset period.
- Tripping of protection device in one of two feeder circuits of any double fed switchboard (for example tripping by transformer feeder protection, transformer Buchholz or oil temperature protection, but not the L.V. incomer protection) shall automatically trip the faulty circuit and close the second feeder circuit (provided its feeding breaker is closed) via the second L.V. incoming breaker or the bus sectionalizer, whatever is applicable.
- Operational switching off of any infeed shall not actuate the second infeed. Manual change-over initiation shall be realized by a separate change-over switch.
- Each transformer feeder shall be interlocked that the LV circuit breaker cannot be closed unless the HV / MV circuit breaker is closed, and if the latter is tripped manually or automatically the former shall also be tripped automatically.

### 3.9.6 Incoming and outgoing main feeders

All main feeders shall be suitable for local and remote control, and equipped with draw out type circuit breakers with current (feeders equipped with motor operated breakers) ratings according to the requirements. Each incoming and outgoing main feeder has to be provided with an instrument panel for control, signaling and measuring devices. Operation voltage of the motor driven feeders will be 110V DC. The main feeders shall be equipped with PTs, CTs and Busbar Voltage Monitoring Definite time delayed, two-phase under voltage relay (27), adjustable in steps, time delayed overload relays and instantaneous overcurrent relays, synchrocheck relays etc. The completely enclosed, dry cast resin type instrument transformers shall be designed in accordance with General Technical Requirements.

### 3.9.7 Motor starters

A typical motor feeder/starter shall be equipped with:

- HRC fuses with auxiliary contacts and load break switch, or
- Fused load break switch, or
- Circuit breaker with instantaneous overcurrent protection
- Starter combination
- Adjustable thermal overload relay and phase failure protection
- Motors larger than 50kW shall have reduced starting current ($2.5xI_N$ max) or star delta starters.

Control voltage shall be 110V DC and MCBs shall be provided for control voltage. Due to the fact that all motor starters must be quickly interchangeable, only draw modules are accepted. The exact number and rating of the outgoing feeders shall be decided by the contractor depending on the equipment provided by him and shall be subjected to the approval of Employer.

Circuit breakers, fused load break switches and motor starter units shall be of the withdrawable mounted type. Where two or more starters or feeders are contained in the same cubicle, they are to be separated by barriers of sheet steel or fire proof insulating material. If required, the metal surface of the cubicle shall be protected by fire proof insulating material. The panels shall contain all respective starters and contactors with their main incoming and outgoing power feeders. The draw out switching devices shall be mounted on trucks or slide in chassis having adequate guidance by greased sliding rails and/or rollers. They shall be connected to the busbars by means of a self-aligning plugs and socket arrangements. Complete isolation of each circuit shall be attained by drawing out the switching device.

The main contacts shall have shutters which automatically close upon withdrawal of the switchgear. The withdrawal of large circuit breakers shall be facilitated by means of cranks gears or other facilities. The contact surfaces of the plugs and sockets shall be silver plated. The contacts shall be amply sized and sufficiently strong to withstand maximum short circuit currents and carry continuously the rated currents without damage or overheating of any kind. The control circuits shall also be provided with plugs and sockets.

The withdrawable units shall have clearly marked service, test and isolated (ready for complete withdrawal) positions. A mechanical interlock shall be provided to prevent withdrawal of the unit unless the main circuit has been opened. The unit shall positively be locked in the test position before it is manually released for complete withdrawal. The test position shall permit local and remote closing and tripping of the relevant switchgear with the main contacts isolated from the power circuit.

All circuit breakers shall be able to be padlocked at their open/racked out position.

Each switchgear room shall be furnished with a switching unit transportation carriage, the height of which shall be adjustable to the different installation heights.

All circuit breakers, load break switches, starters and contactors shall be suitably rated and controlled according to the electrical and mechanical performance and duties they are assigned for. They shall be of the continuously rated pattern generously rated to comply with the site conditions and requirements. Automatically controlled feeders (motor feeders, outgoing feeders shall be equipped with a time delayed automatic tripping device operating in case of voltage failure at the busbars or being actuated by another defined signal.

All motor starters, contactors and their associated devices shall be capable of operating without overheating for a period of five minutes with a supply voltage of 70% of the nominal value.

Molded case circuit breakers and miniature circuit breakers can be used if they are properly selected to stand the maximum short circuit current. All starter and contactor units of the same rating shall be interchangeable. Remote controlled motor starters rated 5kW and above shall include provisions for remote current indication.

### 3.9.8 Switchgear/MCC control

For local switchboard control, all circuit breakers and motor starter contactor units shall have:

- One(1) green coloured illuminated push button for OFF.
- One(1) red coloured illuminated push button for ON.
- One(1) position indicator of the semaphore-type for circuit breaker, electrically controlled, or indicating lamps, included above.
- One(1) amber coloured indicating lamp for fault indication of local protection equipment (tripping of protection relay or device, blowing off power fuse, tripping of miniature circuit breaker of control circuit). This lamp shall remain lit until cancelled by resetting of the device having caused the fault indication. Facilities shall be provided to repeat the alarms, individually or group wise for remote indication or recording.

Remote controlled incoming and outgoing feeders as well as motor starters shall be equipped with key operated LOCAL/REMOTE selector switches. The OFF control shall be effective at all locations independent of the selector switch position while the ON control shall be restricted to the set selector switch position.

All manual operated plant shall have mechanical indications clearly indicating the relevant position.

Each bus section of a distribution board shall have a blue coloured signaling lamp indicating that the control supply is healthy, and each cubicle a yellow coloured signaling lamp indicating heater ON.

Indicating lamp shall be of an approved low consumption type. The hoods covering the lamps shall be made of transparent coloured glass moulds or any other equivalent heat resistant and break proof material and shall be either of the screw or any other approved type to facilitate replacement of the lamps.

Lamp test facilities shall be provided on each panel. Up to 3 panels, forming an assembly, can be fitted with one common lamp testing device.

Individual panels or panel suites shall include indicating lamps for:

- Heaters on
- Control voltage
- Alarm/trip

For local control all motors, valves, drives, etc. the following cast aluminium push button stations shall be provided.

- One (1) key operated selector switch having three positions, fixing the mode of operation of the drive concerned.
- 1pos OFF there is no access to that drive, nor by the incorporated push button not by the superposed control system.
- pos LOCAL means, the drive can be operated only by the incorporated ON-OFF push button. (mainly used for tests and or maintenance purposes)
- pos REMOTE The drive is controlled by the superposed control system only.
- One(1) ON push button
- One(1) OFF push button
- One(1) Emergency OFF push button, which remains locked upon actuation and which can be released only by means of a special key. The effectiveness of this emergency push button shall not be restricted by any other facility, or what so ever, for having a protection function for the human being.

### 3.9.9 Circuit breakers

Circuit breakers shall be of the trip free type with a driving mechanism composed of a spring loaded, energy storing closing and tripping device. Remote controlled circuit breakers shall be provided with an electric spring loading driving motor, manual spring loading and control shall also be possible. Means shall be provided to prevent pumping while the closing circuit remains energized should the breaker either fail to latch or be tripped during closing due to the operation of a protective device.

The CB phases shall be separated by barriers of approved heat resisting, non-cracking insulating material. The LV breakers shall be provided with main and isolating contacts, and with suitable arcing contacts, magnetic arc quenching devices, arc chutes. They shall conform to the short category P2 as defined in IEC 152-1, Table II.

The spring release of the closing mechanism shall be affected by means of a DC solenoid coil and by means of a mechanical pull out handle. Tripping shall be affected by means of DC solenoid shunt trip coil and by means of a mechanical push in button.

The closing mechanism can alternatively be of the AC solenoid coil operated and latched type. Each circuit breaker shall have a device to count the number of closing operations.

The moulded case circuit breakers (MCCBs) shall have shunt trip coil and trip free operating mechanism of the quick break type. They shall have a thermal overload of 125% of the normal full load current and instantaneous magnetic trips which operate at currents exceeding 500% of normal full load currents or 600% of motor full load current whichever is applicable.

Miniature circuit breakers shall be single pole or triple pole with adequate current ratings. The operating as well as the overload mechanism shall be sealed. The mechanism shall provide positive closing, contact roll and wipe, trip free action with follow through on opening. The contacts shall be of anti-welding silver tungsten tips fixed on high conductivity copper backings. The contacts of control relays and of higher rated circuit breakers and contactors shall be silver plated.

#### 3.9.10 Contactors

LV contactors shall be of the air break type with arc shields, class AC3 according to IEC standards. But contacts of the rolling, self-cleaning type shall preferably be utilized and all portions likely to suffer from arcing shall be easily removable.

When closed, the contactors shall withstand the system fault current determined by the next coordinate short circuit tripping device. The associated thermal overcurrent release shall be adjustable in order to fit the motor requirements and be temperature compensated up to 70º C ambient temperature.

#### 3.9.11 Fuses

The HRC fuses shall be suitably sized to cope with the connected loads at site conditions. They shall be of the current limiting type and be of such characteristic as to correspond to the associated switch gear.

Pre-connected fuses up to 63A rated current shall be inserted into lever operated fuse isolators so that no special tool is required for their replacement. Devices shall be provided to indicate blowing of the fuse locally and remotely respectively.

#### 3.9.12 Load break switches

The load break switches shall permit manual operation from the front panel but they shall be designed to allow mounting of a remote control device. They shall have a padlocking device and self cleaning contacts with a high resisting anti arc case and with quick making and quick breaking action, capable to switch the specified rated currents. If suitable, the load break switches can be combined with the HRC fuses.

#### 3.9.13 Small wiring

All wiring within panels, racks, boards, etc. shall be of PVC insulated stranded copper wires. The insulating material shall be of polyvinyl chloride (PVC), tropical grade, or of other approved type. The wiring shall be capable of withstanding, without deterioration, the conditions prevailing at the individual location of installation. The bare ends of stranded wires shall be provided with squeezed sleeves or pins. The minimum cross section shall be as follows:

- 2.5 mm² for all consumers (such as motors, heaters) and current transformer circuits
- 1.5 mm² for control wiring above 60V service voltage
- 0.5 mm² for control wiring below 60V and telephone wiring
- About 0.2 mm² in case the applied termination techniques of standard electronic equipment do not permit the use of larger cross sections.

All secondary wiring shall be arranged and protected to prevent it from being damaged by arcing or by mechanical effects. Wiring shall be neatly run, bundled or in rigid PVC plastic wire ways filled not more than 70%.

Telephone points including the connection to PABX telephone exchange established in administration building of Kelanitissa Power Station and two other communication facilities available within the CEB shall be provided for central control rooms, switchgear room, battery room, relay room, turbine control room etc.

#### 3.9.14 400V neutral earthing

The 400 V distribution system shall be solidly earthed, i.e 400 V side of Unit auxiliary transformer of each Gas turbine unit.

### 3.10 Storage batteries, chargers and DC switchboards

#### 3.10.1 Scope

Main d.c systems shall be provided and shall be rated to supply all the essential load and control requirements of the power station including all dc supplies for safe run-down and cool-down. Preferred voltage levels are to be selected from 125V, 110 VDC, 48 VDV and 24 VDC. Regardless of the rated voltage and number of cells in each battery bank this specification applies as the general guide line for the type and construction of battery cells. The batteries shall generally have both poles fully insulated and shall be suitable for unearthed operation. A full set of battery test accessories shall be provided, mounted in a box.

The direct current installations shall comprise 110V batteries, battery charging equipment, d.c Switchboard and cabling to loads.

110V direct current shall be used to supply emergency lighting, to operate essential motors or actuators and for the tripping of latching contactors. It shall also be used for circuit breaker and protection tripping functions along with operation of alarm, indication and essential control systems. There shall be a separate battery banks to supply UPS system of the Distributed Control System of the station. Ratings of the battery bank required for SCADA and communication is not indicated and the ratings shall be decided by the contractor and submit for the approval.

The 110V batteries, with their charging equipment and associated dc main switchboard shall be mounted in a self-contained free-standing suite of panels, complete with all necessary accessories. Each panel shall be suitably constructed to ensure ample ventilation to the charger and battery but exclude vermin and ingress of dust, with protection. The cubicle doors shall be lockable. Access to the battery charger and switchgear components shall be from the front, whilst cable entry shall be from bottom.

DC supplies to main switchboards and panels shall be duplicated to form a ring. Two removable links shall be provided at each location such that any faulted cable may be isolated without interruption of essential supplies.

The arrangement of batteries, chargers and distribution equipment covered by this section of the Specification is to allow for easy access, for maintenance purposes, to any charger, battery or distribution switch whilst the remaining equipment is kept in normal service.

### 3.10.2 Type of batteries and construction

Batteries shall be of high performance type Nickel Cadmium (NiCd) type and shall be designed according to latest relevant IEC60623, IEC 60993 or IEEE1115 or DIN standards.

Cells shall be delivered discharged and empty condition and shall be fitted with a plastic transit plug. Sufficient amount of electrolyte (with 10% extra) shall be supplied in suitable containers that comply with international transport regulations. Containers shall be labeled to show electrolyte type and regulatory hazard information.

Batteries shall be installed in a separate battery room. Terminal covers, connecting leads, copper connections of adequate cross section between batteries shall also be provided. The connections shall be insulated by PVC or other approved type of taping or sleeving.

The manufacturer shall have at least 15 years of experience for manufacturing similar type of batteries and 10 years of experience for export market. Evidence shall be furnished with the offer to prove the experience.

Manufacturer shall have ISO 9001 certificate for their products and a copy of the certificate shall be submitted with the offer.

Details of the construction shall be as follows and technical literature of the offered product shall be submitted with the offer.

### 3.10.3 Normal operating temperature range

Normal operating range is from 20ºC to 40ºC. Battery shall give its optimum performance in this temperature range and the supplier shall guarantee the operation of the cell within this range does not affect the performance or the recommended life of the cell.

Details of the following shall be provided with the technical literature:

**Positive plate** : Positive plate shall be of sintered type.

**Negative plate** : Negative plate shall be a plastic bonded cadmium electrode, produced with continuous process.

**Plate Tab** : The electrodes shall be seam welded to the plate tabs to produce continuous Interface between the two components, ensuring high current transfer and maximum strength.

**Separator** : Construction of the separator shall be to optimize the distance between the electrodes and to ensure reliability and long life.

**Container and cell cover (lid):** Cell container shall be of high impact plastic single cell cases. Container shall be capable of withstanding specified ambient condition (tropical condition) throughout the life time without any deterioration.

**Cell Vent Plug** **:** Vent shall preferably be of bayonet-fitting flip top, flame arresting type, which shall prevent an external ignition of gas from spreading into the cell when the lid is closed.

**Electrolyte** **:** The electrolyte shall be supplied in liquid form and the concentration of the electrolyte shall be such as to allow the cell to operate up to 60ºC. It shall be possible to operate the battery with temperature fluctuation from 20ºC to 60ºC in tropical climatic condition. Electrolyte level indication shall be incorporated externally to battery casing in each cell with maximum and minimum level markings.

**Terminal pillars** **:** Terminal pillars shall preferably be of copper and shall be nickel plated.

**Pillar seals** **:** The pillar seals shall effectively prevent the escape of electrolyte under operating conditions. Seal shall be a proven design for tropical climate and shall not be deformed during the lifetime of the cell.

**Polarity Identification :** The positive and negative terminals shall be identified using separate colour disc on the pillars. Preferably red disc on the positive plate and blue disc on the negative pillar. In addition positive(+) and negative (-) identification signs shall be moulded on plate lids. All battery cells shall be numbered consecutively.

**External components :** All external components shall be of nickel plated and shall be protected by rigid cover.

**Short circuit current :** Typical short circuit value of the cell shall not be less than 28 times the Ampere-hour capacity for 5hrs. The battery shall be designed to withstand short circuit current without damage.

**Cycling** **:** Details of typical cycle life Vs depth of discharge shall be submitted with the bid. It shall be guaranteed that at 20% of rated capacity depth of discharge the battery is capable of performing more than 10,000 cycles during the lifetime of the battery.

**Effect of Temperature on life time:** Details of effect on temperature on life time shall be submitted with the bid. This shall be given as a percentage of 25ºC life time Vs temperature

**Water consumption :** Typical topping-up interval in years Vs Temperature (values at 20ºC, 30ºC, 40ºC) at recommended float voltage shall be given with the bid.

**Ripple current** : Battery shall be capable of withstanding ripple current up to 0.5C5 peak to peak.

**Shock Load** : It shall be guaranteed that the cell can withstand tests stipulated in IEC 60068-2-27 (bump test at 5g,10g and 25g) and IEC 60068-2-77 (shock test 3g)

**Vibration Resistance :** It shall be guaranteed that the cell can withstand vibration test according to IEC60068-2-77 for 2hrs at 1g.

During erection and commissioning of the batteries, particular care shall be taken to ensure that connections from the chargers are not made until after the cells have been filled with electrolyte. In the event that the battery cells are fitted with transportation plugs on their arrival at site, these must be replaced by the explosion-proof vents before the cells are put into service. Care shall also be taken, particularly during first charge, to ensure that the maximum permissible cell temperature is not exceeded

The following documents (in English) shall be provided along with the shipping documents.

- Installation and testing procedure of battery bank
- Maintenance manual of battery bank

A set of maintenance tools comprising Suction type hydrometer, Rod thermometer (alcohol in glass), level testing test tube, in a separate plastic box shall also be included in the scope of supply.

### 3.10.4 Ratings and Capacity

(5hr rate to1.00V/cell) at 25 °C: 250 Ah (Indicative value for one bank)

### 3.10.5 Site conditions

Operating site conditions are given in meteorological data and attached as Appendix A.

### 3.10.6 Capacities of batteries

The 110V d.c installation shall include two battery banks for the power house and there shall be separate battery banks for UPS system of the Distributed control system and Communication & SCADA. The rating of each battery bank shall be sufficient to provide for the following loads, during a period of three hours.

Continuous Emergency Lighting Loads, Standing Switchgear Loads, Local Control Cubicle Loads, DCS load, Protection relay load, field flashing currents and any other 110V d.c Loads, UPS system load and communication & SCADA loads.

At the end of this emergency duty period, it shall be possible for one Gas turbine black start to be carried out, along with the closure of 11~15 kV generator circuit breaker and 400V ac circuit breakers without the distribution board voltage falling below 99V dc. UPS system shall be healthy and there shall not be any failures of communication and SCADA during the emergency period.

At the end of this emergency duty period, the operation of essential motors or actuators shall not cause the 110V dc distribution board voltage to fa1l below 99V dc.

Complete loss of ac supplies shall be assumed during the three-hour period with an ambient temperature anywhere within the range 10˚C to 45˚C.

In rating the batteries for this duty, it is to be assumed that they are in the fully charged condition at the beginning of the emergency duty period, with the charger at nominal constant float voltage.

The "float voltage per cell", "float charge current" and percentage ripple entered in the Appendix is to be consistent with this nominal constant float charge voltage and with a minimum life of 25 years. An average emergency duty of four times every year may be assumed.

The steady state voltage on the dc distribution boards shall under-no circumstances exceed 112% of the nominal voltage and shall not normally exceed 110%. In the event that voltage dropping diodes are connected between the chargers and the load distribution busbars to meet this requirement, then these diodes shall be arranged such that, failure of one does not result in loss of supply, and that an alarm is initiated. It shall be possible to replace a defective diode in safety and without loss of dc supplies.

If the ratings specified above are insufficient for the correct operation of plant supplied under this Contract then they shall be increased accordingly.

### 3.10.7 Cell connections

The battery shall be supplied with all necessary connections. Connections between battery end terminals and main conductors shall be made in PVC insulated solid copper rod of suitable section. The copper connections shall be supported by porcelain insulators and by bushings where the connections pass through a barrier. Joint faces shall be bright metal, free from dirt and shall be protected by petroleum jelly. Disconnecting links shall be provided to separate the battery units for maintenance purposes. Detailed instructions shall be provided where necessary for making joints. A sufficient quantity of bolts, nuts, washers and jointing material (e.g., petroleum jelly) shall be provided with an additional 20% as spare.

### 3.10.8 Accessories

A full set of maintenance equipment, including the following accessories and durable maintenance instruction cards, shall be provided.

| Item | Amount |
|---|---|
| Hydrometers | 3 |
| Thermometers | 3 |
| Portable testing voltmeter with contacts spears and leads to suit the single battery voltage | 1 |
| Cell bridging connector | 1 |
| Battery log books | 2 |
| Trolley with rubber wheels suitable for the transport of one cell or crate of cells | 1 |
| Hand-operated electrolyte pump with suction and delivery pipes of sufficient<br>length to permit transfer of electrolyte to any cell | 1 |
| Hand-operated siphon tube with suction bulb for emptying any cell into a container placed adjacent to it | 1 |

Suitable containers are to be provided for making up the electrolyte at site.

### 3.10.9 Battery charging equipment

Two battery chargers shall be connected with the dc system. Each charger shall be independent of the other for its operation with the exception of the interlocks specified. Each battery charger shall also be equipped with circuit breakers for ac input and dc output.

Float chargers are to be of the automatic constant voltage type capable of operation from a 400V three-phase supply from the general services auxiliary switchboard. Each battery charger shall be complete with transformer, solid state rectifiers (thyristors and/or transducers if relevant), smoothing circuits, blocking diodes and charge rate control equipment. Diodes shall be non-ageing.

The diodes provided shall have sufficient spare capacity to ensure that cascade failure of diode circuits cannot occur. Full protection against over voltages, including those resulting from hole storage effects, plus high-speed line fuses, shall be included in each diode circuit.

All printed circuit cards shall be individually withdrawable and shall be mounted in a removable frame, with trailing lead, to permit access to circuits for maintenance. Test points shall be brought out to an accessible point on each card to facilitate fault finding. The circuit locations of these test points shall be indicated on the associated schematic diagrams.

The operation and maintenance manual shall indicate the voltage levels and wave forms to be expected under various operating conditions, at each test point.

All necessary interlocks shall be provided to prevent incorrect operation of protective and alarm features during insertion or withdrawal of the control cards.

The manufacturer shall have at least 15 years of experience in manufacturing similar type of battery chargers for export market.

### 3.10.10 Float charging facilities

Each float charger shall be capable of keeping both batteries fully charged with the highest prospective standing load, including future load, connected to the charger. The chargers shall remain in normal float charge operation after 400V supply disturbances.

The above requirements are to be met irrespective of variations in the voltage of the ac supply within the specified limits. The charger output voltage regulation range shall not exceed plus or minus one and four percent (as appropriate to conditions (c) and (d) below respectively) of the nominal constant float voltage or exceed a maximum of 12% in excess of the nominal dc system voltage when connected to the load and operating under any combination of the following conditions:

a). Frequency variation of 49.5/51.5Hz.
b). Rated input ac voltage variation of plus or minus 6%.
c). Output between 10 and 100 percent of rating.
d). Output between 0 and 10 percent of rating.

The nominal constant float voltage being the setting required to obtain the emergency duty rating of the batteries as defined in Clause 3 without "freshening" charges.

Each float charger output voltage regulator shall be adjustable within limits approved by the Employer and shall be so designed that either special tools are required to make an adjustment, or that the adjusting device is contained in a separate lockable compartment.

Arrangements shall be made such that in the event of the battery becoming discharged during ac supply failure, the rate at which re-charging 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 is to incorporate an over current limit to ensure that the charger rating cannot be exceeded by the application of the dc excessive loads or by a short circuit on the dc output, or from loss of one phase of the 400V supply. Control features are to be included to ensure correct sharing of dc load between charges without hunting.

Each float charger output voltage regulator shall be adjustable within limits approved by the Employer and shall be so designed that either special tools are required to make adjustment, or that the adjusting device is contained in a separate lockable compartment.

### 3.10.11 Boost charging facilities

Boost charger facilities shall also be provided to recharge either battery after a heavy discharge. The voltage/current characteristics in the boost charger mode shall have a tapering characteristic in order to minimize gassing during the finishing period of a conditioning charge. Whilst in this mode each charger shall be capable of returning its battery from the fully discharged to the fully charged state within a period of twelve hours.

At nominal rated input voltage and frequency boost charger output shall be such that the maximum voltage shall not be less than 1.7V per cell. Also, the output of a boost charger shall not be less than its specified rating at any battery voltage within the range nominal/plus 20% or such other range as shall be approved.

A suitable manually operated tapping switch shall be provided for use during boost charging. Boost charging of a battery shall only be possible if the battery is first disconnected from the load busbars. If failure of ac supply to any charger, or under or overvoltage failure occurs when one battery is being boost charged, then the associated contactor shall close to reconnect that battery to the load busbars. The associated charger control will automatically revert to the float charge mode, when loss of supply (or boost charger failure) occurs, and will continue to operate in this mode after restoration of ac supplies. Boost charger failure shall be indicated locally and contacts for remote alarm initiation shall also be provided. Contacts shall also be provided to show remotely when boost charging is in progress.

Boost charging shall be selected manually and interlocks shall be provided to prevent both battery banks being boost charging at the same time. The boost charge selector switch shall be lockable in the off position.

### 3.10.12 Alarm and indication facilities

Each battery charger shall be provided with local alarms and instrumentation and provision for remote indication of a common alarm on the DCS. Each charger shall be provided with the following instrumentation and indicating facilities:

- Red/Green: ON/OFF indicating lamps for the incoming AC supply
- Voltmeter: incoming AC supply
- Volt meter: DC output voltage
- Ammeter : with offset zero to register charge/discharge currents.
- Charger fail/low volt relay(s) with fag indication and two contacts for remote indication.
- Charger fail/low voltage relays shall be provided, one for each charger, to indicate locally which charger has failed, and initiate a remote alarm.

Each relay is to operate:

a). In the event of high output voltage due to a defect in the associated charger controls, or
b). With low voltage caused by failure of the associated charger, or a standing load in excess of the charger rating.

Alarm contacts shall be provided on each relay for the high and low voltage conditions. Also one high voltage contact will operate from each relay to trip the associated dc contactor and, if the dc contactor has not opened within one second of the overvoltage relay operating, then the associated ac contactor is to be opened automatically. The sensing point for charger overvoltage shall be before the associated blocking diode. The charger overvoltage alarm shall not be initiated when the associated charger and indication is in the boost mode. The correct operation of the protective, alarm and indication features shall be independent of AC supplies.

The charger fail alarm devices are to detect complete or partial ac supply failure. Visual indication of rectifier fuse failure is also to be provided. The charger fail alarm device shall operate for failure of one element of the three-phase bridge but it is not to operate on switching surges or transient loss of voltage.

The charger AC switch fuse and contactors shall be of the electrically held type, complying general Specification, including a latched overvoltage lockout relay with manual reset features but with operation from the charger control panel in lieu of pushbutton control.

An earth fault detector with flag indication and remote alarm contacts is to be provided for each set of load busbars. Each detector shall utilize a high resistance battery centre tap earth connection, into which the detector operating coil shall be connected, such that the detector operates to initiate an alarm if an earth fault occurs on either the positive or negative pole of the dc system. The earth fault detector shall not operate during the "charging-up" of multi core cable capacitance and the detector circuit resistance shall limit current flow such that external relays will not be caused to operate by a single earth fault on either pole of the dc system.

Pushbuttons for testing the correct operation of the earth fault detector will be included. A separate manually operated test feature will also be included to offset the detector "centre-tap" earth connection to allow external earth faults at or near battery mid-point potential to be detected.

The interior of each cubicle shall be illuminated by an interior lamp suitable for operation on a 230V ac supply, controlled where relevant by an access door operated switch.

### 3.10.13 400V Supply arrangements

Two separate ac supplies will be arranged to supply the control and charging equipment. A supply changeover contactor is to be incorporated in the cubicles to effect changeover of battery charger supplies to "Standby" if the normal "Supply" fails. This contactor shall incorporate ac operating coils such that it will operate if either ac supply is available. Maintenance of supplies to the charger shall not be dependent upon dc supplies.

The changeover contactor shall be of the break-before-make type such that the normal and standby phase or neutral infeeds are never paralleled. The changeover contactor shall be arranged to transfer charger supplies to "standby" if one phase fails or the average three-phase "normal" supply voltage falls below 60% of nominal for more than five seconds. Voltage monitoring between phases shall be used to initiate the changeover. The contactor shall be biased such that the normal supply will be automatically selected whenever both supplies are fully available and indication lamps shall be included to show which is selected.



### 3.10.14 Distribution switchgear and busbars

The cubicles shall be fitted with the necessary switch fuse outlets, and shall incorporate double pole switch fuse isolators for the incoming supply connections from each battery bank (along with dc contactors) mounted adjacent to the charger panel. Moulded case circuit breakers to IEC 60157 shall be used instead of switch fuses provided that equivalent or better protection and other facilities are afforded. The switchboards shall comply with the requirements of IEC 61439.

All contactors, isolators and switch fuse isolators shall be capable of making or breaking the maximum prospective lcad currents. Each battery switch/fuse isolator shall have fuses of sufficient rating to ensure satisfactory discrimination with the largest outgoing circuit-fuse connected to the load busbars.

All isolators shall incorporate integral locking facilities to permit locking of the switch in the open or closed positions. Mechanically operated on/off indication shall be incorporated in each isolator and contactor and the door of each cell shall be interlocked with the isolator mechanism such that access to live parts may be obtained only if the switch is open. Each circuit shall be suitably labeled at the front of the panel and at internal cable terminations.

The dc control supplies shall be monitored with facilities to operate remote alarms if any fuse operates, or if the dc control supply is lost for any other reason. Control supplies shall normally be taken from the busbar side of the contactor but should be automatically transferred to the battery/charger side of the contactor if the busbar supply is lost.

The dc contactors should be of the mechanically latching type suci-3 that loss of dc control supply will not cause the contactor to open. The dc control supply for the contactors shall be monitored with facilities to operate remote alarms if any fuse operates, or if the supply is lost for any other reason.

The dc contactors should be mechanically and electrically interlocked with each other so that it is not possible for both to be open at the same time. Further electrical interlocks shall be provided to prevent either dc contactor from being tripped if this would result in de-energization of either section of the 110V d.c load busbars.

Each d.c contactor shall incorporate additional normally closed and normally open contacts for operation of remote alarms and indications. Open/closed indication lamps shall be provided on the door of each dc contactor cubicle.

The distribution board busbars and attached circuits are to be rigidly supported and capable of withstanding the prospective peak and short time equivalent RMS short-circuit currents without damage. The busbar construction shall be in accordance with relevant IEC standard where appropriate and shall be rated for the maximum prospective continuous load current.

Each battery switch/fuse panel is to be provided with a centre zero sensitive ammeters. The latter is to be complete with shunt fuses and pushbutton so that a check may be made to determine that the battery is receiving its correct float charge. In addition to this an approved facility shall also be provided to initiate an alarm if normal float charge current is not present. The station dc distribution boards shall be equipped with double pole circuit breakers for each incoming, interconnecting and outgoing circuit.

### 3.10.15Uninterruptible power supply (UPS) systems

A secure ac power supply system shall be provided for the operation of control and instrumentation equipment including the DCS operator stations and communication devices, e.g. network switches. The secure supply shall be derived from two inverters fed from separate d.c systems with independent battery backup supplies. Each complete system shall be rated to supply the complete control and instrumentation load of the associated plant.

The performance of the inverter shall be compatible with the requirements of all connected loads in respect of steady state and transient output voltage variation, frequency variation, harmonic distortion, etc.

The short circuit performance of the inverter shall be adequate to ensure correct fuse discrimination on short circuit of the outgoing circuit protected by the highest rated distribution fuse. The duration of the associated voltage depression must not be sufficient to affect the operation of the plant, other than that associated with the faulty circuit.

The control scheme shall automatically transfer the ac load from the inverter to a backup supply on inverter failure. The backup supply shall be provided from a LV emergency supplies switchboard via a transformer and static switch. Operation of the above transfer shall not affect the output of the power station. Facilities shall also be provided for transferring back to the inverter without affecting the power station output. A manual bypass switch capable of switching between the incoming supply and inverter output without a break in the supply shall also be provided. Faults in the UPS shall be alarmed on the DCS. The ratings of UPS equipment shall also be complied to the clause 6.10.6 under capacities of batteries.

## 3.11 Motors

### 3.11.1 General

Motors shall be of the energy efficient type and comply with the requirements of IEC60034. Motor enclosures shall be IP 54 for indoor application and IP 55 for outdoor. All motors shall be of approved manufacture. Motors of the same type and size shall be fully interchangeable and shall comply as far as applicable to IEC standard motor dimensions.

The general construction shall be stiff and rigid, no light metal alloy casings will be accepted. All precautions shall be taken to avoid corrosion. All motors shall be fitted with approved types of lifting hooks or eye bolt as suitable. AC motors shall have squirrel cage type rotors.

Motor windings shall be insulated with materials Class 155($^{0}$F), in accordance with IEC 60085:2007. The stator winding shall be suitably braced to withstand the forces due to direct on line. The winding envelopment and tails shall be non-hygroscopic. The stator winding shall withstand the maximum fault current for the period determined by the associated protective devices. The rotor winding shall be designed to give trouble free continuous service including repeated direct on line starting. The rotor shall be subjected to a 120% over speed test for two (02) minutes without showing any winding dislocation.

All MV motors, LV motors required to operate outdoors, or motors that may be at standstill for relatively long periods, shall be fitted with anti-condensation heaters of appropriate rating. The heaters shall be designed for connection to a suitable low voltage supply and shall be energized when the motor is at standstill. A separate heater terminal box and isolating facilities shall be provided for each motor.

### 3.11.2 Terminal arrangement

Terminal boxes shall be air insulated, totally enclosed and shall be designed to exclude the ingress of dust and moisture. The arrangement of terminals and cable connections shall permit the motor to be disconnected from the supply cable without damaging the seals, glands or connections.

Terminals for low voltage motors shall have insulating barriers between phases or poles.

MV motors shall have phase-segregated terminals and the terminal box and fittings shall not fail in a manner hazardous to personnel in the event of an internal fault.

### 3.11.3 Rating

The ratings of the motors shall be adequate to meet the requirements of its associated equipment. AC motors shall be capable of operating continuously under rated output conditions at any frequency between 95% and 105% of the rated frequency and or any voltage variation between 90% and 110% of the nominal voltage. A transient over voltage of 130% of the nominal voltage shall as well be sustained. Further, the motors shall be capable of maintaining stable operation when running at 70% nominal voltage for a period of 10 seconds. The pull out torque for continuously loaded motors shall be at least 160% of the rate torque and intermittently loaded motors 200% of the rated torque.

#### 3.11.4 Starting

AC motors shall be designed for direct on line starting. They shall be capable of being switched on without damage to an infinite busbar at 110% of the nominal voltage with an inherent residual voltage of 100% even in phase opposition. For starting the motors from the individual main and auxiliary busbars, a momentary voltage drop of 20% referred to nominal voltage should be taken into consideration. With 85% of the nominal voltage applied to the motor terminals, each motor shall be capable of accelerating its associated load to full speed with a minimum accelerating torque of 5% of full load torque.

The maximum starting currents shall not exceed the following values:

- times of rated current for motors rated up to 50kW
- 2.5 times of rated current for motors rated 50kW or above.

#### 3.11.5 Ventilation and type of enclosure

All motors shall be of the totally enclosed fan cooled type. They shall have a closed internal cooling air circuit re-cooled by an external cooling air circuit drawn from the opposite side of the driving end. When motors are installed outdoors, a weather proof design shall be chosen. A hole shall be provided at the lowest point of the casing for draining condensed moisture. Automatically controlled heating elements shall be provided for protection against internal condensation of moisture during stand still. Motors installed outdoors and directly subjected to solar radiation shall be rated such as not to exceed a maximum metal temperature of 85º C. Where necessary such motors shall be provided with sun shields. Vertical motors shall be provided with a top cover to prevent the ingress of dirt.

#### 3.11.6 Tests

Each motor shall be factory tested as per clause 10.7.2.3 and shall undergo a test at site as per 10.8.

### 3.12 Indicating instruments

All indicating instruments shall be in accordance with the requirement of IEC 60051.

Motor ammeters shall be capable of withstanding motor starting currents. Voltage operated instruments shall be protected by a fuse on each pole of the circuit placed as close as possible to the voltage transformer terminals.

## 3.13 Isolated Phase Bus (IPB)

### 3.13.1 General

This specification provides for furnishing an Isolated Phase Bus system complete with accessories as per the Schedule of Equipment for connection between the generator, main step up transformer and other auxiliary transformers at generating voltage level of each generator.

At least following Taps/Termination shall be furnished from the main bus to:

I. Generator
II. Generator Circuit Breaker
III. Unit Transformer (Generator transformer)
IV. Unit Auxiliary Transformer
V. Excitation Transformer

The IPB system shall contain complete descriptions of all equipment to be furnished, detailed data sheets listing the design criteria and to include calculated results of the predicted performance of the Isolated Phase Bus while operating under the specified site conditions specified in 3.4.

All Isolated Phase Bus and accessories shall be built to meet or exceed requirements as listed in the latest edition of IEEE C37.23 “IEEE Standard for Metal Enclosed Bus”.

### 3.13.2 Isolated Phase Bus Design Requirements

The Isolated Phase bus shall be of the Electrically Continuous, Self-Cooled design. Bus sections shall be constructed in sections as long as practical for installation to reduce installation time. The conductor shall be fabricated from high conductivity extruded aluminum tubes of a sufficient diameter and thickness to carry the specified continuous current without exceeding the allowable temperature rise. At all field welded conductor splice joints, the conductor tube shall be factory prepared by beveling the ends of the tube.

The enclosure shall be fabricated from high conductivity aluminum sheets and shall be of the necessary thickness to carry the enclosure currents without exceeding the allowable temperature rise. All enclosure field splices shall provide sufficient space to allow proper welding of the conductor and shall have pre-rolled split weld-in-place covers. The enclosure interior shall be painted with a flat black paint to aid in the dissipation of heat.

The insulators shall be wet process porcelain designed for the voltage and BIL level as specified under this specification. The insulators shall be grouped in sets and spaced along the bus at intervals to supply ample bracing for the short circuit currents. The bus shall be so designed where individual insulators may be removed for maintenance without disturbing the conductor or any other insulator.

In the event that bolted covers must be used, bonding straps of sufficient size to carry the full enclosure currents shall be furnished. Expansion Joints shall be supplied where necessary to prevent undue stress on any components of the bus system due to expansion or contraction.

Terminations of the bus enclosure to the equipment shall be accomplished with flexible insulating bellows to reduce vibration, stress, loading of equipment enclosures, and to reduce induced currents in the equipment. Termination of the bus conductors shall be accomplished with silver plated extra flexible connectors.

Bonding bars or plates shall be supplied to bond between the enclosure phases at each equipment termination. The bonding bars shall be of sufficient cross sectional area to carry the enclosure current without exceeding the specified allowable enclosure temperature rise. The bus enclosure ends shall be insulated from the equipment flanges with insulating bellows to reduce induced currents in the equipment. Each enclosure bonding locations shall have provisions for attaching grounding.

Connections of the isolated phase bus to all transformers shall be performed with flexible connectors of sufficient length to provide a minimum of 12" clearance between the bus spades and the transformer spades when the connectors are removed to facilitate testing of the transformers.

Wall seal assemblies shall be provided where the bus penetrates an indoor to outdoor wall. The seal assemblies shall be fabricated from aluminum and must be complete to include seal-off bushings in the enclosure-conductor annulus. The seal assembly shall be designed to prevent the seal assembly from supporting of any of the bus weight. This seal assembly shall be insulated from the bus enclosure to prevent grounding at this point. Seal-off bushings shall be supplied in each phase at each equipment termination.

### 3.13.3 Testing

All testing related to IPB systems shall be carried out on IEC guidelines. Tests to be carried out shall be as listed below, but not limited to followings.

**Type tests:**

1. Verification of insulation resistance or measurement of the leakage current, both before and after the dielectric test (no longer a prescribed test but can be retained as an in-house screening test)
2. Verification of dielectric properties:
    a. Power frequency voltage withstand or HV test
    b. Impulse voltage withstand test for all LV and HV system voltages
    c. Tan Delta Test
3. Verification of temperature rise limits (for rated continuous current capacity)

4. Verification of short-circuit strength:
    a. For straight lengths and tap-offs
    b. For the tap-offs in a power-generating station, connecting a UAT through the main bus section between the generator and the generator transformer.
    c. For the ground bus in isolated phase bus (IPB) systems
5. Verification of momentary peak or dynamic current
6. Verification of protective circuit
7. 7 Verification of clearance and creepage distances
8. Verification of degree of protection:
    a. Enclosure test
    b. Water tightness test – for all outdoor parts of any bus system (but for outdoor as well as indoor parts for isolated phase bus (IPB) systems)
    c. Air leakage test, for isolated phase bus (IPB) systems
9. Measurement of resistance and reactance
10. Endurance of trunking system with trolley type tapoff facilities

As safety measures new tests added in the latest Standards,

11. Verification of structural strength
12. Verification of crushing resistance (force)
13. Verification of resistance of the insulating materials to abnormal heat
14. Verification of resistance to flame propagation
15. Verification of fire barriers in building penetration
16. Electromagnetic compatibility (EMC) or immunity test and electromagnetic interferences (EMI) or emission test.
17. Additional test on an IPB enclosure to satisfy electromagnetic interference (EMI) requirements

**Routine Test:**

Routine tests are conducted on each completed bus system, irrespective of voltage, current, fault level and constructional details and whether or not it has undergone type tests. The following will form routine tests:

1. To check for any human error
2. General inspection of the bus assembly
3. Inspection of electrical wiring if there is any (such as for space heaters, cold or hot air blowing, enclosure pressurizing or any other protective circuit)

4. Verification of insulation resistance or measurement of the leakage current, both before and after the dielectric HV test. This test may be conducted only on partially type tested (PTT) bus systems
5. Verification of dielectric properties – similar to item 2 under type tests
6. Additional tests for an IPB system are:
   a. Partial discharge test: On all cast resin components such as instrument transformers, bushings and insulators to ensure that the insulation is free from defects and voids.
   b. Checking of welded joints: as in GDCD-198, norms for aluminium welding (CEGB, UK)*: All shop welded joints will be subjected to dye penetration examination and 10% of butt-welded joints, including joints on flexibles, enclosures and conductors, will be subjected to radiographic (Xray) examination.

## 3.14 Cabling and Earthing

### 3.14.1 General

The cable installation to be provided under the contract shall include all cables required for the supply, control, indication and monitoring of all plant provided under this Contract. The installation shall be complete with all cable terminations, cable trays, cable conduits, cable ladder racks, junction boxes, glands, ferrules, lugs, numbered ferrules, cable markers, clips and all fixings, fittings, brackets, cleats, piping and accessories. The Contractor shall undertake all design studies for the electrical distribution cabling system.

Cable conductors shall be stranded high conductivity copper. The conductor cross section of each cable shall be adequate for carrying the prospective fault current determined by the next relevant short circuit protection device.

All cabling and wiring shall be of the flame retardant type to the latest IEC standards and during combustion shall emit no halogen and produce minimal smoke. Cabling and wiring shall be designed and the installation arranged to minimize the risk of fire and damage. The outer PVC sheaths of cables shall have reduced flame propagation characteristics and be anti-vermin impregnated.

The insulation of each conductor shall be identified throughout its length either by colour or embossed numbers. The cable insulation shall include inhibiters for rodent protection.

Each cable shall be identified by a securely fixed fade-free and dirt resistant identification label adjacent to the cable gland at each end of the cable. Single point earthing shall be used for all single core cables.

Cables shall be glanded at entry to each panel with suitable mechanical glands to meet manufacturer recommendations.

For all equipment, conductors up to and including 2.5 sq.mm shall be terminated with agreed crimped terminations. Conductors larger than 2.5 sq.mm shall use an agreed crimped termination cable and core unique identification shall be provided, and terminations to suit manufacturer recommendations for terminal points.

The Contractor shall submit for agreement full details of all loading on cables. No intermediate joints shall be allowed in any length of cable without agreement.

### 3.14.2 Extent of work

The Contractor shall supply and install all cables and earthing connections including the following, but not by way of limitation, to complete the installation as is required.

1 132kV power cables to be laid between Generator Transformers and 132kV switchgears.

2 6 kV power cables to be laid between switchgears, transformers and busbars.

3 400V power cables between switchboards, and from the 400V switchboards to the 400V/230V circuit loads.

4 400V power cables between the diesel generators, motors and the 400V Station Service Board.

5 AC & DC Control cable connections for the gas turbine and station auxiliaries, excitation control equipment, 132kV control equipment, 11kV~15kV control equipment and 400V switchgear control circuits, control room equipment and transformers.

6 Earthing of all equipment and Neutral Earthing of all transformers

7 Excitation system power cables.

8 Cabling for lighting and small power A/C and ventilation and fire protection systems.

9 All necessary required cable terminations

The contractor is to submit detailed cable schedules, block routing diagrams, cable support detail drawings and control cable core numbering sheets to the employer for approval.

### 3.14.3 400V Power cables

400 V cables in power circuits shall be PVC or XLPE insulated wire armored and PVC sheathed overall 600/1000V grade IEC 60502-1.
Cable design, Testing and installation shall be done according to IEC 60502-1.

### 3.14.4 High Voltage Cables (145kV)

#### 3.14.4.1 General

XLPE cables to be offered shall be designed in accordance with the standards described 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. 145kV XLPE cables from manufacturers with a minimum of fifteen years successful experience in manufacturing 145kV cables will only be accepted. Offered 145kV XLPE cables will only be accepted if cables identical in design have a minimum of five years field experience.

**3.14.4.2 Conductors**

The conductor shall comprise stranded, soft annealed, electrolytic copper wires, round and compacted with standardized conductivity, and shall be proof against water penetration in longitudinal axis. Conductors shall comply with IEC 60228.

**3.14.4.3 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.

**3.14.4.4 Insulation**

The XLPE insulation of the cable conductors shall meet the requirements of IEC 60840, IEC 60502 or equivalent IEC publication.

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 vulcanization, 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 Employer, 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 cannot spread internally.

**3.14.4.5 Core Screen**

The screen applied over each individual core shall consist of a layer of semi-conductive XLPE. In order to give protection to the screen swellable against mechanical damage, a copper woven fabric tape may be applied over the screen where considered necessary by the manufacturer.

**3.14.4.6 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 Vulcanization)
- Conductor size.

### 3.14.4.7 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.

### 3.14.4.8 Metal Sheath

The cable shall then be drawn into an extruded lead alloy or aluminium. The thickness and composition of the sheath shall be stated in the Technical Particulars and Guarantees (Schedule 3 of Volume 4). 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.

In case PVC is proposed for the outer covering, the respective Bidder is requested to support this alternative by stipulating the technical and economic reasons.

### 3.14.4.9 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 Employer.

For outdoor sealing ends, polymer insulators shall be provided, designed with a suitable creepage distance 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-vulcanizing 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 Employer. 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.

### 3.14.4.10 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.

### 3.14.4.11 Voltage Identification

The plastic oversheath shall be embossed with the name of the manufacturer followed by: ELECTRIC CABLES - 145,000 VOLTS OR by “Applicable voltage level”. The letters and numbers shall comply with the requirements of BS 6480 or equivalent IEC publication.

### 3.14.4.12 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.

### 3.14.4.13 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 (Schedule 3 of Volume 4).

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 SF6 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 Employer.

### 3.14.4.14 Pulling Eyes

Unless otherwise confirmed in writing by the employer, 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 Employer. 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.

### 3.14.4.15 Surge Arrester

132kV cable end at the generator transformer terminals should be protected against the insulation of transformer and conductors of the system from the damaging effects from transients occurring such as lightning, switching effects and other possible strikes. Metal Oxide type, Polymer base surge arresters are preferred.

### 3.14.4.16 Service conditions

The site conditions are specified in clause 3.4.

## 3.14.5 Cable End Boxes and Glands

### 3.14.5.1 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 make 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 minimize bending of the cable cores.

### 3.14.5.2 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.

### 3.14.5.3 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.

## 3.14.6 Laying Direct in Ground

### 3.14.6.1 Excavation of Trenches

The exact location of each trench shall be agreed at the site with the employer before the installation work begins. Permits for excavation shall be obtained from the Employer. 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 Employer, 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 Employer.

### 3.14.6.2 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.

### 3.14.6.3 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.

#### 3.14.6.4 Cable erection

Cables shall be secured by non-corrodible cleats to supporting steel-work, or on galvanized trays or ladder rack. Wooden cleats are not accepted. Cables shall not be clipped or cleated directly to masonry except as provided above.

All cable supporting steelwork, racks, cleats, ties, trays and fixings in trenches or elsewhere shall be supplied under this Contract. All cables in vertical runs shall be supported to ensure that no strain due to the weight of the cable is taken by any terminating box. The maximum distance between tray supports shall be to the approval of the employer.

Single core cables are to be laid up in close trefoil three-phase groups and erected in separate non-magnetic cleats to the approval of the employer. The intervals between cleats and ties shall be sufficient to prevent excessive movement during the passage of fault current and to prevent fatigue cracking of lead sheaths, if applicable, due to thermal cycling. Spacing between cleats, and between intermediate ties, shall not exceed 4 meters and 1.2 meters respectively on straight cable runs. The maximum spacing between ties shall not exceed 0.3 meters where cables are laid in a curve.

Power and control cables shall generally be run on separate racks.

Where cables are erected on steelwork supports outdoors, sun shades of approved design and materials are to be included and erected as necessary to protect the cables. Cables which are buried shall be provided with protective concrete covers.

### 3.14.7 Tests for Cables at Manufacturer's Work

#### 3.14.7.1 Low Voltage and Medium Voltage Cable Testing

**<u>Routine Tests</u>**

Solid dielectric cables drum lengths shall be subjected to the following tests:

a). Conductor and Copper screen resistance as per IEC 60502 clause 16.2.

b). High voltage test as per IEC 60502.

c). Partial discharge test for XLPE cables shall be carried out in accordance with ICE 60502. The partial discharge test shall be carried out during the H.V. test. The detectable discharge pulse shall not be greater than 10pC at 1.3Uo and 30pC at 2.5Uo.The partial discharge extinction voltage shall be recorded.

d). Voltage test on PE outer covering (30/36kV cables only):8 kV d.c./mm thickness for one minute - 25kV maximum or 4kV a.c./mm thickness for one minute - 21.5kV maximum. If backed-on graphite coating is not provided, cable drum length shall be completely immersed in water for execution of test.

e). Measurement checks as per IEC 60502.

**Sample Tests:**

The sample lengths shall be tested in accordance with IEC.60502 Clause 16. During the H.V. test, the discharge inception and extinction voltages shall be recorded.

**Type Tests:**

The sample length to be type tested shall contain all jointing accessories required on the Contract and Tests shall be carried out in accordance with IEC 60502.

**Site test after installation**

Tests after installation are made when the installation of the cable and its accessories has been completed.

A d.c voltage test equal to $4U_o$ shall be applied for 15min.

As an alternative, and by agreement between the Employer and the Contractor, an a.c voltage test at power frequency, in accordance with items a) or b) below, can be used:

Test for 5 min with the phase to phase voltage of the system applied between the conductor and the metal screen;

Test for 24h with the normal operating voltage of the system.

### 3.14.7.2 145kV Cable Testing

**Factory Test**

**i). Routine tests on cables**

The following tests shall be carried out on each shipping length of cable, to check that whole of each length complies with requirements of IEC 60840:2011.

- Partial discharge test,
- Voltage test,
- Measurement of conductor resistance,
- Measurement of capacitance between conductor and metallic screen,
- Measurement of insulation resistance of cable insulation and jacket (reference test)

**ii). Sample test on cables**

The following tests shall be carried put on samples. The sample teat shall be carried out one length from each manufacturing series of the same type and cross-section of cable, but shall be limited to not more than 10% of the number of lengths.

- Conductor examination,
- Measurement of thickness of the insulation,

- Measurement of thickness of the metallic sheath,
- Measurement of thickness of the jacket,
- Measurement of the cable diameter,
- Hot set test for XLPE insulation.

**iii). Type tests on cables**

Type tests are not required to be carried out if the type test report on the same type is available.

Once successfully completed, these tests need not to be repeated unless changes are made to the cable or accessory, or design or manufacturing process which might change the performance characteristics.

The following tests shall be performed on samples of completed cable at least 10 m in length excluding test accessories:

- Check on insulation thickness of cable for electrical type test,
- Bending test followed by a partial discharge test,
- Tan $\delta$ measurement,
- Heating cycle voltage test, followed by partial discharge measurement,
- Impulse voltage teat followed by a power frequency AC voltage test,
- Partial discharge test,
- Resistivity of semi-conducting screens,
- Check of cable construction,
- Shrinkage test for XLPE insulation,
- Water penetration test

**iv). Type tests on systems, cable and accessories**

The tests specified in this clause are intended to demonstrate the satisfactory performance of accessories in the system. Accessories shall be subjected to the following sequence of tests:

- Partial discharge test at ambient and high temperature,
- Heating cycle voltage test,
- Impulse voltage teat followed by a power frequency voltage test,
- Tests of outer protection for buried joints (as applicable)

**Site test**

Test during the installation:

- Insulation resistance of the jacket after the cable laid
- Checking the cable spacing
- Checking depth of cable position
- Checking of earthing connection and testing of earthing resistance

Tests after installation:

- Checking cable phase
- Checking the link boxes
- Checking of insulation resistance of the cable
- Electrical tests (resistance and DC voltage test) of the jacket
- Measuring conductor resistance of the cable
- Measuring capacitance of the cable
- Measuring AC impedance of the cable circuits
- AC voltage test of the cable system

### 3.14.8 Control circuit cables

Cables in CT and VT secondary circuits and control circuits shall be PVC insulated, armored and sheathed with a minimum conductor size of 2.5mm.

### 3.14.9 Cable sizes

Conductor sizes for cables shall be approved and shall be determined according to the maker's assigned continuous current rating for the site ambient and installed conditions, and without the voltage drop in any part of the circuit exceeding 23% when the cable is carrying the maximum circuit current, and to withstand the prospective fault current and duration. In the case of motor circuits the volt drop may exceed the above limit under starting conditions but shall not exceed 15%.

When a cable is protected by a circuit breaker, which is not of the current limiting type, then the cable shall be able to withstand the prospective fault current, including asymmetric peak, for a period of at least 0.25 seconds without damage.

Conductors and metallic layers where provided, shall be of stranded annealed copper wires to IEC 60228.

### 3.14.10 Cable ducts

Any cable ducts which are in corrosive environment (especially in the battery rooms) shall be of PVC coated type and are to be supplied and installed under this Contract. All ducts are to be sealed at each end by approved means to prevent the ingress of water and vermin.

### 3.14.11 Protection against fire

Armored cables installed inside power station buildings, unless provided with extruded PVC servings, are generally to be without outer servings where they enter or are adjacent to oil filled equipment. Where dry servings have been applied to unarmoured cables to prevent damage to the sheath during installation, they are to be removed when erection is completed.

Where cables pass through holes in floors, the Contractor will be responsible for plugging the holes with a weak mix of cement and sand, or other approved materials after the cables are installed.

Fire barriers of an approved type shall be provided in all cable trenches where they pass through an external wall of the building and between the engine room basement and the switchgear room etc.

Cables shall be positively segregated such that a fire in one cable route cannot affect more than one diesel generator unit or one half of the common services system.

All power and control cables are to be provided with identification markers, of permanent materials and of an approved type.

Where cables are laid direct in the ground, cable route markers are to be provided where required to indicate the location of the cables.

### 3.14.12 Jointing

The Contractor is to be wholly responsible for the sealing and jointing of all cables except 145 kV supplied under this contract.

A record is to be kept of all joints and terminations made. Three copies of this record signed by the Contractor and the Employers's representative are to be supplied to the Employer.

### 3.14.13 Bonding and earthing

Single core cables with sheath which are provided with protective servings are to be bonded together and connected to earth

- at the point of opening out from the trefoil formation at each end and
- at one sealing end only for flat formation

Where single core cables have no protective serving, a bond is to be fitted at intervals of not more than 10m and connected to earth.

Lead sheathed and wire armored three-core cables are to have the armour and sheath bonded together at the end of each cable length and are to be connected to the earthing system at each termination.

Copper earthing bonds are to have a cross-sectional area of not less than 80 sq.mm.

### 3.14.14 Termination of cables

The cores of all cables shall be fitted with approved lettered and numbered ferrules and the conductors made off in terminations of approved type to suit the terminals to which they are connected.

Cable terminating boxes and glands shall be of a type approved by the manufacturer of the cable. For single core cables insulated island layer glands shall be provided with a test link connected between the island layer and earth. Where busbar frame earth leakage protection is specified then an island layer gland shall be provided in all cases.

### 3.14.15 Earthing system

Design of the earthing system of the power station, switchyard shall be done under this contract. The contractor shall provide all necessary details such as dimensions of reinforced steel bars, clamps and earthing tapes etc. to the civil contractors of power station and switchyard who should install the system.

Three phase short fault level of 10 kA shall be assumed for the calculation.
The design shall be based on the following,

- ANSI / IEEE standard 80-2013 or latest on Substation grounding
- ANSI / IEEE standard 665 -1995 or on Generator station grounding
- ANSI / IEEE standard 1050 -1996 Guide for Instrumentation and Control Equipment Grounding in Generating Stations

#### 3.14.15.1 Generator station grounding

Construction of the reinforced cage in the power house foundation shall be the base for the installation of the earthing system. A mesh of interconnected reinforcement steel must be constructed in each level of the power station below the natural surface level. Each level shall be interconnected by several raising reinforcement steel.

All these reinforcement steel shall be electrically connected by special earth clamps to finally form a conductive cage.

On each level a sufficient number of connecting wall plates shall permit the connection of the interior secondary earthing ring system to the primary reinforcement earthing cage. All metal parts shall be connected to this secondary earthing system.

The neutral point of each transformer (wherever required) shall be connected to the mesh below the transformer.

The earthing system of the power station shall be interconnected to the earthing system of the outdoor switchyard by two copper cables of at least 150 sq. mm.

Design of the earthing system shall include the following,

- Calculation of earthing resistance of power station and switch yard separately
- Dimensioning of the earthing conductors (reinforced steel and copper conductors)

- Tolerable step and touch voltages and calculated step and touch voltages
- Mesh size of the reinforcement steel
- Dimension of the raising steel bars to each level
- Level of connecting wall plates above each floor level
- Method of measuring the earthing resistance after the constructions and proposals for possible improvements
- Type and make of earthing clamps for interconnecting the reinforcement steel bars

The Con tractor shall provide final record drawings of all earthing as installed. The combined resistance of the earth meshes of power station and switchyard, shall if possible be less than one ohm and shall not exceed three ohms under any climatic conditions. There are to be separate connections to the station main earthing bar.

#### 3.14.15.2 Lightning protection

A complete lightning protection system comprising roof network and down conductors by means of 80 sq.mm or by higher tinned copper tape, earth terminations of copper clad steel cored each shall be installed to protect station buildings and other important areas.

The installation shall be carried out by the civil contractor and design, material specification preparation of drawings shall come under this contract.

The installation shall be carried out in accordance with corresponding BS Code of Practice CP 326 and the number of roof and down conductors required to complete the protection system shall be based on the conditions as stipulated under "Air terminations" and "Down Conductors" of this code of practice.

## 3.15 Lighting and small power installation

### 3.15.1 Scope of work

This section covers the complete lighting system including lighting fixtures, outdoor lighting poles, lamps, cabling, wiring, lighting switches, photo electric lighting controllers, small power installation such as single phase and three phase socket outlets, all required installation material and accessories for the entire plant.

### 3.15.2 General

The contractor shall perform all relevant design and engineering of the complete lighting system including preparation of the installation drawings and other required documents. The design of the lighting system shall be in accordance with applicable standards. All equipment shall be of such performance and quantity as to perfectly suit the purpose of a dual fuel Gas turbine plant which runs on Diesel and LNG.

The contractor is obliged to coordinate the lighting installation with the installation of other trades such as suspended ceilings, firefighting, air conditioning, piping etc.

In rooms with special architectural requirements and/or suspended ceilings, type and number of the lighting fixtures shall cope with the required illumination levels and architectural requirements. Lighting installation in switchgear and equipment rooms shall be coordinated with the equipment arrangements to provide adequate lighting for operation and maintenance.

The illumination levels of indoor lighting system shall be measured horizontally at a height of 1m above the floor, outdoor lighting and of flood lighted areas at the surface. In new condition of the equipment, the ratio of the minimum to the average illumination level shall not be higher than 1:3, the ratio of the minimum to the maximum illumination level shall not be higher than 1:6. When planning lighting system, it has to be considered that the light sources become dirty and are subject to ageing. Therefore a planning factor for contamination and ageing of 1.43 shall be applied. The whole lighting system shall be designed to produce adequate visual performance and safety and shall be free from excessive glare, stroboscopic effects and flicker from discharge lamps.

Provisions to facilitate erection, maintenance, cleaning and lamp replacement (ladders, carriages, platforms) shall be included.

AC lighting fixtures shall be evenly distributed on the three phases. In large rooms, halls the fixtures shall be mounted in such a manner as to obtain a uniform illumination level if half of the fixtures of a certain area are switched off.

The lighting and small power installation shall be designed and installed in compliance with IEC 60364-4-41 or latest and sub divided into

**3.15.2.1** Normal lighting installations fed by the power plant 400V AC auxiliary services with 100% stand by back of emergency diesel generator, Street lighting, Security lighting along fence/perimeter and area floodlighting in switchyard, tank farm etc.

**3.15.2.2** Emergency lighting circuits, exit and emergency exit lighting circuits (energized all the time) fed by DC systems.

**3.15.2.3** Small power socket outlets for power plant areas, equipment and control rooms, office areas, maintenance and testing areas, and domestic items;

**3.15.2.4** Secondary supplies to distribution boards, transportable and fixed equipment, welding plant, environmental plant, and sump pumps.

**3.15.2.5** The main lighting installation shall be designed to give the IEC recommended minimum levels of illumination in such a manner as to ensure even lighting and to avoid glare.

**3.15.2.6** No individual switching is required for the emergency lighting in all the buildings.

Switching for individual circuits/ set of lamps / a lamp of normal lighting shall be arranged from suitable points.

Circuits feeding outdoor lighting shall be controlled by photo electric cells having an adequate light intensity adjustment range. These cells shall provide automatic "ON/OFF" switching of the lighting. Remote control facilities and manual override switches shall be provided.

The lighting system shall be maintained and protected by the contractor in a satisfactory condition until final acceptance by the employer. Defective materials and equipment damaged in the course of installation or testing shall be replaced or repaired by and at the expense of the contractor in a manner to meet the approval of the employer.

### 3.15.3 Lighting fixtures

All lighting fixtures complete with lamps, tubes, chokes, instant starting control gear, compensating capacitors, power supply units etc., shall be of approved manufacture, constructed from best quality materials and provided with all necessary installations.

Outdoor fittings shall be completely weather proof.

Special precaution shall be taken to protect the wiring from damage by heat generated by fittings and lamps. For compensation of the inductive current of the chokes compensating capacitors shall be provided to obtain approximately unity power factor.

To avoid electrical shocks when touching disconnected fittings which include capacitors, discharge resistors of sufficient size shall be connected in parallel with all capacitors of more than 0.5 µF capacitance.

According to the IEC regulations, the equipment shall be furnished with radio interference suppressers if the maximum interference voltage stated in the regulations is exceeded.

The diffuser of fixtures indicating emergency exits shall be fitted with green coloured, translucent foil bearing inscriptions or symbols as may be requested by the Employer.

The types of lighting fixtures listed below shall be used in the various structures, building and areas according to the requirements. The stated locations for the different types shall be considered as indicative. The lighting fixtures shall be complete in every respect including lamp and control gear. The lighting fixtures in the suspended ceilings shall be according to the ceiling construction. The contractor shall supply and install the types of fixtures stipulated here below.

**3.15.3.1** **Type1(indoor)**: Recessed ceiling fixtures for combining lighting and air conditioning system, body of white finished sheet steel, white metal louver, protection class IP 20, LED or CFL lamps appropriately (Location: suspended ceiling of control room).

### 3.15.4 Cabling

Lighting and socket outlet circuits shall be of PVC insulated cables with copper conductors of minimum 1.5 mm². Nevertheless, it is the responsibility of Contractor to select the right cable sizes in each and every lighting circuit depending on the lighting load. The cabling shall be neatly and clearly arranged.

Cabling in plaster or concrete finished rooms shall be executed with PVC insulated conductors in embedded conduits. In equipment rooms, workshops, storage rooms and the like, cables shall be laid in surface mounted PVC conduits, in areas endangered by or subject to mechanical damage in galvanized mild steel conduits, painted after erection. Where necessary, mineral insulated metal sheathed wires or an approved substitute shall be used.

Separate conduit systems shall be installed for normal, emergency lighting and for security lighting systems. Each and every branch for any lamp shall be connected via junction boxes equipped with terminal blocks, screws etc. wrapping of conductors for any connection is not permitted. The finishing of the cover plates of switches shall consider the architectural aspects.

### 3.15.5 Switches

Lighting fixtures in self-co ntained rooms such as offices, switchgear rooms, battery rooms, etc. switched locally. Where more than two switching points are required (staircases, long corridors, large rooms with several entrances etc.) illuminated push button switches shall be used to control impulse operated relays (110V DC) and contactors arranged in the associated sub distribution boards. Outdoor lighting shall be operated via photo sensing devices with remote operation and manual override facility.

Switches and socket outlets installed in rooms with embedded wiring shall be designed for flush mounting in moulded plastic wall boxes. For hazardous areas and battery rooms, switches and socket outlets shall be specially designed for use in such environments. In all other cases, exposed mounting with shock proof metal clad industrial type housing of adequate enclosure shall be provided. Switches shall either be of the thumbler or rocker dolly type.

### 3.15.6 Power and AC socket outlets and plugs

The power socket outlets and plugs shall be of weather proof, with housing of shock proof plastic material for office rooms and with housing of metal clad industrial type for other area inside the power house. The following types of outlets shall be provided at locations to be approved by the employer.

- Three phase socket outlets (for welding sets) of 16A, 32A and 63A as required with five pins and incorporated switch and mechanical interlocking.
- Single phase AC socket outlets of 13A as required with three pins.

Above three phase and single phase socket outlets complying with IEC 60309 shall be installed to give adequate coverage of all buildings and plant included in this specification.

The finishing of the cover plates shall consider the architectural aspects.

### 3.15.7 Illumination levels

The average illumination level under complete a.c lighting system for the various locations shall be as follows, the indicated values referring to the lamps being in new conditions.

| | | |
|---|---|---|
| - Control room | - | 300 lux |
| - Relay room/protection room/switchgear room etc | - | 300 lux |
| - Rooms with other electrical installations | - | 200 lux |
| - Workshops/HVAC room etc | - | 200 lux |
| - Stairways/rest rooms | - | 150 lux |
| - Engine hall | - | 200 lux |
| - Basement | - | 250 lux |
| - Outdoor/Switchyard | - | 20 lux |

### 3.15.8 Main characteristics

The proposed types of lighting fixtures and all other design features shall be as stated in the bid or the modifications thereof as agreed between the Employer and Contractor.

The lighting and small power installations is fed from 400V a.c station auxiliary services via lighting main distribution board and lighting sub distribution boards. The security lighting such as exits, stair ways, emergency exits, etc., by a separate d.c distribution system from 110V d.c battery. Service voltages shall be as follows.

| | |
|---|---|
| Normal lighting system | : three phase, five wire, 400/230V a.c, 50Hz |
| Security lighting systems | : double pole 110V d.c |
| AC Socket outlets | : single phase, three pins 230V a.c, 50Hz |
| Power Socket outlets | : three phase, five pins, 400/230V a.c, 50Hz |

### 3.15.9 Design features

Indoor and outdoor lighting circuits shall be directly fed from lighting main distribution board and lighting sub distribution boards, to be installed in the power house. Number and locations of the lighting sub distribution boards shall be decided by the contractor during detail design and shall be subjected to the approval of Employer.

The types of lighting fixtures listed in clause 6.16.3 shall be used by the contractor to design, supply and install in the power plant. Switches socket outlets and power socket outlets shall be installed as stipulated in the clause 6.16.6.

### 3.15.9.1 Installations

Cabling and wiring for lighting and small power installations in the control room, offices, rest rooms, conference room, kitchens, toilets, etc shall be flush mounted using PVC conduits, non-metallic underfloor raceways, or integrated metallic cable raceways in prefabricated structural elements like aluminium window frames or mobile wall elements. In suspended ceilings cable shall be laid on cable trays.

Socket outlets and switches for lighting or other purposes shall be flush mounted, installed in embedded device boxes. Junction boxes within concealed wiring shall likewise be of the flush mounted type. Surface mounted steel conduits, switches and socket outlets shall be used in engine hall, basement, workshops, battery room etc.

The mounting heights of switches and socket outlets in closed rooms shall be as follows:

- Socket outlets wall mounted, 300 mm above finished floor
- Socket outlets mounted in all other locations different from walls, 500 - 800 mm above finished floor
- Switches or switch / socket outlet combinations flush mounted in walls or built in cabinets, 1200 mm above finished floor

### 3.15.9.2 Outdoor lighting

Number of circuits for the outdoor lighting installations shall be arranged to achieve a minimum of cable installation and an even load distribution.

All outdoor lighting circuits shall be switched on and off automatically by photo electric switches. It shall be possible to override these photo electric switches by manually operated push buttons.

For the outdoor lighting hot dip galvanized steel poles of about 8.5 m height with lighting fixtures shall be provided. Each pole shall have a terminal box with removable cover. In this box a terminal plate and a miniature single pole circuit breaker shall be provided.

The contractor shall perform all ancillary works necessary for lighting poles installation such as foundations, excavation and fill work, particularly the proper erection, alignment and stability of the poles.

### 3.15.10 Lighting distribution boards

The lighting distribution boards shall be of robust sheet metal, flush fronted design and, depending on size and location, be of the free standing or wall mounted (exposed or flush) type. They shall be of standard construction produced by an experienced manufacturer. The front doors shall be provided with lockable handles (one key type for all sub distribution boards).

An electrical diagram showing all plant and the circuits being connected to the individual outgoing feeders shall be provided on the back side of the front door.

The electrical equipment of main lighting distribution board shall consist of:

- One normal bus bar system, separate neutral and protective earthing bars
- Two main incoming breakers, incoming 1 & incoming 2 from relevant low voltage panels with thermal and magnetic over current release, earth leakage protection and shall be interlocked to avoid circulating currents.
- Outgoing feeders equipped with moulded case circuit breakers (MCCB) with thermal and magnetic over current release and earth leakage protection devices for lighting sub distribution boards. Tripping characteristics of MCCB's & earth leakage protection shall ensure selectivity with other switchgears
- About 20% (minimum 02) spare feeders for each type
- One indicating lamp for common fault indication of the tripping of any protection device installed in the board (fuse blowing, control MCB tripping etc.), mounted in the upper part of the front door, with auxiliary contacts for remote alarm and event recording.
- Terminal blocks

The electrical equipment of lighting sub distribution boards shall consist of:

- One main bus bar system for the specified voltage levels, with separate neutral and protective earthing bars.
- Miniature circuit breakers (MCB) with thermal and magnetic over current release for lighting, socket outlets and control circuits, supervised fuses are only allowed as short circuit limiting element. The tripping characteristics of the MCB's shall ensure selectivity with other switchgear.
- Contactors, auxiliary relays and impulse operated contactors as required for remote control of lighting circuits via push button switches.
- About 20% (minimum 02) spare feeders for each type
- One indicating lamp for common fault indication of the tripping of any protection device installed in the board (fuse blowing, control MCB tripping etc.), mounted in the upper part of the front door, with auxiliary contacts for remote alarm and event recording.
- Terminal blocks

### 3.15.11 Tests

The complete installation and, as far as reasonable, also the individual components shall be tested as follows.

- Visual inspection
- Functional tests
- Measurement of illumination level
- Insulation / resistance

# 4 Control, Instrumentation, Information and Communication System Requirements

## 4.1 Design Conditions

### 4.1.1 General

The design of the Instrumentation and Control (I&C) systems and components shall be consistent with the overall availability, reliability and operational philosophies adopted for the power plant.

The design of the I&C systems shall conform to accepted industry practice for the type of gas turbine and generating units specified under the "Technical Specification". The type and make of I&C equipment shall be internationally proven in gas turbine power plants.

Basically, the I&C system shall be provided according to "Technical Specification" and Manufacturer/Supplier/Contractor's standard practice to fulfil the aims of the Control and Supervisory System as specified in any part of this specification and to guarantee the safe and reliable operation of the plant. Any deviation of the proposed system from the "Technical Specification" is subjected to the approval of the Employer.

The equipment life time shall be 30 years.

I&C system and equipment shall be selected and designed in such a way that the following design and operational requirements are satisfied.

- Ensure safe and efficient operation of the power plant by an optimum number of operators during normal on-load plant operation as well as start-up/shutdown using automatic sequences.
- Be designed to operate satisfactorily over the full range of operating and ambient conditions of the plant. This shall also include operation in hazardous areas where necessary.
- Plant control and instrumentation system shall be designed considering the future operation of plant on duel fuel. (Lanka Auto Diesel and Re-gasified natural gas)
- The control system shall be designed to maximize the level of automation provided for such plant operations as start-up, synchronization, loading, de-loading, normal operation, shutdown, isochronous mode, black start mode, primary frequency control mode, grid frequency control mode, respond to National system control center (NSCC) Automatic Generation Control (AGC) mode commands, retaining at FSNL mode without gas turbine tripping during unavailability of 132 kV supply. The design shall also consider the Employer's philosophy with regard to manning levels.

- Unit Master Controller-coordinated Unit operation capable of handling unscheduled load swings of up to 15 % (actual load) as well as scheduled load ramps of 10 % (actual load) per minute
- Each Gas turbine generator unit shall be able to start, synchronize, load & de-load, monitor and shut down independently and simultaneously locally and remotely.
- The automated sequences shall be designed with a view to optimize the start-up / shutdown times whilst maintaining the mechanical and thermal stresses that the plant is subjected to within allowable limits.
- Capable of operating all gas turbines with a joint load reference set point to control all gas turbine generator units sharing the block load (100~130MW) in regulating the grid frequency.
- A philosophy to optimize I&C cabling from the field and between sub-systems shall be implemented. The approach shall be to hardwire critical signals and use proper data communication links/networks for non-critical signals where appropriate. Field-mounted PLCs with suitable environmental rating shall be used where feasible thereby minimizing cabling costs.
- Utilize a high level of standardization with regard to equipment selection and control logic design, so that the requirements of training for equipment operation & maintenance and holding of spare parts are optimized.
- Have demonstrated satisfactory performance in similar applications for at least 05 years or subject to the approval of the Employer.

#### 4.1.2 Environmental Requirements

All electrical equipment shall be of tropical design and entirely suitable for use under the prevailing site conditions.

The environmental climatic conditions such as air temperature, humidity and air pressure that directly affect the performance of I&C systems are defined in IEC 60654: Part 1. The Contractor shall prepare detailed specifications of I&C systems using appropriate severity levels as per the above standard based on the classification of proposed locations of these systems. For indoor locations like turbine compartment etc., the additional temperature rise shall be considered.

The mechanical influences such as vibration, shock and mechanical stress that affect the I&C systems during operation, transportation and storage are defined in IEC 60654: Part 3. The mechanical design of the I&C equipment shall address these influences as stated in the above standard to minimize the risk of equipment malfunction.

Moving parts (linkages, mechanisms, etc.) for instruments shall be of stainless steel. Casing and bezel material of instruments shall withstand and resist the corrosive conditions at site.

The material of instrumentation and control equipment, which are exposed to the measured media, shall be compatible with the conditions of the respective media and with the piping material.

Open air installed parts shall be protected against sun radiation by means of adequate covers and shall be protected against high humidity and rainfalls.

The material of the equipment shall be suitable for the respective application and industrial service.

Scale plates and finishing are to be of such material that no peeling-off or discoloration will take place with age.

### 4.1.3 Requirements against Explosion Hazard

The selection of I&C equipment for operation in the presence of flammable or explosive materials shall take into account the hazardous area classification of the plant area by relevant standards where the equipment is to be located.

Explosion proof construction or intrinsic safety barriers shall be used to ensure safe operation of equipment in these cases.

The design and installation of such equipment shall comply with the requirements of IEC60079-14 / EN 50014 and shall be supported by the necessary documentation from an appropriate Certification Bureau.



### 4.1.4 Equipment Protection Class

For outdoor equipment (e.g. transmitters, binary sensors, analyzers, actuators, etc.) the minimum protection class shall be IP65. For outdoor distribution boxes and cubicles, the minimum protection class shall be IP55.

The very same is applicable for indoor equipment installed in the process areas.

For cubicles, desks and panels installed in the Central Control Room, Local Control Cubicles and etc., the protection class IP42 shall be applied. Exception may be done for some equipment, evidently not fulfilling this requirement because of specific functional tasks.

Employer reserves his right to ask for higher protection class because of environmental conditions.

### 4.1.5 Isolation requirements

Safety requirements for electrical equipment for measurements and controls shall be designed according to standard IEC 61010.

All isolating circuits and devices used in I&C equipment shall be designed to provide an insulation resistance of not less than 20 MΩ measured at 500 V dc. A circuit operating at

110V ac or 125V dc and above shall be designed to withstand 2 kV (rms) 50 Hz ac voltage for one minute between itself and the rest of the equipment.

### 4.1.6 Electromagnetic compatibility requirements

The I&C equipment shall comply with the requirements of the relevant Electromagnetic Compatibility (EMC) directives. In general, individual items of equipment shall have the relevant approvals (e.g. CE marking or equivalent). Alternatively, the Contractor shall demonstrate EMC compliance by submitting a Technical Construction File with the appropriate Declaration of Conformity for the I&C systems.

The I&C equipment shall not generate electrical or electromagnetic interference (conducted or radiated) at a level that can adversely affect the performance of other equipment or lead to hazard/discomfort to personnel. The relevant parts of IEC 61000 and EN 55011 with the appropriate classification and grouping shall be used to confirm this requirement.

The I&C equipment shall be immune to electrical/electromagnetic interference from external equipment. The relevant parts of IEC 61000 with the appropriate test severity levels suitable for a power plant application shall be used in terms of impulse withstand, electrostatic discharge, radiated electromagnetic energy and voltage fluctuation to confirm this requirement.

### 4.1.7 Codes and Standards

Control and Instrumentation systems, equipment and components shall be designed, manufactured, installed, documented, commissioned and tested in accordance with the latest edition in force of relevant international standards and recommendations. Where such standards and recommendations do not exist and, unless otherwise laid down in this specification, recognized National Standards accepted by the Employer may be used.

Reference to Standards and Codes, where indicated either directly or as “relevant”, is intended to provide a measure of performance, safety, workshop and site testing and methods of erection and/or installation.

In particular, I&C systems shall comply with all but not limited to the latest revision of the following standards.

| | |
|---|---|
| IEC 61131 | Programmable controllers |
| IEC 60688 | Electrical measuring transducers for converting A.C. and D.C. electrical quantities to analogue or digital signals. |
| IEC 61508 | Functional safety of electrical/electronic/programmable electronic safety related systems |
| IEC 61511 | Functional safety -safety instrumented systems for the process industry sector |

| | |
|---|---|
| IEC 60654 | Operating conditions for industrial process measurement and control equipment |
| IEC 60529 | Specification for degree of protection provided by enclosures (IP code) |
| EN 55011 | Industrial, scientific and medical (ISM) radio frequency equipment-electromagnetic disturbance characteristic- limits and methods of measurement |
| IEC 61000-4 | Electromagnetic compatibility (EMC) part 4 : Testing and measurement techniques |
| IEC 61000-6 | Electromagnetic compatibility (EMC) part 6 : Generic standards |
| EN 50014 | Electrical apparatus for potentially explosive atmospheres, general requirements |
| IEC 60079-14 | Electrical apparatus for potentially explosive atmospheres, Electrical installations in hazardous areas (other than mines) |
| BS 6739 | Code of practice for instrumentation in process control systems, installations, design and practice |
| IEC 61010 | Safety requirements for electrical equipment for measurement, control, and laboratory use |
| IEC 60751 | Industrial platinum resistance thermometers and platinum temperature sensors |
| IEC 60584 | Thermocouples |
| IEC 60870 | Tele control equipment and systems |
| IEC 60297 | Mechanical structures for electronic equipment |
| ISA-5.1 | Instrumentation symbols and identification |

Where equivalent standards are used, the Bidder shall declare them in his bid. If the Bidder intends to apply Standards and Regulations other than those specified, he shall provide the Employer with two copy sets of such documents, which shall be complete, unabridged and written in contract language (English).

### 4.1.8 Plant numbering system

An internationally accepted plant numbering system (KKS coding system is preferred) shall be employed to uniquely identify all plant items and equipment using a hierarchy of breakdown levels. The allocation of the plant numbering system in terms of grouping of major systems and reference to physical location of the plant items at site shall be to the approval of the Employer.

All design and O&M documentation shall refer to plant items and equipment using the approved numbering system.

### 4.1.9 Measuring units

The international SI system of measures and weights shall exclusively be used for documents, correspondence, drawings and etc.

All instruments shall be calibrated and inscribed in this system, but no other measuring units than the below tabulated ones shall be used for the below mentioned measured variables.

| **Measuring Unit** | **Measurement** |
|---|---|
| bar | Pressure of fuel, water, oil, compressed air and high-pressure gas |
| mbar | Pressure of turbine inlet air, flue gas and low-pressure gas |
| deg C (°C) | temperature |
| mm or m | levels |
| mS/m | conductivity |
| rpm | rotating speeds |
| % | position |
| $Nm^3/h$ (normal $m^3/h$) | combustion air and gas flows |
| kg/s | fuel flow |
| mm, m/sec or $m/sec^2$ | eccentricity and vibration |
| Hz | frequency |
| A, kA | current |
| V, kV | voltage |
| MW, kW | active power |
| MVar, kVar | reactive power |
| Wh, kWh | active energy |
| VArh, kVArh | reactive energy |

### 4.1.10 Miscellaneous

### 4.1.11 Space Heaters

Any major item of electrically connected I&C equipment prone to suffer from internal condensation of moisture is to be fitted with electrical heating devices of such capacity as to raise the internal temperature slightly against external ambient temperature.

### 4.1.12 Air filters

Where ever louvers for ventilation are foreseen (e.g. controller cubicles), they shall be equipped with washable filters for specified protection class IP4X or better.

### 4.1.13 Labels, Tags, Plates and Inscriptions

Every piece of Instrumentation and Control equipment such as tapping points for local indicating and remote indicating instruments, thermocouples, RTDs, transmitters, switches, local controllers, local cabinets, cubicles, boxes, local panels, Central Engineering Room cubicles and components, Central Control Room components, desks and panels, process computers, couplers, gateways, printers, push buttons and etc. shall be provided with labels (engraved), tags, plates, etc. with plant identification number and text description so as to allow correct operation, easy testing and efficient maintenance.

The wordings on labels, tags, plates and inscriptions shall conform to the wordings used in Engineering and O&M documents.

The size and material of the labels, tags, plates and inscriptions shall be submitted for Employer's approval.

The fixtures shall be of non-corrosive material. The fixation shall be done rigidly. Labels on chains, wires will not be accepted.

### 4.1.14 Locks, Keys and Key cabinets

Every kind of hinged door in Central Engineering Room cubicles, control cabinets, local cubicles, etc. as well as withdrawable chassis shall be secured by means of a suitable lock.

### 4.1.15 Closing of Openings

The contractor shall close all openings, penetrations and cut-outs for walls, floors and roofs, required for piping work, miscellaneous supports, cabling and bus ducts, etc. within his scope of supply.

Special attention shall be paid to the proper sealing/ closing of cable entries etc. The contractor shall supply and install all the necessary materials for sealing work such as steel frames, sleeves, sealing material, flashing, masonry and finishing work.

The sealing shall meet the required fire protection class.

## 4.2 Workshop and Site Tests

The stipulations of General Specifications of Volume 3 and Quality assurance, inspection and Testing of Volume 2 shall also be considered.

### 4.2.1 General

Every piece of I&C equipment provided under this Contract is to undergo workshop and site tests whether specified or not.

Prior to commencement of site installation work, the Contractor shall deliver a site test organization chart giving details of his personnel as well as a list comprising all instruments and other facilities intended to be used for the site tests together with technical details of the same.

### 4.2.2 Work's Inspections and Workshop Tests

Apart from the usual post-manufacture quality control tests on final products, a minimum scope of functional tests shall be carried out in the workshop prior to shipment.

#### 4.2.2.1 General Remarks

The Contractor shall issue a quality assurance program, indicating the kind and extent of inspections and tests to be carried out on plant components. The quality assurance program shall be based on the tests and inspections specified in the various parts of the Specification. These inspections and tests shall prove whether the equipment fulfils the requirements of the Contract in view of

- safety conditions, rules and regulations
- applied standards and regulations
- execution of workmanship
- conformity with the present state of modern technology

The following procedure has to be adhered to with respect to test certificates.

Whenever inspections or tests are carried out all material certificates as well as all other intermediate test certificates, in accordance with the agreed test schedule, shall be made available to the Employer in legible copy for inspection and filing. Further the latest issue of the related drawings, indicating also the state of approval by the Employer, shall be made available.

The same applies to the final work's inspections or workshop tests when all test certificates have to be submitted to the Employer.

A form sheet Titled "Test and Inspection Manual" shall be prepared showing all steps of the test procedure as well as the relating standards and codes.

All these test manuals have to be sent to the Employer in due time before the tests are performed.

#### 4.2.2.2 Visual Inspection, Test Instruments

The Employer may from time to time make visual examinations and may check the plant equipment and the conditions under which it is manufactured or erected at the Contractor's or sub-contractor's premises to make sure that it complies with the relevant specifications and drawings.

All the test instruments should have been calibrated by a recognized statutory institute. Valid test calibration certificates shall be submitted for each test instrument. All the instruments shall be tested with test instruments having valid calibration certificates at the time of test.

#### 4.2.2.3 Test Runs and Functional Tests

Test runs and functional tests shall be carried out on individual equipment as much as possible subjected to the approval of the Employer, to prove the reliability and the correct functioning of the component and its compliance with the stipulations of the Contract. Rated operating conditions shall be simulated if possible, otherwise appropriate conversion factors shall be applied.

Following minimum functional tests shall be carried out in the workshop prior to shipment.

- DCS hardware is setup and interlinked
- Application software is loaded
- I/O module software is loaded and all modules are initialized
- Display/ logging functions of HMI is to be tested
- Alarm/ Protection criteria is to be tested
- Fail safe protection systems are to be tested completely
- Response times are to be tested

The Test results are to be duly certified. No shipment of any component shall take place before it has been completely tested according to the Workshop Test program.

### 4.2.3 Tests at Site

The Site Tests shall take place in two consecutive steps:

- Pre-commissioning and Cold Commissioning Tests
- Hot Commissioning Tests

#### 4.2.3.1 General Remarks

The equipment to be supplied under the Contract shall be tested at Site during erection, commissioning and initial operation. These tests shall prove whether the equipment meets the requirements of the Contract and the safety conditions, whether it has been built and/or erected with satisfactory workmanship and whether the equipment is in conformity with the prevailing standards and regulations as well as with the present state of modern technology. Further the tests shall assure that components did not suffer any damage during shipment and it functions in site as specified.

Where manufacture or finishing is done at Site, tests and inspections shall be conducted as a replacement for an appropriate workshop test. The preliminary check-out and test runs, the trial operation, the initial operation, the reliability test run and the performance tests shall be carried out by the Contractor's personnel in the presence of the Employer.

All tests are to be accompanied with the test records signed by all parties. In case of tests involving also activity of other contractors all remarks and comments shall be placed in the test record signed by all participants.

Acceptance test readings shall be taken with calibrated instruments.

Instruments shall be isolated during pressure testing of the piping and tubing to prevent damage.

In the case of measurement and control systems involving electronic transmission, a simulated input signal shall be applied and varied over the full range.

Each device shall be calibrated and checked for correct operation. Static head shall be considered, if any.

The Contractor shall be responsible for proper protection of the instruments and devices that may be damaged by any of the required tests.

All instruments shall be elaborated to verify that the output or visual indication is correct in the range span of the instrument. Span checks shall be at 0, 25, 50, 75, and 100 % of range. Operational adjustments (zero, offset, suppression, etc.) shall be included in the Contractor's data/ documentation.

After installation, process sensing lines shall be hydro-tested to the same pressure as the process lines to which they are attached.

Instruments shall not be hydrostatically tested.

After installation, instrument air piping shall be pneumatically tested in accordance with the appropriate standards.

Waiving of any tests shall not release the Contractor of his responsibility to fully meet the requirements of the Contract.

Test record forms shall be submitted by the Contractor during the design phase for the Employer's approval.



#### 4.2.3.2 Pre-Commissioning and Cold Commissioning Tests

The Pre-commissioning and Cold commissioning tests begin after the inspection on completion of installation and erection works has taken place with the participation of the Employer and shall cover normally:

- Wiring checks
- Earthing checks
- Power supply checks

- Bus communication checks
- Measurements checks
- Calibration checks
- Setting of limit values
- Actuator check
- Limit switches checks
- Man Machine Interface (MMI) checks
- Single loop checks
- Subgroup checks
- Alarm and protection criteria checks

After the successful completion of these tests the plant can be monitored and controlled on the drive control level from the CCR with all protection and alarms being operative.

In order to avoid any hardware damages, the first energization/operation shall only take place after the cold commissioning test program is successfully completed.

The final scope of the Workshop and Site Test programs is subjected to approval by the Employer.

#### 4.2.3.2.1 Erection Checks/Tests

Erection checks/tests shall be announced and carried out after the electromechanical installation (with all cables connected).

Erection checks/tests of major I&C installations (Control Room, local control cubicles and etc.) shall be done.

Erection checks/tests of field instrumentation for mechanical/process equipment shall be done.

Remark: Continuity and electrical rigidity insulation resistance tests for cables are part of the erection test.

#### 4.2.3.2.2 Construction Tests

Construction tests shall be carried out to prove the completeness of the construction before releasing the Plant or a part thereof for the (hot) commissioning tests.

For the Instrumentation and Control items, the construction tests contain the so called cold commissioning tests, i.e. loop tests and calibration tests, setting of limit values, etc. After all tests were done for unit main components or for main auxiliaries, all test records shall be compiled by the contractor and submitted to the Employer accompanied with the list of outstanding items/comments found during the construction tests.

#### 4.2.3.2.3 Hot Commissioning Tests

The hot commissioning test of any equipment may start after the successful completion of all pertaining construction tests and ends with the checking out of plant to ascertain its fitness for operation in live conditions.

After all relevant tests were done, the Contractor shall apply for and the Employer may agree to the first firing of the GT, respectively, to the first synchronization.

Hot Commissioning Tests shall normally cover:

- Closed-Loop Control checks
- Function Group/Unit Master Control checks
- Control parameters adjustment
- Dynamic behavior checks

The hot commissioning tests are normally followed by a Unit optimization which can begin after the power plant has reached full-power generating conditions and no major obstacle remained unresolved.

The main working tool to be used during the tests shall be the System Engineer's Workstation. If necessary, additional special test or simulation equipment shall be provided by the Contractor.

#### 4.2.3.3 Unit Optimization

After the first synchronization of the Unit, the Contractor shall start with the optimization of the plant, including the optimization of the closed loop controls, the finalization of the open loop controls, etc.

This task will be done under the sole responsibility of the Contractor.

After the unit optimization was done, the Contractor shall confirm the successful completion and apply for the Initial Operation of the unit, demonstrating the results of the optimization under extreme operational conditions as specified before releasing the Unit for the Reliability Test Run and Performance Test.

## 4.3 Field Equipment

### 4.3.1 General Design Requirements

The field mounted instrumentation and control equipment includes all devices such as local indicating devices, transmitters, switches, analyzers, local controllers, etc. with all necessary cabling, wiring, local boxes/cubicles/panels, instrument piping and valves, instrument air supply, erection material, etc. up to the terminals ready to receive multicore cabling to remote locations.

Items inherent to the process piping, such as valves with actuators, solenoids, orifices, sight glasses equalizing vessels, standing pipes etc. may also belong to the field mounted instrumentation and control equipment.

All instrumentation shall be heavy-duty and of proven and reliable design with all materials of construction suitable for the intended application.

The design shall facilitate easy maintenance and repair of the components. Equipment with operating experience less than 5 years (as far as the basic type is concerned) and outdated models shall not be used.

In the case of Gas Turbine Units are being identical, the field instruments, cubicles, etc., shall be similarly located. The highest extent of uniformity and interchangeability shall be reached.

#### 4.3.1.1 Local Cabinets/ Cubicles

Transmitters, switches, local controllers and etc. which are to be used outdoor shall be provided in protective boxes/cabinets with transparent tempered glass windows. Location shall be as close as possible to the mechanical equipment.

The grouping of instruments shall be carried out as practicable as possible.

As far as possible, bottom connections for cable entries, process piping and tubing shall be used. Special care shall be taken to avoid water ingress into the cubicles by cable transitions, process piping and tubing entrances.

No conduits shall be introduced to the cubicles only cables with proper cable glands and rubber sealing (and eventually additional sealing).

The equipment shall be pre-assembled to the highest extent in the Contractor's or Subcontractor's workshop, e.g. tubing of the cabinets/cubicles, etc., including installations of internal equipment as far as practicable.

Piping, tubing, fittings and wiring shall be arranged so that any instrument or device may be removed or serviced without disturbing the piping, tubing or wiring associated with other instruments.

Device housings shall be weather-proof and dust-tight to suit the environment.

All equipment mounted in cubicles/cabinets and the cubicles/cabinets themselves shall be identified with nameplates having plant identification numbers.

Each field mounted instrument e.g. pressure and temperature gauges, shall be supplied alone with instrument brackets or accessories for surface or pipe mounting.

#### 4.3.1.2 Junction Boxes

Junction boxes shall be used to connect the field mounted instruments to the multicore cables laid to the controller cubicles.

All junction boxes shall be identified with nameplates having plant identification numbers.

Junction boxes shall have 20% spare terminals after final commissioning.

#### 4.3.1.3 Measuring Equipment

All instrumentation shall be selected such that the normal maintenance intervals to maintain the performance and function based on the "worst case" plant operating conditions is no more than annually based on manufacturer recommendations.

Electronic instruments shall have solid-state circuitry to the maximum extent possible and the instruments shall quickly respond to any change of the measured variables.

For transmission of measuring signals (other than T/C or RTDs) to the I/O modules, transmitters shall be used where ever possible. The output signals of transmitters shall be a direct current of 4 - 20 mA and be linear, and over a wide range, independent of the burden in the output circuit.

Programmable smart transmitters (e.g. devices capable of communicating using HART or any other standard protocol) shall be provided wherever possible and this is subjected to the approval of the Employer. Each transmitter that is used to transmit a signal to I/O module shall be powered from suitable DC supply or AC supply from UPS and utilize a two-wire or four wire transmission system. Alternatively, a proven "Fieldbus" communication system may be used for communication between the transmitters and I/O module/ controller. Transmitters used for critical signals and functional safety systems shall however be individually hardwired.

Measuring ranges of local indicators, transmitters, etc. shall be selected in such a way that the rated value of the measuring variables appears at approx. 75 % of the span. Range and span adjustments shall be field adjustable as applicable.

The output of electronic instruments shall be short-circuit proof, that in case of a short circuit, the component is not damaged and there are no interactions to the inputs. All electric transducers shall have galvanic isolation.

All devices furnished with electric coil shall be capable of operating satisfactorily between 75 % and 115 % rated voltage.

The sensing elements shall be suitable for the temperature of the medium and pressure variation. Very low drift over time, or temperature and humidity shall be applied to all the instruments provided.

In case of ambient temperature effect on the accuracy, internal thermal compensation shall be provided to limit and minimize the effect.

All measuring equipment shall have high accuracy through the entire range of 0 - 110 %, ensure a long term stability and a very good repeatability. All transmitters shall have an accuracy of ± 0.25 % of full range or better unless otherwise specified in anywhere else in this document.

All transmitters shall have internal diagnostic functions.

All electrical measuring transducers for converting AC and DC electrical quantities shall conform to IEC 60688 Standard.

For closed loop analogue control, for each measured variable, three separate sensors, detectors, transmitters, etc. with separate tapping arrangements shall be provided.

For important plant protection functions as well as for the protection of important assemblies and drives, the corresponding analogue and binary variables have to be measured by three independent devices whose signals have to be wired to different data acquisition modules, that are plugged in different modular frames of the I&C cubicle in order to get a 2 out of 3 selection of field signals.

Measuring elements and chambers of transmitters, pressure switches, etc., shall be of stainless steel or better material.

All mechanisms of regulation and setting shall be insensitive to vibrations and shocks.

The terminal arrangement of the transmitters shall include facilities to allow checking of the output signal without disturbing any permanent connections.

Electronic transmitters shall be of the indicating type or equipped with separately mounted local indicator. Generally, the minimum requirements for local Instrumentation are:

- Pressure gauges with isolating valves at each high pressure shut-off valves
- Pressure gauges with isolating valves at inlet/outlet of each pump
- Pressure gauges with isolating valves at pressurized vessels, heat exchangers
- Differential pressure indication for all filters
- Thermometers at inlet/outlet of each heat exchanger
- Thermometers at vessels containing hot liquids (e.g. lube oil)
- Test valves and connections necessary for commissioning and tests
- Thermometers at bearing oil outlets
- Level gauges/measurements on tanks, pits, etc.
- All necessary standard instrumentation on package units as per manufacturer’s standard

Electronic instruments for fuel system as well as other hazardous areas shall be of the intrinsically safe type.

Contacts of level switches, pressure switches, flow switches, temperature switches, limit switches, etc., and of all other pilots shall be of the snap-action type gold plated. The mechanical life time of the measuring element and the switching element shall be 2.5 million operating cycles. The creeping-action type shall not be accepted. The contacts shall be best suited for the control voltage applied and be properly selected for the prevailing ambient /atmospheric conditions. Mercury contacts shall not be accepted.

Only double throw contacts shall be used. Contacts shall be rated to suit their required duty. These contacts shall be equipped with the suitable series and parallel resistors in order to detect connecting cable wire break/short-circuit conditions through I/O modules.

Devices for interlocking/ protection and alarm systems shall be separate, i.e. contact devices and sensors serving commonly for interlocking/ protection and at the same time for supervision and/or alarm purposes shall not be accepted.

In case the contact devices of indicating type (e.g. flow switches) have standard scale, this scale shall not be used for calibration purpose.

Adjustments on the switches shall be provided for calibration purposes. Adjustments shall have protective covers.

If not otherwise specified, the accuracy of the contact/ switching devices shall be 1 % or better. The type of the equipment, especially in respect of accuracy and the other technical data has to be approved by the Employer.

The residual differential display (hysteresis) of contacts shall be in a range of 3 - 5 % of the full scale range. However, it shall be adjustable, depending on specific requirements.

The meters, instruments and etc. shall be of standard size, be selected to guarantee unique appearance of switchgear, control panels, control desks, etc. The front glasses shall be of anti-glare type. The scales shall be 90º to 360º ranged type.

All external screws, bolts and nuts shall be of stainless steel.

All instrumentation and control functions shall be shown on the piping and instrumentation diagrams. The symbols to be used shall be in accordance with ISO standard. The identification system shall be in accordance with the plant identification system and shall be subjected to the approval by the Employer.

### 4.3.2 Installation of Instrumentation

#### 4.3.2.1 General Requirements

The installation of all instrumentation shall comply with the guidelines given in BS 6739 or an international equivalent standard. The recommendations of the instrument manufacturer shall also be taken into consideration.

Fittings shall be selected from a single manufacturer as much as possible considering the easiness of maintaining the Plant.

Each tapping point shall be dedicated to only a single instrument.

The Contractor shall place the equipment accurately in position; level the equipment, including the panels; assemble all equipment which requires assembling; and make ready for service.

Each device shall be mounted and piped so that repair, calibration, removal and replacement may be accomplished without interruption of service of adjacent devices. Piping and tubing shall not run across the face or rear of any device in a way that will prevent the opening of covers or obstruct access to leads, terminals, or instruments for servicing.

All instruments shall be installed in such a manner as to protect all equipment from moisture, excessive temperature & variations.

Local mounting of instruments on pump bases, foundations, etc. where equipment are liable to experience shocks and vibrations is strictly forbidden. Field instruments shall be located away from equipment/locations where severe/ continuous vibrations or shocks may occur/to be expected. However, vibration/shock proof equipment of appropriate grade shall be applied, where necessary.

Instrument piping shall be routed to allow easy removal of valves, tube bundles, motors, etc. Piping which must pass through such an area shall be able to isolate and remove.

An allowance for thermal lagging on process piping shall be included when locating and routing instruments and tubing.

Hot lines (surface temperature above 60°C), shall be covered with appropriate screens or insulation, if required for personnel protection.

Indicating instruments shall be located/sized so that their dials are easily readable from their applicable operating levels. Where possible, instruments shall be located in illuminated areas.

Sensing instruments and their associated valve manifolds, relative to the process connection shall be located, in a way to avoid gas pockets in a fluid-sensing line or liquid pockets in a gas or vapor sensing line.

#### 4.3.2.2 Installation of Impulse lines

Lines shall be neatly installed, straight vertically and horizontally.

Lines shall be installed so that they are free from contact with sharp corners which could wear or cause damage to the pipes.

Lines shall not be supported from structures or piping subjected to vibrations.

Lines shall be supported and run in areas where it will not be subjected to mechanical damage.

Lines shall be installed with sufficient clearance from all steel and concrete surfaces. In no case shall they run in direct contact with painted or unpainted concrete surfaces.

Full lengths of lines with as few unions or fittings as possible shall be utilized to the maximum extent practicable.

The minimum bending radius for lines shall be three times the outside diameter of the pipe.

Bends in lines shall be made by industry standard tools. Tools used for bending shall be of the mandrel type, of good quality, and shall not damage the pipes by nicking or flattening.

The Contractor shall determine the exact sensing line routing to result in an installation consistent with generally accepted instrumentation procedures and good engineering practice.

Connection of stainless steel lines to process line isolation valves shall typically be made by socket-weld adapters.

Pipes containing liquids shall be arranged in such a way that their slope allows entrained air or gas bubbles to rise to vent points, and liquids or solid deposits to fall to settling chambers or blow down points. In pipe runs where obstructions have to be avoided, the pipes may be run in a series of slopes providing that gas vents are fitted at high points as settling chambers shall be arranged in positions suitable for ease of operation.

Primary sensing lines at local panels and racks shall be as short as possible and neatly arranged with easy access to blow down connections and instrument valves or manifolds.

Primary lines between the instrument valve or manifold and the instrument shall be arranged properly not to apply strain to the instruments when connections are made.

Instrument valves or manifolds shall be rigidly attached to the local panel or rack framing so as not to strain the lines when operating valves.

Valve drain connections and drop or dirt chambers shall be installed at low points of impulse lines.

All high points in liquid sensing lines shall have a vent connection. However, generally no high points shall be allowed.

If a sensing line has a liquid purge, the line shall be arranged so that the purge flow is upwards.

If a gas purge flow is into a process liquid, the purge flow shall be down.

The discharge of bleed connections shall be piped to a safe disposal point if opening the bleed may create a hazard. The outlet of the valve on an atmospheric bleed shall not be plugged or capped to avoid potentially hazardous pressure build-up on the downstream of the valve.

A pair of head-type sensing lines shall run together, to the maximum extent possible, to keep both lines at the same temperature.

Sufficient piping flexibility shall be provided for each installation to accommodate process connection primary point motion and thermal growth of the piping itself during hot blow down and during normal operation. The requirements for slope shall not be violated by the configuration.

Instrument lines shall be grouped together and run in common trays wherever possible. All instrument lines shall be appropriately supported throughout their entire run.

Whether specifically specified or not, the Contractor shall furnish anchor bolts, mounting brackets and straps, air sets, tubing trap supports, tube and piping supports, hangers, wire connectors and any other miscellaneous hardware or material required to properly install and place in service the furnished equipment.

Material for line clamps, bolting, line raceways, and other supports shall be compatible with material used for lines.

#### 4.3.2.3 Instrument Air Supply lines

Routing of branch headers shall not interfere with process piping, electrical cable trays, or equipment and shall not obstruct walkways or stairways.

Main and branch air lines shall incorporate low point moisture traps. All instrument air piping shall be sloped so that drainage toward drip legs or moisture traps will be facilitated.

Each header or main line shall be provided with outlets as close as possible to the point of application. Outlets shall always be taken from the top of the pipe to minimize condensed moisture carry-over.

A shutoff valve shall be installed at each takeoff from the branch header for air supply lines to the equipment requiring instrument air.

Filter/reducing stations (regulators) shall be furnished with a pressure gauge and a separate relief valve downstream of each reducing valve.

#### 4.3.2.4Instrument Lines Support

Brackets and means of support of instrument pipes for instrument process sensing lines and instrument air supply shall be furnished and installed by the Contractor.

All supports shall be secured in place by expansion anchors in concrete or by welding to structural members of the plant. Welding of supports to structural members is to be reviewed by Employer before installation.

Expansion bends shall be provided as necessary to allow the movement (including thermal) of supporting structures.

Lines subjected to severe vibrations shall be supported as required to minimize damage from vibration.

Lines and supports shall be arranged in such a way that harmful stresses are not applied to the instrument. Line supports shall be designed and installed so that pipes will not be crimped or damaged.

#### 4.3.2.5Line Connections

The Contractor shall provide all the test, purge, vent, and drain connections as required.

As far as practical, bends rather than tube or pipe fittings shall be used to change direction of a run of pipe.

Flare less or threaded connections or seal welds over threaded or flareless fittings may not be used where weld connections are required. A weld fitting may replace a threaded or flareless fitting, except where removal for test, calibration, or maintenance may be required.

Impulse line connectors in service which cannot be inspected and tightened must be of welded type.

Lines that must be connected to vibrating equipment shall be provided with flexible connections. These vibration loops shall not form gas pockets and liquid traps.

Elbow fittings are to be used only where the pipes cannot be installed by bending.

Compression fitting shall be installed in accordance with the manufacturer's recommended procedure.

When connections are made, the pieces being connected or joined shall be clean and free of residue, borings, and foreign materials which may plug an instrument or make it inoperable.

Lines shall be blown free of foreign matter before connections are made.

### 4.3.3 Instrument Valves

#### 4.3.3.1 General

All valves shall be of approved manufacture, design and material.

All primary isolating valves and valves used for protection purposes shall be capable of being locked in the "OPEN" or "SHUT" position. Fittings associated with locking of valves shall be securely attached to the valve body. Padlocks for locking the valves shall be supplied if necessary by safety reasons.

Blow-down valves shall be provided where necessary.

The preferred direction to close instrument isolating valves, vent/test valves and valves on instrument valve manifolds is clockwise. Where this is not possible, the direction to close shall be clearly marked on the hand wheel together with the word "CLOSE or "SHUT." Where spindle extensions are provided they shall be independent of the valve body and provided with separate support.

#### 4.3.3.2 Primary Isolating Valves

The primary isolating valve shall be located at the tapping point and capable of being subjected to the temperature and pressure of the main line.

Double isolating valve shall be provided for rated pressure above 40 bar.

Where the primary isolating valve at the tapping point cannot be made easily accessible, a further isolating valve shall be provided adjacent to the measuring device so that double isolation is achieved, when disconnecting the device without closing the primary isolating valve at the tapping point.

Double isolation shall be provided for hazardous services as well.

#### 4.3.3.3 Instrument isolating Valves

The instrument isolating valves shall be located on the connecting pipe at the measuring device end of the line. These valves shall be as near to the instrument as practicable and shall be of the needle type.

The arrangement of pipework and connections shall be such that the temperature of the instrument isolating valve or instrument valve manifold does not exceed 55°C.

The valve may form part of a valve manifold or be an individual valve.

#### 4.3.3.4 Venting and Test Valves

Vent and Test valves may form part of an instrument valve manifold together with the instrument isolating valve.

In all applications vent/test valves shall be located as close to the instrument as possible such that the maximum amount of entrained air can be vented from the pipe work and a minimum pipe work volume is achieved for testing.

#### 4.3.3.5 Equalizing Valves

Equalizing valves shall be provided for all differential pressure measuring devices. The equalizing valve shall be positioned as close to the measuring device as possible and may form part of an instrument valve manifold.

#### 4.3.3.6 Blow-down Connections

Blow-down pipe work and valves shall be provided in the connecting lines to all transmitters where necessary.

The valves shall be capable of being subjected to the pressure and temperature of the main line.

The blow-down pipe work connection shall be made at a point as close to the device as practical and preferably at the lowest point in the system.

There shall not be any open blowdown or drain connections inside panels or local equipment housings. All instrument vent/ drain points shall be directed to a safe position away from maintenance personal and vented/ drained in an environmentally friendly manner.

### 4.3.4 Types of Measuring Instruments

**4.3.4.1** Pressure Measuring Instruments

##### 4.3.4.1.1 General Design Requirements

Pressure measuring instruments shall have linear scales.

Over-ranging the measured pressure shall not affect the pressure instrument nor its calibration.

Pressure instruments for viscous, hot or inflammable liquids e.g. diesel oil or with suspended solids shall be fitted with appropriate diaphragm seals.

Pressure devices on pulsating services shall be equipped with pulsation dampers.

Pressure switches/ transmitters for fuel system shall be of explosion-proof/intrinsically safe type.

Each gauge, switch and transmitter for pressure measurements shall be equipped with a pressure gauge isolating valve such that the device can be removed without any disturbance to the plant operation.

A test connection of screwed type shall be provided for each critical pressure measuring points of the processes enabling the facility for the operator to connect a separate pressure measuring device whenever required for trouble shooting purposes.

#### 4.3.4.1.2 Pressure/ Differential Pressure Transmitters

Pressure gauges with position transmitter devices will not be accepted as pressure transmitters.

Pressure transmitters shall withstand at least 115% of nominal input range without damage or calibration change.

All differential pressure transmitters shall be capable of withstanding without damage or calibration change, full rated line pressure as a differential input. The high and low pressure connection of differential pressure gauges shall be marked accordingly.

The error for pressure transmitters shall be limited to a maximum of ±0.1% from full span.

#### 4.3.4.1.3 Pressure Gauges

Gauges measuring low pressure ranges that can be exceeded by a higher containment pressure shall be fitted with over-range protection. Gauges shall be fitted with vent/test valves. Blow out devices shall be provided for high pressure applications.

Pressure instruments shall be shock and vibration proof preferably by filling with glycerin and shall be equipped with toothed wheels and toothed segments of the machined type. They shall completely be made of stainless steel.

The pressure gauge shall be equipped with a radial connecting stud, to allow the mounting on a gauge holder.

The error for pressure gauges shall be limited to ±1 % of the full-scale deflection (FSD).

Pressure gauges shall be 160 or 100 mm in diameter (e.g. 160 mm for important measurements and higher elevation, 100 mm for aggregates with high amount of local measurements, however uniform size for a given area shall be used). For local gauges, Stainless steel case, white dials and black lettering are required. Scale graduation shall be in "bar".

Pressure gauge mechanism shall allow a fine adjustment (both zero and span adjustments).

#### 4.3.4.1.4 Pressure Switches

The accuracy for pressure switches used for critical actions shall be limited to ± 0.5 % of the full range. The accuracy for pressure switches used for non-critical controls and alarms, shall be limited to ±1% of the full range. This is subjected to the approval of the Employer.

Pressure switch shall be selected in a way that the required pressure set point is within 65% – 80% of the full range.

Use of contact manometers shall not be accepted.

Switches shall have adjustable set-points and adjustable hysteresis, as required.

#### 4.3.4.1.5 Differential Pressure Gauges and Switches

All descriptions for pressure gauges and pressure switches shall be applied to differential pressure gauges and switches.

The high and low-pressure connections of differential pressure instruments shall be marked accordingly.

#### 4.3.4.1.6 Installation Requirements

For gas measurements, pressure instruments shall be arranged above the tapping point; if this arrangement is impossible condensate traps and blow-down valves shall be installed.

In case of flowing substances, the measuring point shall be selected in regions of undisturbed flow according to the requirements of applicable Standards and Codes.

Pressure gauges over 10 bar as well as pressure transmitters and pressure switches shall not be directly mounted on the pressure tapping point. They shall be mounted apart from the tapping point and grouped if practicable in gauge panels, instrument cabinets, etc.

Each pressure switch and transmitter for absolute or differential pressure shall be equipped with an instrument isolating valve, drain valve and with a test connection with isolating valve and plug.

Wherever possible, a single instrument valve manifold shall be used instead of separate isolating, drain and equalizing valves.

Instruments supplied with diaphragm seals shall be installed in accordance with the manufacturer's instructions.

#### 4.3.4.2 Temperature Measuring Instruments

##### 4.3.4.2.1 Thermocouples and Resistance Temperature Detectors

All temperature measurements except the local temperature measurement and other specified exceptions shall be measured by means of thermocouples (T/C) or resistance thermometers (RTD).

Unless otherwise the temperature lagging due to the thermo-well cannot be neglected, a thermo-well shall be used where ever a temperature measurement is required in high pressure/ corrosive fluids/gases and where ever removal of the sensing element is required without affecting the process.

The selection of Resistance Temperature Detectors (RTDs) or thermocouples for temperature measurement shall be based on accuracy, reliability and measurement range considerations. Type K thermocouples and Pt100 3-wire RTDs are preferred for normal applications. Type Pt 100 shall not be applied for measuring values above 250 °C .

For RTDs used in critical controlling functions, an accuracy of Class A or higher as per Standard IEC 60751 is preferred. For non-critical applications, instruments of accuracy class B or C shall be used as per standard IEC 60751.

For Thermocouples used in critical controlling functions i.e. Gas turbine exhaust temperature monitoring, accuracy shall be 1.5°C until 375°C and 0.4%/°C for temperature greater than 375°C or better. For non-critical applications, instruments of Type K Accuracy Class 2 shall be used as per standard IEC 60584.

Head mounted temperature transmitters are preferred where feasible. Where thermocouples are employed, cold junction compensation shall be provided.

In the case of direct immersion metal couples of the mineral insulated type, the couple up to the associated junction box shall be capable of easy replacement. A flexing coil shall be provided in the couple between the junction box and the carrier.

Where thermocouple/RTD assemblies are supplied, a disconnection head shall be arranged clear of the pocket and associated lagging and shall be sufficiently long as to prevent excessive temperature of the head assembly.

The temperature sensors shall be selected in such a way that only a small number of different spare inserts are required.

For resistance temperature detectors, 2 or 3 wire circuits shall be applied.

The sensing elements shall be insulated from the cladding.

The completed measuring devices (e1ements with protective wells) shall have a fast transient response for temperature changes.

The thermo-wells shall be of stainless steel and of adequate length to ensure sufficient penetration into the fluid to give a precise measurement.

The elements shall fit into wells as described above ensuring a good heat transfer from the well to the element e.g. by an appropriate liquid or material where necessary.

The protective wells shall be selected for a maximum life endurance.

Generally, inserts with two thermocouples/resistance thermometers shall be provided so that one of them is available for spare.

Thermocouples and resistance thermometers for bearings or motor windings must withstand, without damage, vibrations. For bearings the protecting sleeve may be of the type fitted with springs, which presses the sleeve to the hot surface in order to maintain a good thermal contact.

#### 4.3.4.2.2 Local Thermometers

Local thermometers shall be of the industrial expansion type. However, mercury expansion type shall not be accepted.

The bulbs shall be of stainless steel and of adequate length to ensure sufficient penetration into the fluid to give a precise measurement. The bulbs shall fit into wells as described above ensuring a good heat transfer from the well to the bulb, e.g. by an appropriate liquid or material.

The design shall allow a free swiveling of dial in order to obtain the best reading.

The casing shall be weather-proof and dust tight and of stainless steel.

The dials shall be 100 or 160 mm in diameter (e.g. 160 mm for important measurements and higher elevation, 100 mm for aggregates with high amount of local measurements, however uniform size for a given area shall be used) and bear a black lettering with scale graduation in degrees centigrade on white background.

Mechanism shall allow a fine zero adjustment.

Local thermometers shall have an accuracy of ±1.5 % of the span range or better and shall be insensitive to ambient temperature variations, shocks and vibrations.

#### 4.3.4.2.3 Temperature Switches

Temperature switches shall be of the liquid/gas expansion type.

The accuracy for temperature switches used for critical actions shall be limited to ± 1 % of the full range. The accuracy for temperature switches used for non-critical controls and alarms, shall be limited to ±2% of the full range.

Repeatability shall be limited to ±1% of the full range.

Select the switch range that enables the desired set point to fall in the mid 60% of the adjustable range.

Switches shall have adjustable set-points and adjustable hysteresis, as required.

#### 4.3.4.2.4 Installation Requirements

Elements for liquid service shall be located so that they are always submerged.

Elements for air and gas service shall be located so that they sense the average temperature.

Capillary-type temperature instruments shall have their capillary supported and protected similar to instrument tubing. Excess length of capillary shall be limited and neatly coiled and provided with permanent protection to prevent damage.

The temperature indicators shall be oriented so that they are visible from operating positions when they are used for operating purposes.

Temperature elements installed in piping shall be located providing access for servicing, calibration, or replacement, and shall not be located where vibration or shock is expected.

Adequate space shall be provided for the removal of thermocouples, resistance temperature detectors (RTD) or indicators from their protecting wells.

All wells of local thermometers, resistance thermometers and thermocouples shall, as far as possible be of the weld-in-type.

Shop-welded thermometer wells shall be covered by screwed plugs for protection during transportation and erection.

The wells shall be designed in order to achieve fast speed response.

All thermo-wells shall be of the stainless steel material.

#### 4.3.4.3 Flow Measuring Instruments

Fuel oil flow for individual gas turbine units for metering purposes shall be measured with Coriolis type mass flow meters. The error for these transmitters shall be ±0.05% or better of the top measuring range. The repeatability shall be ±0.025% or better of the top measuring range.

The error of the density measurement obtained from the mass flow meters shall be ±0.0002 $g/cm^3$ or better of the top measuring range. The repeatability shall be ±0.0001 $g/cm^3$ or better of the top measuring range.

The fuel flow measurement shall be transferred to control system via suitable means. The instantaneous fuel flow measurement and the totalized fuel flow for each gas turbine unit shall be available in HMI. The density measurement shall also be available in HMI.

Local indications of instantaneous and totalized fuel flow shall also be provided for each gas turbine unit.

Flow meters employing alternative measurement principles may be utilized for appropriate applications subject to the agreement of the Employer.

Local flow indicators may be of differential pressure type, propeller type, lever type or floating body type. U-tube manometers and mercury filled instruments shall not be permitted.

The accuracy for the local indicators shall be 2 % of the top measuring range.

Sight flow gauges shall be of the through vision type, with a glass window at each side of the flowing stream.

#### 4.3.4.4 Level Measuring Instruments

Level measuring devices may be of the direct measurement, differential pressure or electrical/electronic type as appropriate to the application.

##### 4.3.4.4.1 Level Transmitters

For corrosive or dirty liquids preferably ultrasonic non-contact devices shall be provided. For ultrasonic devices temperature compensation is required.

Displacement type instruments shall be mounted in external cages with flanged connections, rated the same as the vessel. This type of instrument shall not be used for applications involving viscous, corrosive or flashing liquids.

Level transmitters employing alternative measurement principles may be utilized for appropriate applications subject to the agreement of the Employer.

For level transmitters the error limits shall not exceed ±0.5% of full span.

##### 4.3.4.4.2 Level Indicators

For local indication of level, direct measuring devices shall be used wherever possible. Unless otherwise agreed by the Employer it shall be possible to remove any level measurement device without the vessel or other instruments being taken out of service.

Each gauge shall be fitted with top and bottom isolating valves with full bore drain valve at the bottom and plugged vent at the top. Flanged connections, rated the same as the vessel, shall be used.

#### 4.3.4.4.3 Level Switches

The external cylinder magnetic type and float type shall be used wherever possible. The level switches with float chamber shall be provided with isolating and drain valves. Connections shall be by flanges. Floats shall be made of stainless steel. These mechanisms will include an adjustment of the working point and must be insensitive to effects of vibrations and shocks.

Floats shall be suited for the maximum test pressure and temperature of the system.

A stilling well shall be used in all cases, where displacement or float-type elements are located inside a vessel, to reduce the turbulence. Stilling wells shall be firmly supported. Head room shall be provided to permit withdrawing them if they are removable.

External-chamber level instruments shall be installed with process piping. The root valves and shutoff/isolating valves for these instruments shall be of the gate type.

When gauge glasses and level instruments are installed on the same standpipe, the gauge glass shall be oriented so that it can be used in calibrating the associated level instruments.

The accuracy for level switches shall be limited to ±2% of the full range.

Level switches employing alternative measurement principles may be utilized for appropriate applications subject to the agreement of the Employer.

### 4.3.4.5 Exhaust Gas Monitoring System

A continuous on-line Exhaust Gas Monitoring System shall be installed as per the requirement of Central Environment Authority and as specified in this specification, All necessary provisions including tapping points, sampling points to connect an Exhaust Gas Monitoring System shall be provided in exhaust stacks of each Gas Turbine Unit. Continuous on-line Exhaust Gas Monitoring System shall be capable of monitoring at least O2, CO, NOx, SO2 etc. content and opacity of the flue gas of Gas turbine.

A separate provision shall be provided for the Central Environmental Authority of Sri Lanka to collect exhaust gas samples of each Gas Turbine Unit periodically.

### 4.3.4.6 Vibration Measuring Instruments

The measurement devices have to be supplied by an experienced manufacturer such as Bently Nevada or equivalent. At each bearing there shall be two vibration detectors (orthogonal pair) installed for relative shaft vibration (Rotor). Upon manufacturer recommendation, vibration detectors for absolute bearing vibration shall also be provided.

Vibrations measurements shall be incorporated in turbine protection systems to protect the turbine from excessive vibration.

#### 4.3.4.6.1 Shaft Vibration (Relative Measurement)

Sensors of the non-contacting type (inductive, eddy current) are prescribed. Two orthogonally mounted sensors on each bearing have to be connected to two-channel amplifiers for each supervised bearing. The vibration has to be indicated locally and remotely in HMI and alarms and necessary protection actions shall have to be initiated in case of excessive vibration values.

Sensors shall be oil proof and designed for operating temperature.

#### 4.3.4.6.2 Bearing Vibration (Absolute Measurements)

For the bearing absolute vibration, a solid state sensing device shall be provided. Moving coil type devices shall not be accepted.

Sensors shall be designed for operating temperature.

The output signals have to be indicated locally & remotely and alarms and protection actions for excessive vibration have to be initiated.

### 4.3.4.7 Miscellaneous Measurements and Control

#### 4.3.4.7.1 Position Transmitters

Position transmitters of the potentiometer type will not be accepted for any automatic control purpose.

Inductive position transmitters or similar types are acceptable.

The accuracy, linearity and repeatability shall be selected according to the standard practice of the manufacturer considering the criticality of the application.

#### 4.3.4.7.2 Turbine Shaft Position Measurements

Turbine Shaft position sensors shall be inductive or Eddy current type, oil proof, designed for the operating temperature.

Each sensor shall be connected to a separate amplifier.

#### 4.3.4.7.3 Speed Measuring Instruments

The speed shall be picked-up by three speed probes which are to be located above a toothed impulse disc of the turbine rotor.

An average value shall be calculated from these three speed signals. The deviation of each channel from the average value shall be supervised. A channel shall be switched off if a pre-adjusted limit is exceeded.

The actual speed value shall be used for speed controller, acceleration limiter and speed supervision.

If the Gas turbine and generator unit comprises of multiple shafts, separate speed pickups shall be utilized to measure the speed of each shaft.

For over-speed protection separate speed pickups shall be utilized.

#### 4.3.4.7.4 Local Controllers

For simple control functions which are not essential for the operation of the plant and which need no interference by the operator during start-up, shut-down and operation, locally mounted controllers can be used. These automatic Controllers shall be of simple and reliable design.

They shall have an indication of controlled variable and a set point adjuster for 0 to 100 % of full scale range wherever applicable. All local controlling provisions shall be provided as applicable (start, stop, local remote selectors, emergency stop and etc.).

The local controllers shall be insensitive to vibration and shall be mounted in separate cabinets near of the equipment they are serving.

In case the local controllers are including the measuring systems for pressure, temperature or level, the appropriate specification shall apply to the measuring systems including tapping point, piping and valves.

#### 4.3.4.8 Electrical Measurements

All electrical instruments shall be of flush mounted design, dust and moisture proof. AC ammeters and voltmeters shall have moving iron system of not less than 1.5 accuracy class for connection to the secondary side of instrument transformers. DC measuring instruments shall have moving coil systems of the same accuracy. Watt meters shall be of electronic type.

All indicating instruments shall generally withstand without damage a continuous overload of 20% referred to the rated output value of the corresponding instrument transformers. Ammeters shall not be damaged by fault currents within the rating and fault duration time of the associated switchgear via the primaries of their corresponding instrument transformers. All instruments and apparatus shall be capable of carrying their full load currents without undue heating. All instruments and apparatus shall be rear connected, and enclosures shall be earthed. Means shall be provided for zero adjustment of instruments without dismantling.

When more than one measured value is indicated on the same instrument, a measuring point selector switch shall be provided next to the instrument and shall be engraved with a legend specifying each selected measuring point.

### 4.3.5 Final Control Elements

#### 4.3.5.1 General Requirements

Irrespective of the specific function that a control valve performs in the control scheme (i.e. modulating, inching or on/off), control valves shall have a local control facility and local indication of the actual position of the valve where necessary. The normal operating mode shall be “remote” from the CCR via the DCS. The local/Remote selector switch shall be local to the valve and the selection shall be transmitted to DCS.

Control valves shall be supplied with suitable actuators matched to the operational and environmental requirements of the plant. In general, electro-Hydraulic servo valves shall be used for modulating duties, however, motorized control valves may also be used in specific control loops with the approval of the Employer. On/Off control valves may be motorized or pneumatically/ hydraulically actuated with a solenoid pilot valve.

Control valve actuators shall be designed to drive the valve to a safe position from the process view point on failure of signal and/or air supply. For each valve application, due consideration shall be given to whether the safe state is open, closed or for the valve to remain in the last position prior to loss of control (“stay put” design). The fail-safe position for all pneumatic control valves shall be advised during the detailed design of the system.

In general, all control valves shall have end-position detection by limit switches and indication in the CCR. Modulating and inching valves shall have transmitters to indicate the valve position in the CCR, the measurement of which shall be taken directly from the actual valve position.

Valve actuators shall be directly mounted on the valves, as far as possible.

Enclosures with position transmitters and limit switches shall be provided with space heaters to maintain the temperature inside above the dew point.

#### 4.3.5.2 Motorized Valves

Motorized valves shall consist of self-contained actuator units with motor, gearbox, electric/electronic controls, limit/torque switches and all auxiliary devices installed in the actuator housing where ever possible. A local/remote selector switch with open/close controls shall be located on the actuator. The actuator shall be provided with a hand wheel for operation of the valve in an emergency. The operation of the hand wheel shall disengage the actuating motor to prevent damage during hand wheel operation.

Semiconductor power-electronic switches rather than contactors shall be used in the actuator for switching the motor supply.

Each end of the actuator travel shall be fitted with suitable limit and torque switches and correctly set up for preventing over travel and consequential damage to the actuator. The stopping of the operating mechanism on limit or torque switch shall be determined based on the specific application for which the valve is used.

#### 4.3.5.3 Pneumatic Actuators

Pneumatic actuators for On/off applications shall make use of a solenoid pilot valves where applicable. Where solenoids are used as pilot valves, the air supply shall be conditioned properly (i.e. conditioned through dryers to remove moisture).

#### 4.3.5.4 Solenoid Actuators

The solenoid actuators shall be of standard weather and water-proof type. The insulation of the coils shall be of class "H".

The solenoids shall have a manual testing facility with a tool or special key and also normal status indication to avoid misuse/ mal-operation and for trouble shooting purposes.

All solenoids shall be designed for continuous operation as applicable.

#### 4.3.5.5 Manual valves

Manually operated valves critical to the process shall be provided with end position limit switches for control & protection functions and indication in the CCR via the HMI.

#### 4.3.5.6 Motor Control Centers

Motor Control Centers (MCC) used for on/off control of pumps, fans etc. shall have a hardwired interface with the related control system. The MCC shall have the facility to select the point of control, i.e. local-MCC or remote-HMI, On/Off local controls, as well as local status indications.

MCC shall have the facility of padlocking in off position and shall be of the withdrawable mounted type. The draw out switching device shall be mounted on trucks or slide in chassis having adequate guidance by greased sliding rails and / or rollers. They shall be connected to the bus bars by means of a self-aligning plug and socket arrangements. Complete isolation of each circuit shall be attained by drawing out the switching device.

The main contacts shall have shutters which automatically close upon withdrawal of the switchgear. The withdrawal of large circuit breaker shall be facilitated by means of cranks, gears or other facilities.

The contact surfaces of the plugs and sockets shall be silver plated. The contacts shall be sufficiently strong to withstand maximum start circuit currents and carry continuously the rated currents without overheating. The withdrawable units shall have clearly marked service, test and isolated positions. Mechanical interlocks shall be provided to prevent withdrawal of units unless main circuit has been opened. Switchgear room shall be furnished with a switching unit transportation carriage, the height of which shall be adjustable to the different installation heights. Motor feeders shall be provided with overload and phase failure protection. All motor feeders shall be provided with manual ON/OFF facility, green colored indication for motor "STOP", red colored indication for motor "RUNNING", amber colored indication for fault indication and a Local/ Remote selector switch.

- A typical motor starter shall be equipped with:
- Isolator
- Contactor of required size
- Fuses of required size
- Overload relay with adjustable range
- Auxiliary relay for remote control
- Fuse for control circuit
- Position indicators

The interface between the MCC and the control system shall be standardized. This shall include on/off command inputs to the MCC and on/off/unavailable/fault feedback signals to the control system. The command inputs to the MCC shall be electrically rated to allow a direct connection (i.e. without the use of external interposing relays) with the controller binary output module.

Segregation of cabling and binary I/O modules shall be provided for duty/standby modes of pumps and fans.

## 4.4 Plant Control and Supervisory System

### 4.4.1 General Requirement

The control, monitoring, protection and information management functions for the power plant shall be carried out by an overall Distributed Control System (DCS). The offered Distributed Control System shall be based on latest generation of microprocessors having proven in similar power plants in the last 03 years as far as the system family is concerned.

The remote control and automation concept shall be adapted such that the Gas Turbines are capable of fully managing and supervising from the Central Operating Desk in the Central Control Room.

At the plant end of the DCS, real time process data shall be acquired using plant-mounted instrumentation and sent to I/O subsystems that are located either locally or remotely. In the case of local I/O, the subsystem shall be designed to tolerate the plant environment in which it is operating.

The I/O sub-systems shall transmit the plant data using suitable data links to controllers that are either physically distributed around the plant or located at a centralized equipment room with functional segregation, for data processing and execution of sequence logic and modulating control algorithms. Depending on the application and the implementation philosophy, a controller and its I/O system may be part of the "native" DCS family, a high integrity fault tolerant version of the DCS (e.g. turbine control/protection system) or a stand-alone dedicated system.

Each Gas Turbine control and protection system shall be a stand-alone system and shall be of the "native" DCS family. This stand-alone system shall be located in a local control cubicle preferably and shall be connected to the DCS through process network as per the expected Basic System architecture for DCS is shown in Appendix E3.

A separate controller for Electrical controls shall be provided.

The controllers shall communicate with each other and the Human Machine Interface (HMI) part of the DCS to send/receive data, command and feedback. This shall be achieved using a dual redundant communication network, with the HMI and the controllers from the DCS family interfacing seamlessly to the communication network while the "foreign" controllers shall interface to the network using gateways or protocol converters as necessary.

The DCS HMI shall provide a fully integrated control, monitoring and alarm facility to the plant operator with a view to optimize the visibility and controllability of the process and minimize operator manning levels. In addition, local control and monitoring facilities shall be provided where appropriate for use during normal operation, maintenance and commissioning. The DCS and local controls shall be designed such that it shall not be possible to operate any item of plant from both remote and local points simultaneously.

The HMI workstations for plant supervisory and control shall be located at the Central Control Room (CCR). Local workstations for each gas turbine unit shall be provided having HMI and engineering (programming and diagnostic) facilities. All HMI related components other than the Operating workstations (OWS) shall be preferably located at a Central Engineering Room. Programming and diagnostic center (System Engineer's workstation) in the Central Engineering Room shall provide all equipment/software necessary for system programming/ configuration, system failure detection, trouble shooting and etc.



### 4.4.2 Functional Requirements of Plant Control and Supervisory System

The DCS shall provide but not limited to the following functions:

- Allow fully automatic unit operation including unit start, synchronization, loading to target set point as applicable and shut-down under safe and controlled conditions to achieve optimum startup / loading / de-loading / shutdown times.
- Provide a hierarchy of automation allowing the sequencing of a set of automatic actions relating to a plant item (function group) to sequencing a set of function groups for higher level automation and optimized operation of the plant.

- Operator's intervention from the Central Control Room (CCR) shall be possible on each individual hierarchical level of control from single drive up to group and block controls. In case of any failure of higher levels of the system, operation on the lower levels shall be possible to a considerable extent without any interruption of plant services.

- Turbine speed-load control by governor and generator voltage control by AVR.

- Automatic synchronization facility of GCB and 132 kV CB shall be provided remotely at CCR and locally at local control cubicle.

- Manual synchronization facility of GCB and 132 kV CB shall only be provided at respective local control cubicles.

- Facility of dead bus closure of GCB and 132 kV CB shall only be provided manually at respective local control cubicles with appropriate safety interlocks. The selector switches off/test/man/auto for the automatic synchronizer shall be provided at the local control cubicle.

- Perform modulating control functions to maintain the operating parameters of the power plant (e.g. real power, reactive power) as well as parameters of its various sub-systems within acceptable limits of their set points

- Provide a load management function for the coordinated control and load sharing of all units.

- Co-ordinate protection and emergency trip functions relating to various items of plant provide an integrated HMI for the whole power plant from the CCR and integrate stand-alone control and protection systems of the power plant to provide supervisory monitoring and high level control of these plant items via the operator HMI located in the CCR.

- Provide an extensive supervision and control facility for electrical systems of the power plant from the CCR.

- Provide plant alarm monitoring and interlocking functions.

- The arrangement of the DCS system shall be such that the mimic controls, indications and alarms shall be integrated into the DCS system and the total functionality of the plant control cannot be affected even during a failure of DCS HMI (SCADA terminal).

- Provide a unified plant data logging facility with accurate time stamping to a common time reference to produce accurate sequence of events logs, other events and plant data trends.

- Provide efficient facilities for plant data archiving and retrieval of historical data.

- Provide adequate diagnostic facilities for maintaining and trouble-shooting the control and monitoring systems

- The high-level plant management sub-systems of the DCS such as the plant historian shall interface with the DCS communication network to extract plant data. These sub-systems shall communicate within the DCS in such a way that the real time operation of the DCS is unaffected.

- External third party control systems (e.g. CEB NSCC SCADA system for on-line load dispatch and remote monitoring, third party vibration monitoring system) shall be interfaced to the DCS by suitable means (e.g. hardwired, communication link) for data exchange to allow high level cross-monitoring and power station overall control functions.

- The DCS shall also interface with the power station administrative Local Area Network (LAN) via its communication network and gateway server protected by suitable firewalls for transfer of plant data to high level plant management and reporting applications which will later be installed in the power plant administrative computer systems.

- Contribute to the safety of personnel and equipment under all plant operating conditions.

- Maximize the availability and efficiency of the plant.

- Enable the plant to be operated and maintained with the minimum of appropriate personnel consistent with cost effectiveness and safety first priority given to the local controls

- Capable of operating all gas turbines with a joint load reference set point to control all gas turbine generator units sharing the block load (100~130MW) in regulating the grid frequency.

- Allow Primary frequency control mode, Grid frequency control mode, response to NSCC AGC commands, isochronous mode of operation, black start facility and retaining facility at FSNL during unavailability of 132kV supply.

### 4.4.3 System Design

#### 4.4.3.1 General Design Requirements

The control hardware of the plant control and supervisory system shall consist of control processors, I/O modules, communication modules and communication networks. The control processors shall be capable of executing multiple modulating control and logic sequences in a time shared arrangement within the processor and shall have the power to meet the sampling frequency requirements of the control algorithms dictated by the process. The I/O system shall be functionally and geographically distributed as required. The system shall be resilient to environmental conditions and external disturbances (electrical noises, EM fields, lightning, walkie-talkies, radiation, temp etc.) that it can be subjected to.

The gas turbine control & protection systems and electrical distribution control & protection system shall have sufficient redundancy in terms of processing channels, field devices, I/O voting systems and power supply such that no single failure in the I&C systems can cause a forced outage of the unit. The power supply for the I&C systems shall be from a secure source (UPS AC system or battery DC system).

The control system hardware shall contain standard cards/ modules of a limited number as far as type and variety are concerned. All cards/ modules shall have multiple functions according to the task to be fulfilled and shall contain:

**4.4.1.1.1** The necessary hardware (microprocessors, storage elements, converters, etc.)

**4.4.1.1.2** the software (firmware and user specific application programs)

The variation of functions shall be possible by software modifications without changing hardware components.

As far as the system and the components are concerned, internal safe design shall be applied. It means that no failure of system elements, on-line change of external influences (short-circuits, wire break, noises, etc.) will cause erroneous operation or deterioration on any hardware or software system. The circuitries shall be protected against interactions between cards and systems (e.g. galvanic isolation).

The system shall have extensive diagnostic facilities to facilitate trouble-shooting and maintenance operations. All failures, anomalies and missing functions shall be automatically detected by the system itself and alarm shall be given to the diagnostic station in clear text, showing the exact origin and the kind of failure. This auto-diagnostic system is required for every card, module, peripheral, etc. belonging to the system. The failure has to be annunciated also at the concerned equipment (e.g. LED on the front plate of cards, modules, for easy identification) and announced in the control room (e.g. by group alarms). A “hot replacement” facility shall be available for all redundant hardware without affecting the operation of the overall system.

#### 4.4.3.2 Process Control Components

For I/O modules, following requirements shall be applied:

- Distinct input modules will serve as interfaces between process signals and the digital system and will accomplish the signal conditioning for analogue signals from analogue transmitters with 4-20 mA output, thermocouples, RTDs, Impulse signals (counting) and etc. and for binary signals from local switches, proximity switches, and etc.
- High insensibility against noises and other disturbance signals
- Intrinsically safe input circuits, where required.
- High insensibility against over voltages (as per relevant IEC standard)
- High accuracy of conversion for analogue modules (resolution minimum15 bits without prefix signal). Deviation from this shall be subjected to the approval of the Employer

- Supervision of analogue signals verification against limiting values
- Linearization of thermocouple and resistance thermometer signals
- Reference-correction facilities for thermocouples/ temperature compensation for thermocouples.
- Connection of 3 or 4 wire RTD measuring devices
- Supply of transmitters via galvanic isolation and supervised fusing for each transmitter circuit.
- Analogue output signal 4 to 20mA or 0V DC to 10 V DC or 1 V DC to 5 V DC (if necessary)
- Supply of external contacts with voltage generated by the system itself where necessary
- Contact chattering protection
- Input circuit supervision (short-circuit, wire-break and ground fault detection)
- Supervised fusing for binary input circuits
- The interposing relays for the process shall be part of the I/O system
- Fully installed and wired spare I/O shall be a minimum of 20% for each type of I/O. Provision for future expansion of the I/O by 20% by installing additional modules in the I/O racks shall also be given.

For Control Processors, following requirements shall be applied:

- Time stamping of scanned data shall be done as close to the field as possible and shall make use of a master real time clock reference for the whole system derived from the station master clock system.
- The control processors shall have data communication modules that allow the interfacing of "foreign" systems which are not part of the main control system family by acting as gateways or protocol converters.
- The loading of a control processor shall not be greater than 40% on average with peak load within 65% of its capacity. The memory usage of a control processor shall be within 50% of what is provided.

For communication networks, following requirements shall be applied:

- For information network a modern internationally accepted communication protocol shall be used to exchange data. IEC60870-5 series or latest IEC standard network protocol is most preferred.
- The control processors shall communicate with each other and the HMI via a dual redundant fault tolerant communications network. The network shall have sufficient bandwidth to handle the worst case data traffic under transient conditions of the plant without a noticeable reduction in the speed of response of the control system and the operator HMI.

- Adequate fault detection of the network, data error detection and correction facilities shall be provided as part of the basic design of the communication network. It is necessary to make available all information of the system at each point of the network.
- The loading of the communication network shall be within 40% of its capacity during normal conditions and not greater than 65% under abnormal plant conditions.

**4.4.3.3 Proprietary/ Stand-alone Plant Control**

Contractor's design may include packaged plant that include integrated control systems. It is accepted that such systems may be included for a variety of reasons.

These reasons may include:

- Safety critical functions that rely on high-speed response to process variables
- Systems where performance and functional guarantees (and subsequent warranties) are dependent on the use of the package control system
- Geographical location of the auxiliary plant making it more appropriate to treat such areas as stand-alone systems with dedicated control, monitoring and protection equipment without adverse impact on reliability, availability and safe operation of the plant as a whole.

Where the use of such systems is accepted, the packaged control system shall, nonetheless, comply with all other requirements of this specification. Such systems shall maintain the principles of redundancy, reliability and availability. The Contractor shall make every effort possible to standardize I&C equipment used (e.g. type of Controllers, process transmitters etc.) in these systems to minimize operator/maintenance personnel training and spare parts requirements.

Where employed, these proprietary control systems shall interface with the DCS such that high level control and supervisory monitoring facilities for these items of plant are available through the DCS HMI located in the CCR. The method of signal exchange with the DCS for foreign controllers and the signal exchange lists shall be agreed with the Employer during detailed design. Local control and monitoring facilities shall however be provided for these systems for use during commissioning, maintenance and operations.

**4.4.3.4 Dedicated/stand-alone controllers and their operator interface**

The control, sequencing and protection functions for certain plant items, e.g. fire protection system, Emergency Diesel Generator Units etc. are generally implemented in dedicated control/protection systems. These systems shall have a local operating facility for commissioning and maintenance purposes, however their normal operator interface shall be via the DCS HMIs located in the central control room (CCR) thereby achieving a single coordinated plant interface. Some simple systems due to their robust nature and minimal impact on overall availability and reliability may be provided only with local controls with the approval of the Employer.

#### 4.4.3.5 Electrical system control

The control, monitoring, alarm and protection equipment required for generators, transformers, HV/MV/LV switchgear etc. which form part of the electrical systems of the power plant are described in the part of the specification dealing with electrical equipment. This section however focuses on the interface requirements of these systems with the DCS for the overall control and monitoring of the power plant via the DCS HMI located in the CCR.

Interfaces with control, monitoring, alarm and protection systems associated with the generator (e.g. Automatic Voltage Regulator, excitation system, generator protection system, synchronizing equipment etc.), HV circuit breakers/disconnectors /earth switches and power transformers (e.g. tap changer, transformer protection equipment) shall be established with the DCS. The interface design shall be such that reliable remote operation and supervision from the CCR is achieved for these electrical systems. The interface philosophy shall be to hardwire all critical signals to the DCS and use proper communication links to transfer non-critical data.

All electrical distribution switchboards of the power station with the exception of sub-distribution panels/cubicles for minor loads shall be monitored and controlled via the DCS from the CCR. This shall include status, data and alarms associated with these switchboards including those for all the incoming and outgoing feeders, isolators, bus couplers, earth switches and transformers. Suitable devices, e.g. current/voltage transformers, transducers, auxiliary contacts etc. shall be provided at these switchboards for this purpose. Critical interfaces (e.g. open/close commands and breaker status feedback) between the switchboards and DCS shall be hardwired as a minimum for security purposes, while the non-critical data may be monitored using dual redundant suitable communication links between the switchgear and the DCS.

Miniature circuit- breakers with two sets of auxiliary contacts, one for automatic protection, and the other one for intentional switch-off shall be provided and selectively alarmed.

For each distribution bus, a voltage supervision with alarm in the control room shall be provided.

The main concern shall be to minimize the risk of failure, and in case of abnormal condition, to minimize the damage and to facilitate the detection of failure.

#### 4.4.3.6 Requirements of safety instrumented shutdown systems

Safety Instrumented Systems (SIS) shall be supplied where necessary to prevent danger to personnel and damage to plant by initiating an automatic emergency shutdown (ESD) operation on detection of an unsafe operating condition of the plant. It is a mandatory requirement that adequate safety integrity is engineered into the overall plant and equipment in accordance with IEC 61508 and IEC 61511.

The SIS design shall include two stages in its design process, viz. Safety Integrity Level (SIL) selection and SIL validation. The SIL selection includes the definition of a target SIL when undertaking a Preliminary Hazards Analysis (PHA) or a formal Hazards and Operability (HAZOP) study of the various sub-systems of the plant. The SIL selection shall be done by one of the standard techniques currently used in the industry, e.g. Risk Graph method.

The SIL validation initially includes a description of the design approach taken to achieve the target SIL for the identified sub-systems, followed by calculations to prove that the target SIL has been achieved. A Cause and Effect diagram shall also be produced by the Contractor to support the design of the SIS.

The functional safety which is being engineered into the system shall be documented for all Safety Instrumented Systems (e.g. Gas turbine emergency trip and protection systems, fuel shut-off system) in terms of both the target SIL and the design approach offered to meet this target for each sub-system. This documentation shall also show how the overall functional safety in terms of the SIL shall be assessed. This shall take on board the plant measurements, the associated cabling, data networks if used, the logic which acts on the measurement data, and the control/shut-off valves or other control elements which shall put the plant into a safe condition.

The redundancy of the electronic system shall be at least of two channel design. Internal on line self-checking routines shall be used on both channels.

The turbine protection system shall be a triple redundant with 2 out of 3 selections and online supervision of the channels.

For protection purposes normally closed (NC) contacts and de-energies to trip philosophy shall be used.

High level monitoring of these shutdown systems shall be organized via the DCS so that the status of these systems can be presented on the operator screens for monitoring from the CCR. Where special high integrity controllers with certified SIL rating are available in the DCS family, they may be considered for emergency shutdown functions as long as they are engineered as independent nodes of the DCS with the DCS communication network being used only for high level monitoring from the CCR.

Emergency trip push buttons for individual Gas turbine units shall be provided in CCR, local control cubicles and suitable locations in the field.

### 4.4.4 Operator Stations in Control Room and Central Functions

#### 4.4.4.1 General Requirements

The expected Basic DCS Architecture is shown in Appendix E3. However, the final design shall deviate from this and it is subjected to the approval of the Employer.

The CCR HMI workstation shall consist of its processing unit, dual headed 24", high resolution LED VDUs, keyboard and mouse.

The workstations shall be connected to both networks of the redundant communication network. Network switches which enable the connection of the workstations and peripherals to the communication network shall be intelligent/ managed to optimize network traffic.

Printers of the laser jet type (colour and black & white with A4/A3 printing facility) shall be provided in the CCR for printing alarm/event logs (on request), reports, trends and screen copies. Sufficient quantities of workstations, printers, switches etc. shall be provided to maximize the availability of the HMI. At least three (03) numbers of Operator workstations (OWS) shall be provided for Central Control Room.

The local operator stations shall consist with 17" LED VDUs, keyboard, mouse and hardware required for monitoring and maintenance.

An engineering (Programming and Diagnostic) facility via System Engineer's workstation with desks shall be provided for modifications to the control system configuration, screen graphics and application software as well as to run diagnostics. This facility shall include password protected workstations with high resolution VDU. Also this engineering workstation shall have the facility of online monitoring of the control logics of the power plant.

The HMI workstations shall be based on an Operating System (OS) which is rugged, user-friendly and has been field-proven for continuous use in industrial applications (Microsoft Windows OS such as windows 10 or latest is preferred).The bidder shall describe in his bid the recommended methodology and the provisions made in the workstations to prevent the inadvertent entry of computer viruses into the DCS via data transfer facilities such as Compact Disk (CD/DVD) drives and Universal Serial Bus (USB) ports that are available in the workstations.

Computers for HMI workstations, System Engineer's workstation, Historian servers, Control Servers shall be from reputed manufacturers such as hp, Dell, Compaq or equivalent. LED VDU's shall be from reputed brand names such as Dell, hp or equivalent. Contractor shall select latest computers and other peripheral devices available in the market at the time of designing the plant which will be suitable for his system. The Central processing units shall be of Intel core i7-7th generation or latest for such computers. These shall be high speed machines specially designed to work in a critical environment requiring intensive calculations, data processing and handling.

The control desks for locating the DCS HMI workstations in the CCR shall be ergonomically arranged consistent with the plant operating philosophy. The arrangement shall be suitable for plant control and monitoring by the minimum number of operators with the possibility of access to workstations by more operators for special operations.

All CCR equipment including workstations, printers, network switches etc. shall be powered from plant UPS source.

The Central Control Room shall have a false floor to enable easy routing of I&C, communication and power cables to the various workstations, computer peripherals etc.

Local control cubicles shall have 2x100% duty air conditioning facility.

All CCR furniture including control desks, fully adjustable swivel chairs, printer desks, document storage facilities, etc. shall be supplied and fully colour coordinated with the rest of the CCR.contr

An architectural drawing of the offered DCS HMI showing the number of workstations, peripherals, network switches etc. included in the offer as well as the grouping and connections of these devices shall be submitted with the bid. A drawing which shows the proposed layout and locations of equipment and furniture within the CCR and Central Engineering Room shall also be provided with the bid submission.

#### 4.4.4.2 Control and HMI software

The software for the control processors and I/O systems shall be engineered using a library of standardized function blocks covering an extensive range of binary logic functions and continuous-time signal processing / control functions derived for sampled data systems. A detailed description of all function blocks in the library shall be supplied as part of the Operating and Maintenance (O&M) manuals. The software design shall comply with the requirements of IEC61131-3. It shall be possible to modify the controller presets (e.g. gains, time constants, limits etc.) and implement minor logic changes on-line via the System Engineer's workstation. Internal variables of the control logic shall be dynamically visible using the System Engineer's workstation for testing and trouble-shooting purposes. Software licenses for unrestricted use by the Employer shall be supplied for all packages required for operation, diagnostics and reconfiguration of the system.

Following operator levels shall be included in the operator workstations with separate password protected user accounts.

| | | |
|---|---|---|
| Engineer | – | Administrator rights |
| Operator | – | Operator rights |
| Monitor | – | Only for monitoring the system |

The HMI application software shall be fully developed when installed at site and tested rigorously before plant commissioning. This shall include graphic displays, function group sequence displays, tabular displays, diagnostic displays, databases, alarms, trends and reports to operate and manage the power plant in a safe and efficient manner. The execution of the function groups (sequence logic) implemented in the system shall be fully visible to the operator in terms of status, interlocks and permissive which affect the various steps of the sequence. Sequence logic shall mainly consist of main operations such as Standstill, Unit starting, shutting down, Line operation, black start facility, grid frequency control, AGC mode, isochronous mode of operation and retaining at FSNL during 132kV connection failure. Their implementation shall be flexible enough for the operator to intervene at any point where-ever possible for any manual operation and restart the sequence from the point where it was halted. In case of failure or interrupting the execution of sequence logic it shall be possible to identify the missing or faulty conditions by following a link from each step. It shall be possible to develop additional HMI screens (mimics) and modify existing ones on-line without affecting the operation of the plant. Software licenses for unrestricted use by the Employer shall be supplied for the HMI operating system, its application software and associated tools.

#### 4.4.4.3 HMI screen layout

Plant systems shall be represented graphically on the DCS HMI in a format that mimics the plant Piping & Instrumentation Diagrams (P&IDs) and/or the Single Line Diagrams (SLDs). Symbols used for the representation of devices shall be complied with recognized industry standard. Colours used for the representation of process piping and electrical system bus bars shall conform to the global plant colour scheme and shall be unique to each discrete system.

A dedicated area on the top of the screen shall show the designation of the power plant and the unit concerned.

Screen layout shall be designed to optimize the efficiency of data display. Ideally, any given system shall be displayed on one screen. However, it is recognized that some systems are too complex to achieve this requirement. In these instances, clearly identified and logical links shall be made between the pages that make up the complete system for easy navigation between screens. In all instances, where the operator passes from one screen to another, it shall be possible to return directly back to the previously viewed screen. At least last three alarms shall be displayed in every display screen.

The main or highest level DCS screen (mimic) shall represent, in as simple a manner as possible, the entire plant and give the operator the main control parameters, such as power out, fuel flow, fuel pressure, terminal volts, etc. It shall be possible to reach any sub-system screen from the main screen by following as few links as possible. The navigation facility provided shall be simple and unambiguous to the plant operator.

Each analogue value shall be numbered with its proper accuracy and floating point showing also the engineering units. All display components shall be provided with identification codes according to the agreed Plant Identification System.

Each operator workstation VDU shall show at least following sections separately and shall be menu selectable.

- Overall coordinated Power output of the whole plant
- Single line electrical diagram for the power plant
- Gas Turbine and Generator section for each unit
- LV/MV/HV switchgear section
- Emergency and Black Start Diesel generator section
- Duty/ standby pump/fan selection
- Separate screens for Diesel fuel system and RLNG system
- Turbine auxiliary system of Gas Turbine units
- Turbine supervisory system
- Alarm/event section
- Common auxiliary system
- Sequence control section
- Screen for Primary frequency mode selection and related indications
- Screen for synchronous condenser mode selection and related indications
- Screen for controls for NSCC AGC mode and related indications

Above VDU graphic screens shall be designed as much as possible user friendly to the operators and they shall be subjected to the approval of Employer. Also they shall accommodate all necessary sub graphic screens for effective control and monitoring of the power plant.

#### 4.4.4.4Special Tasks of Operator Interface

The plant monitoring/ control system shall support the operator with proper monitoring when executing special tasks like system startup and etc.

By this task the operator shall follow-up logic sequences and monitor the control loop.

Before starting, the operator may ask for initial criteria and shall get a summarized list of operating instructions and a check list of starting criteria to be fulfilled. Missing criteria and not fulfilled steps shall be pointed out allowing the operator to carry out the necessary steps to fulfill all criteria required for starting.

During start-up, the operator shall get all necessary information from sequence synoptic such as Logical steps, time exceeded, missing criteria list, executed steps of the sequence, not yet executed steps of the sequence and end of sequence.

Through the operator Interface, lists of variables with plant identification numbers, description, current acquisition value or parameter, etc. shall be visible with various filtering options. Filtering options for variables shall be sub system, plant identification codes, type of variable, depending on the scan mode, alarm state and etc.

#### 4.4.4.5 Alarm and event management

The alarm philosophy shall be such that alarms shall only be generated where the condition requires operator attention to prevent plant damage, reduction of plant life, loss of efficiency, loss of availability or other abnormal conditions.

Alarms shall be initiated by means of:

- Position or limit switches
- Pressure, temperature, level or flow switches
- Protection relays
- Fuses and miniature circuit breakers
- Auxiliary contacts of switchgears, breakers, and etc.
- Electronic limit value monitors
- HMI software based on operational values at a given moment or generated by programmed digital system itself as far as internal failures (system alarms) are concerned

All fusing and miniature circuit breaker for I&C items shall be included in the alarm system so that any MCB trip will be annunciated. These alarms shall be combined to a group alarm per cubicle or switchboard. The grouping of alarms shall be carried out in such a way that identification of an announced fault within the respective group is easy.

There shall be several levels of priority assignable to the plant and system generated alarms. All alarms shall be displayed on the alarm screen of the HMI, logged in chronological order and stored for future analysis. The listing up of alarms and events shall be done showing, the precise date and time with the required resolution, plant identification code, clear text/ denomination of alarms and events, status message (open, close, off, high, low), in case of high/low alarms the actual value derived from the analogue value.

A small alarm window capable of displaying the last few alarms (typically 3) shall be provided as a permanent window in all operator screens. The occurrence of an alarm shall initiate a visual and audible warning on the operator workstation. Alarm acknowledgement facilities shall be provided. Alarms shall be printed on demand. Facility to silence audible warning shall be provided.

Intelligent alarm filtering shall be employed. There shall be adequate facilities for alarm filtering on the basis of priority, sub-system, time window etc. as well as a combination of these filtering criteria.

Provisions shall be made in order to minimize the occurrence of nuisance alarms and to keep selected alarms in off monitoring state by operator intervention whenever necessary.

Differentiation between alarms and events shall be done by colour coding. Further differentiation of alarms according to the degree of urgency shall also be done with different colour coding.

All process related events and operator actions affecting the process shall be logged in the system and stored for future reference. Events shall be printed on demand.

#### 4.4.4.6 Data logging and trending

All plant/equipment data shall be logged in the DCS. The data shall include analogue and binary signals whether hardwired or received via communication links, alarms & sequence of events, operator actions and internally generated relevant data. The data shall be stored in a redundant system memory (i.e. redundant Historian servers) for a pre-defined period of time (not less than three months) and automatically transferred to a networked archiving medium (magnetic) for long storage.

The HMI shall provide the facility to trend the plant data obtained in real time or retrieved from logger memory or archives in a graphical form on the screen with respect to time including zooming facility of trends. The Contractor shall set up a number of trend displays with various combinations of critical process variables for use by the operator.

It shall be possible to obtain minimum, maximum, average and slope of a selected period of a data trend. Possibility to export stored sampled data in excel or csv format shall be provided.

#### 4.4.4.7 System overall performance

Real time plant data shall be presented on the HMI screens with a maximum refresh period of 1 second. This requirement applies to both data and alarms displayed symbolically (shape changes, colour changes, flashing etc.) and alpha-numerically.

System time shall be GPS synchronized. GPS antennas for this purpose shall be installed by the contractor at suitable locations.

Commands issued from the operator HMI shall be applied to the final control elements of the plant within one second of it being issued from the HMI inputting device.

The sampling of plant data for modulating control and execution of the control algorithm shall be at a rate chosen to match the dynamic response of the process to be controlled. The

DCS shall have sufficient processing power to ensure an execution period of 100 ms or better for control algorithms associated with fast-acting processes.

Further to above, the following performance shall be guaranteed for the plant control and supervisory system:

- Better than 1 ms resolution time for alarms and events. For signals with the same time tag the sequence shall be correct
- Less than 500 ms cycle-time for normal closed loop controls
- 100 ms or better execution period for fast acting control processes
- interrupt for open loop controls
- 1 s of HMI refresh rate
- 1 s to get a synoptic (mimic diagram) on the display upon operator's request
- 1 to 1.5s to get the confirmations on the display upon operator's command from the keyboard/display/mimic.
- Sequence of events time tagged with less than 1 ms resolution
- Less than 20 ms response for protection functions
- 250 ms or less refresh rate for data trends on HMI

#### 4.4.4.8 Reports and Logs

For plant follow-up and off-line analysis different kinds of logs shall be available. The following kind of logs shall be automatically generated. These reports shall be of pre-defined format to the approval of the Employer. Further required report formats will be decided at the design and commissioning stages.

**Event and Alarm Log:**

This shall contain all alarms and events in chronological order, giving the following data;

- Exact time (with the specified resolution)
- Identification code
- Denomination of item in clear-text
- Attribution (high, low, open, close, etc.)
- The actual value in case of alarms derived from analogue values

**Disturbance Log:**

This log shall be configured for important plant items. When one of the designated major plant events occurs, its Disturbance record with events captured in its pre-trigger and post-trigger windows shall be stored in chronological order in the DCS for future analysis. It shall be possible to adjust the duration of the pre-trigger and post-trigger windows of the Disturbance record. The system shall have the facility to store a pre-defined number of Disturbance records. The Disturbance records shall be printed on demand.

**Sequence of Events Log:**

This facility shall be provided as part of the DCS to record the events leading up to and following major plant events (e.g. changeover of pumps, tripping of major items of plant and etc.) and accurately determining the first cause of the major event. The inputs to be monitored for the Sequence of Events (SOE) log and the major plant events that trigger the recording shall be scanned continuously and their state change time stamped with an accuracy of 1 ms. The time stamping reference shall be obtained from the master clock of the DCS so that events recorded by the various I/O systems of the DCS can be sorted in the correct sequence in time.

**Periodical plant data Log:**

This log shall be configured for important plant parameters to be logged periodically. A facility shall be provided to automatically generate the reports at hourly, per shift, daily, weekly, monthly and yearly intervals or on request.

**Balance of Energy Log:**

This log shall be configured to get the individual total energy of each gas turbine unit, total mass fuel flows of relevant gas turbine unit at the end of each day, month, yearly or on demand.

**Maintenance Log:**

This log shall be configured to get a list of the main components that have reached or will soon reach the limit of a prefixed maintenance period. This log shall be generated periodically, at the end of each day, month, or on demand.

**Performance Calculation Log:**

Upon operator's request and periodically, different performance calculation logs shall be generated. These calculations shall include efficiencies, heat rates, fuel consumptions, periodical integrated values, maximum load, minimum load, average load, maximum & minimum reactive power produced etc. of individual gas turbine units.

**Binary/ Analogue Status log:**

Status of all analogue and digital inputs and commands for the whole unit or for prefixed groups shall be arranged in to a report upon operator request with the plant identification code numbers.

**Scan remove (off-scan) log:**

On operator demand, the list of all measuring points disturbed, simulated or removed from the scanning shall be provided.

**Counters Log:**

This log shall be configured to get a list of the main components of which the start-up/ shutdown counters and operating hour counters have to be monitored (e.g. motors, actuators, circuit breakers, turbine and etc.). The list shall indicate the cumulative start-up/ shutdown counter and operating hour counter of individual component. In case of this system restoration, the facility to initialize these values with the last accumulated values shall be provided. This log shall be generated at the end of each day or on demand.

### 4.4.4.9 Station Clock system

A master clock shall be supplied as part of the station clock system to provide a common time reference for the whole power station. It shall be referenced to a GPS signal.

The master clock shall provide real time reference to the DCS and all other plant control, monitoring and protection systems by suitable interfaces capable of achieving time synchronization among these systems for their data acquisition and logging activities.

Station clocks shall be supplied and installed at various locations of the power station. One big size clock shall be mounted on the turbine hall if the offered Gas turbine units are not of packaged type but installed together in a turbine hall. If the offered gas turbine units are of packaged type, dedicated station clocks shall be provided inside each control cabinet. The exact quantity, locations and architectural design of the clocks will be finalized during the detailed design stage, however, a reasonable provision for a typical power station shall be included for this item in the Contract. A large alphanumeric display showing hours, minutes and seconds shall be installed in the CCR for indicating the local time. The station clocks and the digital display shall be driven from the master clock.

The contractor shall establish a list of recommended spare parts for the operation of clock system over a period of at least 10 years.

### 4.4.4.10 Interconnection to National System Control Centre (NSCC)

#### 4.4.4.10.1 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.

The National System Control Centre shall be informed about the general plant status for monitoring and control purposes. NSCC shall monitor and provide the active/reactive power scheduling, controlling and load dispatching functions for the generating plants.

For the purpose of power plant integration with National System Control Center, the necessary SCADA signals shall be made available through a suitable SCADA gateway system specified below. The required SCADA signal list for one gas turbine generator and generator transformer unit is attached as Appendix K. If required there shall be a possibility to configure additional signals to be exchanged with NSCC.

In case of any failure in the communication link with NSCC, the operator shall be notified through alarms about the communication failure.

#### 4.4.4.10.2 Master Station at National System Control Center – Sri Jayewardenepura

The Master Station equipment will be a dual SCADA/EMS server system "e-terra habitat", based on Linux operating system supplied by M/s. GE T & D India Ltd.

The system will consist of;

**Dual SCADA/EMS servers**

Hardware: HP DL 560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Dual Application Servers**

Hardware: HP DL 560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Dual FEP Servers**

Hardware: HP DL 560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Historical Data Server**

Hardware: HP DL560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Dual Application Server**

Hardware: HP DL560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Dual ICCP Server**

Hardware: HP DL560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**OTS Server**

Hardware: HP DL560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Web Server**

Hardware: HP DL560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**Patch Management Server**

Hardware: HP DL560 Gen9 Server/500GB-SATA HDD/4 GB RAM.

**(a) Stations with IEC 60870-5-101 (Not Applicable)**

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 four numbers parallel IEC 104 SCADA rings established via Fiber Optic Multiplexer network).

### 4.4.4.10.3 Scope of Supply of SCADA and Communication Equipment SCADA Gateways

**a) SCADA Data Schedules- Circuit Data**

**SCADA Gateways**

SCADA gateway as per clause "7.4.4.10 of Technical Specification – "SCADA SYSTEM EQUIPMENT AND DEVICES".

Gateway System Comprising:

- 02 Nos. Gateway Computers with redundancy
- 01 No. Separate Software Access Keys (Separate Dongle/License key) shall be provided
- 01 No Spare Modules for each interfaces and cables and Accessories
- 01 No Laptop/Software tool to access the Gateway computer, for maintenance purposes.

If any license or software is required for add new signals or change the database they should be provided.

**Communication Ports**

- 02 Nos. RS 232(V.24/V.28) serial ports
- 02 Nos. 10/100Mbps Ethernet Ports (electrical)

All these ports should not be built in a single interface module. There should be separate interface modules for these ports for redundancy purposes. All the ports should be surge protected.

**Required SCADA**

All Analog Measurements, Station Controls, Events and Alarms shall be made available as per IEC 60870 – 5 – 104 protocol for integration and configuration to the National System Control Center. Provisions for IEC 60870-5-101 shall be available in the provided gateway. The communication interfaces shall be configured as per the requirement of Employer. The SCADA signal list is attached in Appendix-K. The integrated signals shall be tested up to the NSCC by the contractor

Provision shall also be made available in the gateway for communicating with Master station at Regional Control Center in future.

**For establishing the communication link with NSCC following items shall be provided.**

- A fiber optic cable (at least 8 cores) shall be drawn from the new gateway to the FOX 515 Fiber optic multiplexer at Kelanitissa 132 kV GSS for intergrading the SCADA signals with NSCC
- An outdoor multicore (at least 10 nos. pairs) copper cable shall be drawn from control room to the FOX 515 Fiber optic multiplexer at Kelanitissa 132 kV GSS for providing operational telephone facilities.

### 4.4.4.10.4 Remote Terminal Units (RTU) and SCADA Gateways

**(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 National System Control Center. The RTU/Gateway also should communicate with the Regional Control Center in future.

The RTU/Gateway should be powered by dual power supplies for redundant power arrangement. Separate MCBs shall be mounted on the RTU/Gateway panel and it should be clearly marked below the particular MCB.

**(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**

v. Two Nos. of Gateway units.

vi. Two Nos. of IEC 101 output ports and Four Nos. of IEC 104 output ports for the Gateway (Two ports for System Control Centre and two ports for Regional control Centre including redundancy)

**(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. Modules of the RTU should be easily Replace/Add to minimize the outage time. RTU should be able to get IEC-61850 protocol signals and send the required signals to NSCC via IEC 101 and 104. If any license is required for interfacing IEC-61850 signals, it should be provided even IEC – 61850 signals are not available in the station. 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 centers via IEC60870-5-101 and IEC60870-5-104. . If any license or software is required for add new signals or change the database in any format (hardware wiring/IEC-61850) they should be provided.

**(b) Gateways**

The gateways shall be an industrial grade computer with redundant, uninterruptable power supply units.PC based gateways which contains moving parts will not be accepted. The gateways should be designed for a life of 20 years. The gateways shall communicate with remote control centres via IEC60870-5-101 and IEC60870-5-104. If any license or software is required for add new signals or change the database they should be provided.

Each gateway should comprise with,

- Dual Power Supplies
- Two Nos. of RS232 ports configured for IEC 60870 – 5 – 101 communications.
- Four nos. of RJ45 ports configured for IEC 60870 – 5 – 104 communications.
- All the SCADA communicating ports shall be separately work from each other, this mean, if the gateway has IEC 60870 –5–101/104 communications, all the ports should

not be built in same interface. There should have separate interfaces as redundant interface.

- All the ports shall be wired through surge arrestors/surge protecting device.
- Separate Ethernet interfaces(RJ45) for logging to the gateway directly for configuration and maintenance purposes
- Separate user login shall be configured to access remotely via Engineering PCs or SAS computer

**(4) Gateway Functionality**

The gateway system should work as Hot-Standby mode. If any failure of Hot machine, without any time delay, standby machine shall pickup the system to Hot mode.

Gateways shall be independently operated from SAS. In any case of failure of SAS, data reporting to NSCC should not be disturbed.

Each gateway shall be synchronized with SAS GPS system. If a GPS is not available/cannot be used separate GPS system should be provided.

The gateway should support for the all the parameters which are mentioned in the signal list which will be configured for NSCC integration. There should be a facility to change the each communication and protocol parameters according to the requirement as per the defined parameters in IEC 60870 – 5 – 101/104 protocols. Interoperability List shall be provided for the approval before purchasing the equipment.

The defined "Supervisory Control" level under SAS Configuration Chapter is Located at a National System Control Centre SCADA (Supervisory Control And Data Acquisition) system through the Gateway. Hence, Separate Control Hierarchy Level shall be made available for the National System Control Center Operations.

**A. 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.

**B. Input / Output SCADA Signal Functionality**

**a. 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

**b. Analogue input**

- Unipolar and bipolar measurements
- Current input: 4 to 20 mA
- Resolution: 12 bits
- Accuracy: +/- 0.05%

**c. Command outputs**

- Single commands
- Double commands
- Set point commands
- Select (check) before execute commands

**C. Communication Functionality**

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. Direct Digital Link via Digital PLC Equipment.
2. 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 Multiplexer.

**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.

**(5) Mechanical Details of Equipment**

The equipment listed 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) 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.

**(7) Schedule of Tests at Works**

- Construction check
- High voltage test
- Insulation resistance measurement
- Temperature rise test (Certification of type test may be accepted)
- Power consumption measurement
- Operation tests (both Simulation and actual operation)
- Redundancy Verification Tests
- Others

**(8) Environmental**

Operating temperature 0°C.to +55 °C

Relative humidity 5% to 95% (non-condensing) according to DIN 40040 Class F

**(9) 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 mm2 copper.

However, for Current Transformer Secondary wiring side, since transducers will have to be wired in series, the wiring will be of 2.5 mm2 or 4.0 mm2 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.

**(10) Training**

Comprehensive on-site training with following content shall be provided for electrical engineers of CEB

- Training programme for Installation, Configuration and Maintenance of the gateways with relevant software including adding new signals and new bays for future requirements
- On the job training on trouble shooting, programming, operation and maintenance

**(11) Spare parts and Tools**

- 02 Nos. Gateway Output Interface (Ethernet) with cables
- 01 No. Laptop computer with gateway installation, configuration & maintenance s software with License

**4.4.5 Metering**

The metering data shall be made available to the DCS for display, logging, reporting and archiving purposes using suitable means.

### 4.4.6 Plant Management systems

#### 4.4.6.1 Vibration Monitoring System

Separate vibration monitoring system shall be supplied, by a reputed supplier who provides such proven systems especially for Gas turbines over a period of 5 years or more such as Bently Nevada or equivalent. The proposed system shall be compatible with ISO 10816, 2014 standard. The monitoring system shall be supplied with redundant power supplies. The monitoring system shall be interfaced with unit control systems and DCS using suitable means.

#### 4.4.6.2 Plant historian system

A redundant "historian" system shall be supplied for long term storage of all relevant plant data. The system shall be based on a field-proven database (e.g. PI from OSIsoft, Inc) and shall have an open interface (e.g. OPC) for data acquisition. The system shall acquire all relevant process data (e.g. flow, pressure, temperature, metering data etc.) and alarms & event from the DCS and store them for the life of the plant. The historian shall incorporate an efficient algorithm to optimize the sample points stored without compromising the data quality and integrity.

Sufficient storage capacity shall be provided in the system to meet the requirements of a plant historian function. The data shall be stored in a redundant system memory for a pre-defined period of time (not less than three months) and automatically transferred to a networked archiving medium (magnetic) having RAID 5 or 6 configuration at the end of the retention period with suitable data compression technologies without losing too much information. Facilities shall be provided to back up the data stored in the system memory and Network Attached Storage (NAS) to CD/DVD.

The retrieval, display and processing of historical data stored in the system shall be straight forward. It shall be possible to present historical data from different time periods in trend displays. Facility for historical data retrieval to external storage devices such as external hard drive shall also be provided.

#### 4.4.6.3 Provision for Plant Performance Monitoring system

The DCS shall allow integrated control and safeguarding system to communicate with third party control and information systems utilizing OPC connectivity standards. Where connection to high level plant management and reporting applications are to be done through administrative Local Area Network (LAN), suitable firewalls to prevent unauthorized access shall be provided.

### 4.4.7 Central Diagnostic and Programming Station (System Engineer's Workstation)

The task of this station is the maintenance and the modification of system configuration required.

Other than the DCS related component configuration, Diagnostic and programming functions of electrical protection relays shall also be facilitated through this workstation or if not a separate workstation shall be provided for that purpose.

#### 4.4.7.1 Central Diagnostic Functions

The main tasks of the diagnostic station shall be as follows.

- Monitoring of all events and faults of the digital system and the peripherals (like supply failure of transmitters, switches, I/O modules, gateways, controllers and etc.) along with the alarm and protection system
- Indication of the exact time when the event/ failure occurs
- Indication of each parameter and signal of the system on demand
- Simulation possibility of each input/ output signal

All operator interventions in the system like simulation, off monitoring, etc. shall be considered as events.

#### 4.4.7.2 Central Programming Functions

The central programming functions shall contain all necessary functions for programming/ configuration, modifications/ reconfiguration and for the documentation of the above task.

- Viewing/ documenting the system structure/ configuration
- Viewing/ documenting each system signal and parameter
- The possibility to elaborate or to modify the structure of the system (configuration/ reconfiguration)
- The possibility to introduce new parameters or to modify existing ones
- Documentation of the actual system configuration, in tabular and graphic form, cross reference lists, signals lists, etc.
- Set-up of calculation programs
- Graphic editing programs
- Reconfiguration or an expansion of the I&C system have to be done without any interference or change of design to the existing station.
- Logging of operator interventions shall be done.

#### 4.4.7.3 Graphic Editor for Process Mimics

The editing of mimic graphics for process monitoring shall be able to carry out easily, without any special knowledge in computer programming. Special software tool packages shall help the operator in his task.

A symbol library with preprogrammed symbols with possibility of further user defined extensions shall be provided. For better orientation dotted background shall be provided.

## 4.5 Particular Conditions for Instrumentation and Control

### 4.5.1 General Requirements for the Scope of Work and Services

#### 4.5.1.1 General Scope of Work

The Contractor shall complete the scope of supply by such items not specified but found necessary to comply with the Contractor's proper design and/or ensure a reliable and safe operation of the plant.

If during design, construction, testing and commissioning and for the completion of the work, any additional instrumentation and control equipment becomes evidently required and is considered by the Employer to be essential for the safe and reliable operation of the plant, it shall be provided at no extra cost to the Employer.

In case the Contractor proposes or supplies any additional plant auxiliary equipment, all corresponding instrumentation and control equipment shall be included in his scope.

#### 4.5.1.2 General Scope of Services

The scope of services concerns the I&C system of the entire plant and shall cover but not limited to the following:

- Elaboration of the I&C works and drawing/documentation and delivery of them including all revisions according and "As Built" condition
- Manufacture, inspection and testing of the equipment in the manufacturer's works pursuant to the Contract requirements and the approved documents
- Packing, insurance and delivery of the equipment to the Site including local transportation and storage at the Site
- All programming and configuring works related to the delivered equipment
- Erection and installation of the equipment and cabling pursuant to the requirements of the Contract
- Elaboration of plans and programs for cold and hot commissioning of the I&C equipment, which are subject to approval by the Employer

- Cold and hot commissioning according to the approved program
- Training and providing necessary support and instructions of the Employer's operating staff, including comprehensive operating instruction
- Optimization, Trial Run
- Initial Operation
- Reliability Run
- Performance Tests

**4.5.1.3 Instrument Engineer Liaison**

The Contractor shall assume full responsibility for instrumentation and is required to arrange with the principal instrumentation supply manufacturer the assignment of one qualified project instrument engineer conversant with English language to be fully responsible for the supply and work covered under this section of the specification. The scope of responsibility shall include, but not limited to the following duties:

- Assume complete responsibility for the satisfactory handling of the contractual instrumentation requirements from the time the Contract is awarded until Final Acceptance.
- Be responsible to answer questions relating to production orders, systems engineering, drawings, scheduling, delivery, instructions or service and startup assistance.
- Supervise systems engineering, checkout and be responsible for assuring that equipment production, all items manufactured, will be compatible with their related interconnected systems.
- Supervise the development of controls, logics, schematics and wiring connection diagrams and assure compliance with the specification and manufacturer's production and shop drawings.
- Correlate instruction manuals and assign qualified personnel most familiar with the detail requirements of each area of supply.
- Coordinate special training programs and courses which become necessary as a result of the Employer's request for assistance in his personnel training program.
- Supervision of erection at site, tests, commissioning and putting instrumentation and controls in reliable service.

The Contractor shall assign one competent qualified Site instrument engineer, who is well informed about the station control and instrumentation systems, for the complete Guarantee period from the issuing of the TOC for the Unit.

After issuance of final acceptance, the contractor shall supply remote technical support for trouble shooting and modification for a period of five years without additional cost to Employer.

All costs for the services of such instrument engineers shall be included in the Contract.

### 4.5.2 Scope of Supply for the I&C Equipment of Gas Turbine Units

#### 4.5.2.1 Scope of Work

The following but not limited to shall be supplied, installed and commissioned, including marshalling racks, ready for commercial operation:

i). Central Control Room with operating workstations, printers and other peripherals, Desks, Chairs, Panels and etc.

ii). Emergency Trip buttons for each Gas Turbine unit shall be provided at Central Control Room facility as well

iii). Engineer's workstation, clock system, NAS, network components, Desks, panels, Cubicles/ cabinets and etc.

iv). The generator control panel shall contain all devices necessary for operation, control and alarm annunciation of the generator and of the associated equipment for local and remote operation, and shall include as a minimum:

- Selector and control modules for Manual or automatic synchronization, Manual or automatic voltage regulation, Manual or automatic change-over of auxiliary supply, Set-point Adjuster for voltage regulator
- Control switch for generator circuit breaker
- Indication facilities for generator in operation and synchronizing device in operation
- Voltmeters with phase selection, Ammeters, Power factor meter, MW meter, MVAR meter, Frequency meter, Excitation voltmeters, Excitation delta voltmeters, Pre-selected MW, Double voltage and frequency meter for manual synchronizing, Synchroscope

v). The gas turbine control panel shall contain all devices necessary for operation, control, individual alarm annunciation and protection of the gas turbine and its associated equipment, for local and remote start-up, loading, unloading, shut-down, and emergency trip, and shall include as a minimum the following devices:

- Selector facilities for Local or remote control, Speed control, Load control, Frequency control, Exhaust temperature control, Base or peak load limitation, Fuel selection, Normal or fast start black start mode
- Speed/Load set point adjuster

- Push buttons for Emergency tripping
- Indication for Fuel Selection, Local or remote control, Operating (start) sequence, Flame (failure) indicator, Starting device in operation, Speed control operation, Load control operation, Grid Frequency control operation, Temperature control, NSCC AGC control mode, Black start mode, synchronous condenser mode
- Measurements for Rotating speed, Gas temperature inlet turbine, Exhaust-gas temperature, Air inlet temperature, Compressor-discharge temperature and pressure, Lubricating oil temperature, Lubricating-oil pressure, Bearing temperature, Cooling/atomizing air temperature, Cooling water temperature, Critical temperature of components, Vibration of all main bearings, Pressure differential of air inlet system including gas filters, Fuel pressure in front of GT-fuel system, Wheel space temperature and etc.
- Protection provided for Over speed, High exhaust gas temperature, Flame failure, Turbine inlet temperature high, Low lubricating-oil pressure, Low control oil/air pressure, High lubricating-oil temperature, Low fuel pressure, High vibration, Fire within the unit

vi). Control cubicles located locally or in control building as required

vii). Control and Sequencing for operation of Gas turbine units

viii). Protection and Electrical Control System as required for safe and reliable operation of plant

ix). Necessary I/O allocations, HMI mimics for fuel skid monitoring, HMI controls for fuel transfer and necessary control logics implemented in the controller for future RLNG operation

x). Controls and I&C equipment for proper operation of the whole plant as specified elsewhere in this document

xi). Each exhaust stack of gas turbine unit should be installed with warning system to protect from possible aero plane crashes and nearby air craft landing and same should initiate respective alarms and warnings in HMI computers in local control cubicle and remote control cubicle.

### 4.5.2.2 Control and Sequencing System

#### 4.5.2.2.1 General

One complete Control and sequencing system shall be provided for each gas turbine generating set with the following basic functions:

- All plant Auxiliary System preparation
- Preparation of fuel supply
- Fuel supply checking
- Start-up preparation

- Start-up until full speed (Island operation)
- Synchronizing
- Loading
- Variation of inlet guide vanes
- Unloading
- Base load operation
- Peak Load Operation
- Black Start operation
- Primary frequency control
- Grid frequency control
- Shut-down
- Shaft-turning/cooling down phase
- Purging at low speed
- Protection against over-speed, high gas turbine exhaust temperature, loss of flame, high vibration, insufficient lubrication and cooling, etc.
- Fuel transfer facilities

Start-up preparation and starting shall be fully automatic achieved with one command operation.

#### 4.5.2.2.2 Governing System of Gas Turbine

The governing system of the gas turbine shall be of triple redundant type and shall incorporate:

- Control for fuel supply
- Control of bleed valves/IGV's for start up and stop
- Control of IGV's during full speed variable load operation
- Constant speed regulation
- Two electronic over speed trip devices with provision for testing the operability while the gas turbine is in operation
- Turbine inlet temperature limit control, based on exhaust gas temperature and pressure ratio or compressor discharge pressure
- Over temperature/vibration/lube and control oil supply trip mechanism with provision for testing the operability while the gas turbine is in operation
- Adjustable dead band setting of the governing system.

### 4.5.2.2.3 Speed & Load Control Requirements

**1. General**

The gas turbine shall be capable of operating at full speed operating conditions under speed control on an isolated grid as well as in parallel with national grid. Setting of the speed/load set point shall be possible from local HMI and Central Control Room.

The control from the Central Control Room shall provide the following functions (control modes):

- Startup control
- Speed control (for turbine-generator operation not connected to the grid)
- Load control (pre-selected load control, base load, peak load and respond to NSCC AGC load dispatching commands)
- Frequency control (isochronous mode)
- Frequency control (Primary frequency control, connected to the grid)
- Frequency control (Grid frequency controlling with supplementary controls)
- Exhaust temperature control (for Base load, Peak load operations and IGV controlling modes)

Output signals of the controller shall be limited by overload, over-speed, acceleration and temperature limiting devices of the gas turbine governing system as well as by operating limits of the generator.

The speed control system shall enable the turbine to be operated isolated or on the grid within the permissible speed range. Speed adjustment related to rated speed shall preferably be possible in a range of ±5 %. The rated speed at no load condition shall be adjustable within ±0.5 % for easy synchronization.

The speed control characteristics shall allow a stable operation under all conditions and the dead band of the regulation system shall not exceed 0.1 % of the rated speed. The droop factor is adjustable between 2% and 10% while GT is in operation. The automatic starting sequence control shall cooperate with the speed control. It shall increase speed up to nominal speed supervising all relevant plant conditions to protect the unit from damages or thermal overstress. In case of load rejection (switching over from load to speed control), the speed set point shall be adjusted automatically to rated speed. Tripping of the unit by over-speed signals must be avoided in any case, even at full load rejection. Over-speed occurring under any conditions must not have any harmful effect on the turbine generator unit nor on its auxiliaries.

Load control shall be activated automatically after closing of the generator circuit breaker, and the change-over shall be bump less. The load control system shall act either as frequency control, constant load control or as temperature control. The load (speed) set point shall be adjustable from no load to full load and peak load.

The constant load control shall be fully automatic to preselected value achieved by variation of the speed setting only.

The temperature control shall be fully automatic to a pre-selectable value and shall keep the outlet temperature constant by varying the load.

When reaching limiting temperature values of the gas turbine by increasing the load, the output signal of the speed control shall be limited and a visual signal must be remotely given showing "Base Load". Provision shall be made to increase the limiting temperature to allow for peak load operation. When reaching this limit, a visual signal must be remotely given showing "Peak load".

The Contractor shall state the minimum generation capacity required for stable operation when operating under load control and operating parallel with other turbine-generators.

## 2. Load Frequency Control

The gas turbine generator units shall have the capability to operate in all but not limited to the following load frequency control modes. These modes shall be selectable depending on the operating conditions of the generator. If any new operating modes are available, they shall be included as well. The operating limits and dynamic rate constraints of the gas turbine generating units shall be taken in to account to ensure that the gas turbine generator unit operation is within plant's feasible operating region.

### 1). Isochronous mode of operation

Each gas turbine generator unit shall have the capability to operate individually in isochronous mode during isolated operations to maintain the frequency at the nominal value (50 Hz). Necessary controls for each gas turbine generator unit shall be provided in HMI for the operator to select isochronous mode of operation.

### 2). Speed Droop control mode (Primary speed control mode)

Each gas turbine generator unit shall have the capability to operate individually in speed- droop control mode while connected to the national grid. Necessary controls for each unit shall be provided in HMI for the operator to select Speed-Droop control mode of operation. The operator shall have the ability to change individual control settings (load rates, frequency dead bands, individual droop settings and etc.) for speed-droop control mode for each unit online. The droop setting for each unit shall be configurable at least within 2% - 10%. Provisions in HMI to select preselected load control mode or base load operation mode shall be provided. In preselected load control mode, provisions shall be made in HMI to provide a load reference set point by the operator.

### 3). Automatic Generation Control mode (AGC)

#### 3.1). Automatic Generation Control within the power plant:

Facility of automatic generation control while connected to the national grid to restore grid frequency to nominal value (50 Hz) through load reference set point adjustment shall be provided, installed and commissioned. This automatic generation control facility shall have the capability to incorporate all the gas turbine units of this power plant in regulating the grid frequency. Each gas turbine generator unit shall be given individual load reference set points to compensate the system load variations. The individual gas turbine generator units which shall be incorporated in automatic generation control mode within the power plant shall be selectable through HMI.

Operator shall have the ability to change the specific individual control settings (speed-droop settings, the load rate, individual allowable minimum & maximum load set points and etc.) for this control mode. Operator shall be notified through alarms when a unit reaches its minimum or maximum allowable load. The droop setting for each unit shall be configurable at least within 2% - 10% for this mode of operation.

The facility of automatic generation control shall be redundant in a way that a failure of one controller with automatic generation control module shall not affect this mode of operation.

HMI shall provide the facility for the operator to select whether individual load reference set points or a joint load reference set point which is to be provided to the selected gas turbine generator units to share the load in regulating the grid frequency in primary frequency controlling mode. Under this mode power plant shall be capable of allowing automatic increase or decrease of power responding to the grid frequency shifts, between the minimum load capability of each unit and the rated power of each unit or any setting imposed by the operator within the limits.

Operation of individual units shall be transferred to a safe mode in case of any communication loss between gas turbine controls and the automatic generation control facility and the operator shall be notified through alarms about the communication failure.

#### 3.2). Incorporation with installed AGC facility in National System Control Centre:

The Automatic Generation Control facility to be commissioned in National System Control Centre will provide the active power scheduling and load dispatching functions for the generating plants. The offered gas turbine generator units shall have the provision to respond to these AGC functions in both normal and emergency modes of operations. Individual control parameters (load rate, minimum & maximum allowable loads and etc.) for this function for each unit shall be configurable.

Provisions shall be made in HMI for the operator to select whether the individual gas turbine generator unit is running on AGC mode with the National system control center or on free governor mode. Controls shall be provided to limit the load within minimum and maximum allowable limits and shall notify the operator about the limit violations through alarms.

Under this mode, the individual active power and reactive power shall be controllable from system control center. Control of Active and reactive power shall be obtained through either "set point control" or "Raise/Lower control". Provisions shall be made in the controller to incorporate these load reference set points or Raise/Lower commands to control active and reactive power of each gas turbine generator unit.

Following SCADA signals related to this facility shall be made available through the existing gateway (ABB COM 581) as per IEC 60870-5-104 protocol for the purpose of integration with the National System Control Centre.

**Signals for Controls:**

1. MW/ MVar setpoints
2. MW/MVar Raise/Lower commands
3. MW/MVar set point validation if any

**Signals for Indications:**

4. Generator governor mode of operation (AGC mode / free governor mode)
5. Generator governor Auto/ Manual indication
6. Generator control mode (Supervisory/ Remote)
7. Generator AVR Auto/ Manual indication
8. Generator AVR mode (Supervisory/ Remote)

**Signals for Measurements:**

9. Generator active power
10. Generator reactive power
11. Generator voltage
12. Generator frequency

Operation of individual gas turbine generator units shall be transferred to a safe mode in case of any communication loss between gas turbine controls and the automatic generation control facility in National system control center and the operator shall be notified through alarms about the communication failure.

#### 4.5.2.2.4 Black Start mode

Each gas turbine generator unit shall automatically get started during the unavailability of 132 kV supply to the plant and reach FSNL and wait for intervention of the operator for synchronization.

Necessary controls, protections and operator interfaces shall be developed and included in the I&C system to facilitate the safe starting of gas turbine in a black out condition through both

“Auto” and “Manual” mode selection.

#### 4.5.2.2.5 Retaining at FSNL during unavailability of 132 kV supply

All the control and instrumentation systems necessary to retain the gas turbine unit at FSNL without turbine tripping during unavailability of 132 kV supply shall be provided. This shall include all necessary means to supply fuel pumps and all the other necessary auxiliaries with DC power or any other means and necessary control logics and protections to retain the system at FSNL.

The system shall be commissioned for proper functionality.

### 4.5.2.3 Alarm Annunciation System for the Gas Turbine Units

The alarm system shall be equipped with visible and audible annunciation in the local control panel of the unit and at the Central Control Room. It shall have test, acknowledge, and reset pushbuttons and as a minimum the following local annunciation, the annunciations at the Central Control Room may be combined to group alarms.

The following alarms shall be provided as a minimum. Below “A” is referred to Alarm function and “T” is referred to tripping function.

- Battery under voltage (A)
- Cooling liquid level "low" (A)
- Fuel inlet pressure "high" (A)
- Fuel inlet pressure "low" (A)
- Fuel temperature "low" (A)
- Turbine over speed (T)
- Incomplete starting sequence (A)
- Exhaust temperature "high" (A) and (T)
- Exhaust temperature differential "high" (A) and (T)
- Generator Stator temperature "high" (A) and (T)
- Flame failure (T)
- Lubricating oil temperature "high" (A) and (T)
- Lubricating oil temperature "low" (A)
- Lubricating oil pressure "low" (A) and (T)
- Lubricating oil pressure "high" (A)
- Lubricating oil tank level "low" (A)
- Emergency lubricating oil pump "operating" (A)

- Lubricating oil tank level "high" (A)
- Lubricating oil filter diff. "high" (A)
- AC lubricating oil filter diff. "high" (A)
- Control oil pressure "low" (A ) and (T)
- Turning gear fault (A)
- Bearing metal temperature "high" (A) and (T)
- Bearing vibration "high" (A) and (T)
- Air inlet filter differential pressure "high" (A)
- Vapor extractor stopped (A)
- All the individual electrical protection relays of the unit, of the unit step-up transformer, the auxiliary supply transformer, and of the L.V. supply system (A) and/or (T), as applicable
- Fire with audible alarm (T)
- Emergency trip (I)
- Generator Protection (A) and (T)
- Rotor earth fault (A) and (T)
- Negative phase sequence (A) and (T)
- AVR Fault (T)

**4.5.2.4 Gas Turbine Protection System**

The protection system shall have the task of protecting the gas turbine unit from possible damage which could be caused due to abnormal operating condition. It shall consist of the following minimum protection:

- Over speed protection
- Over temperature protection
- vibration detection and protection
- loss of flame detection and protection
- fire detection and protection
- emergency stop
- lubrication oil protection
- Control oil or air protection
- High exhaust gas temperature

- Flame failure
- Low fuel level
- Sensor failure alarm
- Emergency trip button
- Bearing metal temperature
- Lube oil temperature
- Fire protection

**Over speed Protection:**

The over speed protection must at least possess two independent electronic systems or two channels with which is arranged to shut down the gas turbine unit at over speed of 10 %. The over speed protection device shall be checked at shut down and during start-up to ensure, that it is working properly.

**Over Temperature Protection:**

Over temperature of the turbine exhaust temperature shall produce an alarm and at a higher than the set value, the turbine shall be tripped.

**Combustion Monitor:**

The function of the combustion monitor is to reduce the likelihood of extended damage to the gas turbine if the combustion system deteriorates. This function shall be effected by examining the temperature control thermocouples and compressor discharge thermocouples. When the pattern of the exhaust thermocouples readings become abnormal, warning and protective signals shall be generated by the combustion monitor and sent to the gas turbine control panel.

From exhaust temperature thermocouple readings, the average exhaust temperature is determined and alarm and trip limits above and below this value are calculated using the exhaust temperature and the compressor discharge temperature parameters.

Important signals of the combustion monitor shall be included in the event recording.

In addition, the monitor shall have a built-in "self test" and shall alarm for all internal failures including the loss of AC-power, and shall also detect and alarm defect thermocouples.

**Loss of flame protection:**

Protection shall be provided according to the manufacturer’s standard.

**Fire detection and protection:**

Protection for Gas turbine units shall be provided according to the manufacturer’s standard and as per Chapter 09 of “Technical Specification”.

**Lubrication oil protection:**

For protection lube oil pressure and lube oil temperature are to be considered.

**Emergency stop:**

Emergency stop push-buttons from any location (Local control cubicle, Central Control Room and etc.) are to be connected hard-wired to the GT protection system.

**Performance and Condition Monitoring System:**

In order to achieve better efficiency, higher availability and timely maintenance of the gas turbines, a monitoring and diagnostic system shall be provided. The system shall gather the necessary information and process them in real time to detect and early warning of the following as a minimum:

- Compressor Fouling
- Compressor Surge
- Turbine Fouling
- Exhaust Temperature
- Cooling Air failure or problem
- Vibration

**Forced Shut Down by Trips:**

A trip diagram shall be prepared by the Contractor and submitted to the Employer. All post trip actions must be executed automatically. The main post trip control features shall be summarized by the Contractor.

#### 4.5.2.5Control of all Other Systems

The control of all the other systems must basically be of such a nature that a fully automatic operation is guaranteed. It shall be noted that in the event of unavailability of individual devices or equipment, without tripping the Gas Turbine units, the appropriate auxiliary devices or standby equipment, if available, shall start automatically. Thus, for example, if the main lubricating oil pump fails, the AC driven auxiliary oil pump is automatically switched on and if the latter should fail then the DC (battery) driven emergency lubricating oil pump is automatically switched on, thus maintaining lubricating oil supply under all circumstances.

### 4.6 Cabinets/Cubicles and Racks

Mechanical enclosures such as cubicles, racks and panels used for I&C systems shall conform to the relevant sections of IEC 60297: Part 3 for uniformity of dimensions and arrangements.

The painting and finishing requirements for I&C cubicles, panels and junction boxes shall be as per the general specification applicable to the power plant.

The cubicles and panels shall be mounted in such a manner as to minimize external vibration being transmitted to internal components, for which suitable anti-vibration mounting arrangements (e.g. anti-vibration pads) shall be used.

The layout of the interior of cubicles, junction boxes and panels shall facilitate easy access of components and terminals during commissioning and maintenance. In general, 20% of spare capacity shall be provided as a minimum in cubicles, panels, racks and junction boxes. This shall include unused module slots, unallocated wired I/O channels, unused terminal bars, space for additional external cables etc.

If forced ventilation is to be used in cubicles and panels, 100% redundant fans shall be employed with facilities for fan failure detection and alarming on the DCS. Thermostatically controlled anti-condensation heaters shall be installed in cubicles and panels where necessary. Maintenance facilities such as internal lighting (i.e. illumination lamp work on door limit switch) and a 230V ac power socket shall also be provided in cubicles and panels.

Suitable identification methods shall be provided for sub-assemblies and terminals in cubicles and panels. This shall include modules, racks, power supplies, pre-fabricated cables, I/O termination boards, external cables and their conductors, terminals etc. A “DANGER” label shall be provided with shroud for terminals connecting 110 V and above.



## 4.7 Cabling and Wiring

### 4.7.1 I&C Cabling

All power and control cables for the instrumentation and control systems shall form a safe and reliable network.

I&C cabling shall use multi-pair cables with screens, multi-core cables and optical fiber cables as appropriate. The cables shall be of the flame resistant and fire retardant type. The protection method for I&C cables from physical abuse and rodent/insect attack shall be to the approval of the Employer.

The multi pair/multi core cables shall be made up of copper conductors of not less than 1 mm2 cross section except for those associated with interposing relay cubicles and power supplies where higher conductor cross-section shall be chosen based on volt drop considerations. I&C cables of less than 1 mm2 cross-section shall be subject to approval by the Employer and would only be considered in cases where special cable termination methods requiring a smaller cross-section (e.g. Maxi-termi-point connections with 0.5 mm2 cross-section conductors) are part of the Contractor’s standard design of the equipment.

Instrumentation control equipment grounding shall be carried out as per the IEEE 1050 guide.

Screened instrument cables shall be used to transfer analogue and binary signals. In an electromagnetically noisy environment double screened (screen for each pair and common metal screen) instrumentation cables shall be used for all analogue signals. Where armored cables are used they shall be provided with glanding facilities.

The analogue and binary signals from sensors, switches and transmitters shall be transferred by individual signal cables to junction boxes.

Cabling between electronic cubicles and the switchgear, the control room and the field junction boxes shall be made by screened instrument trunk cables. Trunk cables shall have 20 % spare wires after final commissioning.

Adequate separation of I&C cables from power cables and segregation of I&C cables for different systems shall be provided. Redundant cables shall be installed over separate routes to minimize the possibility of a common failure. Appropriate segregation and spacing shall be maintained between power cables, signaling cables and low level instrumentation cables along cable trays and within the cubicles.

The specifications in the Electrical section and other relevant specifications shall also be applied.

### 4.7.2 Wiring in Cubicles/ Panels

The wiring inside of cubicles, desks and panels shall be made in the manufacturer's factory to the highest extent possible.

Disconnectable connections shall preferably be done by plug-in connector blocks, individually by spring loaded FASTON type connections. Use of screwed terminals shall be avoided.

Fix installed wires and cables shall be connected by termi-point or wire wrap technology, without using soldering. For coaxial and flat cables for bus systems appropriate reliable special connections shall be provided. In case of fiber optic cables all connections shall be factory made.

Direct cabling of cards is not allowed. Plug in cards shall be used. All wiring/ interconnections between card sockets shall be freely accessible for maintenance.

The grounding system shall be designed as per relevant IEEE guide. The earthing scheme proposed for I&C systems shall reduce the effects of electrical/electromagnetic interference and ensure the safety of personnel. The earthing scheme used shall be to the approval of the Employer. All metallic parts of cubicles and panels including doors shall be earthed by earthing conductors/braids of suitable cross section using serrated washers to ensure a positive contact. Cable screens shall be terminated in such a way that earth loops are not introduced. Cable screens shall be terminated only at one end for which an insulated 'clean' earth bar shall be provided in cubicles. The earth bar shall be connected to the site earth via the cubicle safety earth at a single point. Armored cables when used shall have their armors connected together externally, but shall be electrically isolated from the cubicles. The cable armors shall be connected to the site earth at a single point.

External cables entering the cubicles and panels shall be adequately secured and supported by a suitable method, e.g. cable glanding. Outdoor I&C enclosures, e.g. junction boxes and plant-mounted control panels, shall only use cable glanding for this purpose. Alternate methods may be used for indoor cubicles and panels to secure and support the external cables. In this case, the cable entry area shall be sealed by a suitable method to guarantee that the cubicle/panel has the required fire rating and is dust/vermin-proof.

### 4.8 Cleaning and Protection

After complete installation of each piece of equipment, the Contractor shall clean and touch-up each piece of equipment with paint as required.

During construction, instruments and cubicles/cabinets shall be protected at all times from wetting, dirt, and physical damage.

When connections are made, the pieces being connected or joined shall be free of residue, borings, and foreign materials which may plug an instrument or make it inoperable.

Tubing shall be blown free of foreign matter before connections are made. Tubing and instrument connection shall be capped during storage.

Alter installation, but before it is placed in service, the Contractor shall protect equipment from damage or contamination. All work shall be done in an orderly, workmanlike manner and shall present a neat appearance when completed.

For painting and cleaning requirements, refer to relevant General Specifications.

### 4.9 Mandatory Spare Parts

At least following spares for control and instrumentation equipment shall be included in Schedule 2, Mandatory spares in volume 5 as listed below.

- At least one CPU card of each type installed in the plant. If the number of installed CPU cards is more than five, two (02) cards of each type shall be supplied. If the number of installed CPU cards is more than ten, three (03) cards of each type shall be supplied.

- At least one control card (Input/Output cards, Interface cards, communication cards, memory modules etc.), power supply modules or cards of each type installed in the plant. If the number of installed control cards is more than five, two (02) cards of each type shall be supplied. If the number of installed control cards is more than ten, three
- (03) cards of each type shall be supplied.

- At least one complete server computer with software, one complete HMI PC with softwares, and one complete Engineering workstation with softwares of each type installed in the plant. These computers shall include dedicated interface and communication cards.

-

- At least one data switch, one network hub of each type installed in the plant. If the number of installed data switches or network hubs are more than five, two (02) units of each type shall be supplied.

- One network storage device installed type in the plant

- At least one transmitter from each type installed. If the number of transmitters installed exceeds five, three (03) transmitters shall be supplied.

- One complete set of Thermo couples and RTDs which is an equal quantity to the number installed in one Gas Turbine unit

- At least one indicator (pressure/temperature/level/flow/voltage/current and etc) or 10% spare amount of each type installed in the plant, which ever the highest

- One vibration sensor of each type and one electronic card from each type installed in vibration monitoring system of the Gas Turbine

- One or 30% of spares amount, whichever is higher shall be supplied for each type of transducers, switches, actuators, solenoids and instrument valves installed in the Gas Turbine. One spare item shall be supplied for each type of transducers, switches, actuators, solenoids and instrument valves installed other plant accessories except the Gas Turbine.

- One spare relay from each type of auxiliary relay, ten spare fuses from each type and rating

- At least one or 25% of the heat detectors, smoke detectors from each type installed in the fire protection system, which ever the highest.

- One set of complete Gateway computer system for SCADA system

# 5 Civil Requirements

## 5.1 General

### 5.1.1 Introduction

This is a Turnkey Contract and the Contractor shall have allowed for all Civil Engineering, building works and services required for the satisfactory performance of the Works. Where a detail, material or other item is not covered in this Specification then the detail shall be based on standard building practices and the material shall be the best of its kind but in all cases shall be subjected to approval by the Employer.

### 5.1.2 Construction Programme

The Contractor shall submit with his Tender an outline Construction Programme based on the overall programme showing how the Works are to be completed in the time available. Within one month of acceptance of the Tender, the Contractor shall forward to the Employer,

Three (3) copies of the following :-

**5.1.2.1** A chart detailing the Civil Engineering designs, Plant manufacture, delivery and erection programme, the programme of work, for the complete contract work for Employer's comments or approval. Copies of the chart approved by the Employer, as required by the Employer, shall be provided by the Contractor. The chart shall indicate realistically the various phases of work for all items of the Contract from the commencement of the Contract to its final completion. Key dates shall be incorporated in Schedule 2C - Deliveries and Completion Times.

If at any time during the execution of the Contract it is found necessary to modify the approved chart, the Contractor shall inform the Employer and submit a modified chart for approval. Such approval is not to be deemed to be consent to any amendment of the completion date stated in the Schedule.

Although variations in the programme are permitted the Contractor shall be required in arriving at his price for the work to take account of any possible changes including climate and local customs and conditions since no variation in price will be permitted once the Contract, which is turnkey, has been awarded. To this end, the Contractor will have to show by detailed network, using an approved software associated with Project Management, the effect of the variable components referred to above on the overall programme for the information of the Employer.

**5.1.2.2** The project implementation schedule shall be reflected on a software associated with Project Management proposed for project planning, scheduling and control which shall be offered after acceptance of the Tender. This software shall be installed at the Contractors' main site office within one and half months of acceptance of the Tender.

The system adopted shall be based on a critical path network covering all items of the Contract from commencement to final completion. Full facilities for resource management covering manpower, plant, material availability and line requirements shall be provided within the program. The system should be able to draw from datasets prepared separately i.e. computer based stores inventories, datasets covering line material requirements, etc.

The system should have the flexibility to permit quick and easy investigation of the effects of Work Programme changes and the imposition of resource restraints. A flexible, selective, report writing facility shall also be provided within the system, along with a graphics facility capable of presenting relative progress in terms of S curves resource analysis in histogram form and selected parts of the network in bar chart format.

To permit the Employer to make independent investigation of changes to the Programme of Work, the Contractor shall supply a software associated with Project Management, with all operating manuals and documentation, for the sole use of the Employer. The Contract shall also supply all data necessary to operate the program to monitor progress and investigate changes to the programme of work. Updated data shall be supplied to the Employer at least monthly and possibly more frequently at critical stages of the work. The Contractor shall provide for the Employer's representative on site, a weekly summary of the work he proposes to carry out during the following week. The summary shall reach the Employer's representative not later than Friday of the preceding week.

In addition, the Contractor shall submit to the Employer within the first week of each month the following:

(i) Rates of progress shown by S curve shall be submitted with the programmed progress and shall be updated each month with another S curve indicating actual progress relative to the programme.

(ii) Updated histograms shall be provided to augment the information given on the allocation of resources.

(iii) A progress/programme bar chart to be updated each month for CIF works under the Contract and covering a period of two (2) months (one (1) month retrospective and one (1) month prospective). Each update shall be in the possession of the Employer by the first day of the month.

### 5.1.3 Design Programme

The Contractor shall submit within two weeks from the date of commencement of Contract, a detailed drawing list and programme showing the phasing and issuing of drawings for approval.

### 5.1.4 Civil Sub-contractors

The Contractor may employ a Sub-Contractor to carry out the civil works. If the Contractor intends to Sub-contract the Civil Engineering and building works design and/or construction, full details of comparable works carried out elsewhere by the sub- contractor, together with details of the financial stability and capability of the sub- contractor shall be submitted at Tender stage. Names, position to be held and experience are to be submitted for staff to be employed for the Site.

### 5.1.5 Assistance to Employer

The Contractor shall provide and maintain for the sole use of the Employer's staff all surveying instruments, including Total Station and testing equipment required for checking and setting out and for controlling and testing the quality of materials and workmanship. The Contractor shall also provide all the assistance that the Employer requires, including chainmen, labourers and others for the purpose of checking the setting out, tests etc.

### 5.1.6 Temporary Site Office

The Contractor shall provide temporary site office constructed using containers with Air Conditioned and other facilities (as described in Cl 5.2.3.4 of this volume), for the sole use of the Employer during the project period. The container offices shall become, upon completion of the Contract, the property of the Employer.

### 5.1.7 Records and Drawings

The Contractor shall keep at the site accurate and up to date records and drawings of the works and shall provide the Employer with copies of these records. At the end of every week the Contractor shall submit to the Employer returns of labour, plant and materials employed on the site during that week. At the conclusion of the Civil Engineering and building construction works, the Contractor shall supply reproducible copies of all drawings with soft copies in AutoCAD and Adobe Acrobat formats, showing detailed constructed works, including location of drains, services, foundations, roads, etc.

### 5.1.8 Contractor's Proposal

The Contractor shall submit with his offer sufficient information and drawings to enable the full extent of the proposals for the civil engineering and building works to be assessed.

The drawings showing civil engineering and building works, which have been provided with the tender document, are intended to give only a guidance to the principles to be followed and the standard required. The Contractor may vary the details according to his particular requirements, subject to the approval of the Employer and provided that the overall scheme remains unaltered. It is expected that the Contractor's design proposal for the facilities will not differ greatly from that shown in the Specification document drawings.

The Contractor shall complete the Schedules for the Civil Engineering and building works based on his own design proposals.

### 5.1.9 The Site and Sub-Soil Conditions

The Contractor shall perform all the necessary clearing, grubbing and preparation of the site; removal and disposal of all debris; excavation and trenching as required; the handling, storage, transportation and disposal of all excavated material; all necessary sheeting; preparation of subgrades; pumping and dewatering as necessary or required; protection of adjacent property; backfilling; pipe embedment; surfacing and grading; demolishing of existing contrete foundations; removal of buried cables and other related work.

The Contractor shall remove all abandoned switchyard structures and other associated items (if any) located inside the Site premises. All removed switchyard items and other associated items shall be moved to a location within the KPS premises as per the instruction given by the Employer.

Reports of previous Soil Investigations done using boreholes within Kelanitissa Power Station (KPS) are included in Appendix F to this Specification, for information. The Contractor shall carry out a complete and thorough topographical survey and subsoil investigation including physical and chemical tests on samples etc., to justify all criteria used in the Civil Engineering design. The Contractor is responsible for all interpretation and for any further tests that are required to justify his design. The information is given without liability as to its accuracy and no responsibility will be accepted for its validity. The Contractor is entirely responsible for the underground obstructions, services and for any other information required for the satisfactory design of the structures, and shall have no claim for additional costs, rate of progress or variation to programme incurred as a result of the ground conditions or underground obstruction.

### 5.1.10 Foundations

#### 5.1.10.1 Design of foundations

The design of all the foundations for the plant buildings and structures are to be such that differential and total settlements or other movements shall not exceed acceptable limits. Angular displacements resulting from settlement shall be maintained before the limits likely to produce structural damage or to interfere with the efficient running of all plant and equipment. The design of all items listed above is to be to the approval of the Employer and will be particularly rigorous in the case of the turbines and stacks.

The Contractor shall provide descriptions and methodologies to be adopted in each type of foundation works, with the bid.

Foundations for rotating or reciprocating plant shall be designed so as to ensure that the elastic strains from machinery loads will be uniform within the limits prescribed by the machinery manufacturers and that the natural frequency of the parts and whole of the foundations and all structures adjacent are within a safe margin from the frequency of out of balance forces.

The transmission of vibration shall be kept to a satisfactory minimum and effective measures shall be taken to ensure this.

For the turbine buildings, the maximum allowable live load on the ground floor SLW60 loading or such higher loads as are necessary to allow for all the static and dynamic loadings from the plant and equipment offered, unless specifically agreed otherwise by the Employer. Throughout the Works the Contractor will be required to base all foundations on a sound formation, in particular the foundations for the blocks, turbine sets and for the stacks. All formations must receive the Employer's approval for use before being blinded.

The Power House and Machine Foundation, Inlet Air Chilling system, Fin fan cooler, Fuel Pump House, Exhaust Stacks, Switchgear room, EDG building, Black start Generator building, Fire Pump House, Transformer Bays, Switchgear room, water treatment plant, fuel oil treatment plant and permanent washrooms shall be founded on level ground, in view of the facts of recommendations of soil investigation report. Each foundation shall be designed to resist all static and dynamic internal and external forces and couples and torque reactions. In reinforcement design, attention shall be given to resist cracking due to early thermal shrinkage.

Anti-termite treatment shall be carried out for the soil layer underneath foundations. The Contractor shall provide descriptions and methodologies to be adopted in Anti-termite treatment, with the bid.

Gas Turbine and Generator foundations shall be designed to limit vibration of the machine. In addition, consideration shall be given to the isolation of building foundations by suitable means to limit the possibility of the structure vibrating.

The Contractor will be expected to carry out a vibration survey consistent with ISO 4866 to determine the following.

i). The attenuation of vibrations in the ground surrounding the proposed generating plant.

ii). The level of the current vibrations in relation to those suggested in the current British Standard for the effect of vibrations on personnel (BS 6472, latest version) at locations such as the residential housing and in the CEB's existing plant and equipment, office buildings in the vicinity. Similarly, the level of the current vibrations in relation to those suggested for the effect of vibrations on structures (DIN 4150-3, or equivalent).

iii). An Assessment of the level of vibrations that are likely to emanate from the proposed new generating plant.

iv). How will the additional vibrations from the new generating plant affect those measured in (i) and assessed in (iii)

v). What will be the vibrations in the proposed Switchgear room, EDG building, Black start Generator building and how will this affect personnel and equipment.

The results of this survey will provide information to assist in the choice of the appropriate type of foundation. The Contractor shall provide with his tender, full details of the measures proposed to minimize the transmittal of vibration from Gas Turbine to other structures.

Gas Turbine foundation shall be designed in accordance with BS 8004 Standard. Particular attention shall be given in the planning and design to achieve a foundation with the minimum of surface cracking.

The foundation shall be of simple form, with a minimum of pits, ducts and holes. All holes shall be, where possible, of circular form. Re-entrant corners shall have as large a splay as possible. All cast-in inserts shall be of a shape and form to avoid local stress concentrations. Holding down bolts shall be full length type set in circular holes of as small a diameter as possible.

If practicable the foundation shall be designed to permit construction in a single pour.

The Contractor shall be responsible for determining the Properties of the soil and the rock to be used for the design and the costs for all tests deemed necessary to determine these properties, shall be included in the tender sum.

Reinforcement for the machine foundation shall be deformed high yield steel detailed without hooked ends.

The foundation shall be designed to resist all static and dynamic internal and external forces and couples and torque reactions with particular attention given to reinforcement design to resist cracking due to early thermal shrinkage.

The procedure for the design, construction and testing shall be as follows:

1). The Contractor shall submit to the Employer a Draft Engineering Report describing, in detail, the proposals for design of the unit foundation. The report shall include the following:

- A statement describing all loads that will be applied to the foundation including, static, dynamic, thermal, dead and live loads.
- Full details of the design methods to be used for dynamic and static analysis.
- A list of drawings and bending schedules to be produced by the Contractor for construction of the foundations.
- Materials testing procedures to be applied to the construction.
- Details of the supervision proposed by the Contractor for the construction of the unit foundations.

2). The Draft Engineering Report will be reviewed and approved, or commented on, by the Employer within 07 days of receipt. Any comments shall be discussed and agreed with the Employer prior to preparation and issue of the Final Engineering Report.

3). The Calculation Report including calculations, drawings, bending schedules and specification for the generator foundation shall be submitted within 2 weeks of issue of Final Engineering Report. The Employer will review and comment on the Calculation Report within 7 days of receipt.

4). At least 4 weeks before construction of the machine foundations the Contractor shall submit to the Employer for approval, a Construction Method Statement describing in detail the proposal for the construction of the unit foundations. The method statement shall include the following:

(i) Details of the mix design and sources of supply.

(ii) Full details of the formwork with particular reference to the installation of holding down bolt formers.

(iii) Details of the placing procedures including method of placing, standby arrangements, number of vibrators and number of supervisors and operatives.

(iv) Details of how foundations are to be cured.

(v) Details of how concrete is to be placed and compacted without cold joints and without any cracking due to plastic settlement.

The Construction Method Statement will be reviewed and approved, or commented on, by the Employer within 7 days of receipt.

The Employer will reject any foundation not constructed in accordance with the specification and approved method statement.

5). Within 03 weeks after construction of the unit foundations the Contractor shall issue to the Employer a Construction Report including full details of the construction and materials testing results and As-Built drawings.

6). Prior to expiry of the maintenance period, at a time to be agreed with the Employer, the Contractor shall carry out a full vibration survey to record the vibrations of the foundations and to compare these with the prediction of the initial Vibration Report. The results of the survey shall be submitted to the Employer as an addendum to the initial Vibration Report.

**5.1.10.2 Equipotential Bonding of Ground Slabs Using Steel Reinforcement**

Steel reinforcement in the top of the concrete ground slab to be used to form and equipotential bonding system shall be fixed as follows:

Where bars or sheets are lapped either within a bay or at construction joints the lapped bars shall be securely tied. Any loose rust, mill scale, paint, oil, grease, soil, concrete, grout or any other material that may impair the bond between the bars shall be removed from the bars before they are tied.

If bars or sheets are not lapped at expansion or movement joints provision shall. be made for lying a flexible metal strap across the joint. and welding the strap to the end of the reinforcement at each side of the joint. The spacing of straps across any joint shall not exceed 10 meters. At least two straps must be provided to ensure that no bay is isolated from any adjacent bay.

Steel reinforcement in pile caps, plinths, pits, trenches or any other feature breaking into the slab shall be bonded to the reinforcement in the slab in accordance with the above requirements.

Provision shall be made for connecting the equipotential bonding system in the ground slab to the station earthing system at not less than two points.

Provision shall be made for connecting the equipotential bonding system in the ground slab to holding down bolts associated with the steel columns, base plates and other steelwork which is not directly connected to the station earthing system.

The potential gradient control systems as achieved by the above measures shall be brought out approx. 200 mm above finished floor level and shall be connected at several points with the building steel structures unless already connected subgrade or to the main equipment earthing bus or directly with the subgrade electrode network or whatever is most suitable and/or applicable. The potential gradient control systems shall not. be used in lieu of or as a replacement of the equipment earthing system.

Connection of rebars to form interconnected grid 3 x 3 m, electrically bonded, approx. 100mm below Finished Floor Level, with connection points for earthing copper conductors.

### 5.1.10.3 Site Investigation

As soon as the Contract has been awarded, the Contractor shall carry out a complete and thorough topographical survey and subsoil investigation including physical and chemical tests on samples etc., to be used in the Civil Engineering design.

Before any work is commenced, the Contractor is to forward to the Employer 3 copies of a complete report on the topographical survey and subsoil investigation with foundation recommendations.

Existing soil reports are attached for information only.

### 5.1.10.4 Programme

The programme for the Civil Engineering and Structural Works shall be in the form of a master network with sub-networks as necessary.

The programme shall show all activities required for the proper and efficient programming and progressing of the Contract including, but not restricted to, start and completion of design stages, approval stages, procurement stages, manufacture, shipment, detailed site construction stages, erection and take over stages by the Employer.

Anticipated and actual resources to all activities shall be programmed and updated regularly.

### 5.1.10.5 Samples

Each supplier must be willing to admit the Employer to his premises during ordinary working hours for the purpose of obtaining samples of the materials. Alternatively, if required by the Employer, the Contractor shall deliver the samples of the materials to the Employer's site office.

Samples shall be taken in accordance with the relevant approved National Standard where applicable. Materials subsequently supplied shall conform within any specified tolerances in the quality of samples which have been approved.

### 5.1.10.6 Work Prepared off the Site

The Contractor shall give to the Employer written notice of the preparation or manufacture at a place not on the Site of the manufactured component to be used on the Works stating the place and time of the preparation of manufactures so that the Employer may make inspection at all stages of the Work and not only when the component is completed.

Any component which is prepared or manufactured without such notice having been given may be rejected if the Employer considers that his inspection was necessary during the progress of the preparation of manufacture.

### 5.1.10.7 Surface Levels and Water Levels

Before any work or any section of the Works is commenced all necessary levels, including ground water levels. shall be taken and agreed with the Employer and the recorded levels shall be submitted by the Contractor to the Employer in the form of a drawing.

### 5.1.10.8 Setting-Out

The setting-out shall be by means of rectangular co-ordinates. The principal axis of the coordinate system shall be parallel to the centre line of the buildings.

Before commencing any work of construction the Contractor shall establish at least four substantial and permanent monuments accurately fixing the two principal axes

Four permanent works bench marks shall be similarly established and shall be checked.

### 5.1.10.9 Drains, Streams, etc.

All drains, pipes, channels, water courses or streams and any other existing works temporarily cut through or disturbed by the execution of the Works are to be restored to the satisfaction of the Employer. The water flowing in them may continue to flow in a full and free manner as it did before the disturbance.

#### 5.1.10.10 Standardisation

In order that maintenance shall be simplified and the storage of spare parts be restricted to a reasonable minimum, the detail design of equipment and fittings is to allow for the maximum possible standardisation of equipment.

#### 5.1.10.11 Temporary Structures

The Contractor shall submit to the Employer for consideration completed drawings and calculations relating to strength and anticipated deflections of all temporary works and stagings he proposes to erect, not less than four weeks before putting such work in hand. The comments of the Employer shall not diminish the Contractor's full and entire responsibility in respect of such temporary works or stagings.

#### 5.1.10.12 Fences Cut Through

Fences forming boundaries of plot occupied by the Works shall not be cut through or destroyed for more than the distance necessary to permit the erection of new boundary wall etc., and the Contractor shall maintain the enclosure and security of all such plot.

#### 5.1.10.13 Existing Services

The Contractor shall locate all existing mains and services, whether or not shown on the tender drawings, and is to execute the in such a manner that he does not damage or interfere with such mains and services. The Contractor shall accept responsibility for damage or interference to these mains and services required by the execution of the Works and shall carry out all necessary repairs at his own expense to the satisfaction of the Employer.

#### 5.1.10.14 Assistance to Engineer

The Contractor shall provide all assistance required by the Employer.

#### 5.1.10.15 Roads

The road (6.0 m wide) for the plant within the boundary with curbs on both sides shall be graded to falls leading surface water into road gullies, open trenches or catch pits which shall be taken to the main surface water drainage system.

The road and pavement construction shall be of bitumen macadam or concrete respectively, to withstand the heaviest loads to which they may be subjected.

Lamp posts, LED street lamps and foundations every 20 m alongside every road.

#### 5.1.10.16 Existing Boundary Walls, Perimeter Fencing and Entrance Gates

The section of the structure required to be removed for transport of construction materials, mechanical and electrical equipment shall be rebuilt, to match the existing works.

### 5.1.10.17 Drainage System

Surface water drainage systems:- Surface water shall be collected into main open channel drains which are then to discharge into existing channel. Alternatively, the surface water is to discharge into approved properly designed disposal systems as approved by the Employer. The Contractor will be responsible for obtaining all necessary consents and approvals from the appropriate authorities for the discharge of water into existing systems or watercourses, etc.

Sewage drainage shall discharge into existing sewage systems in KPS.

The drainage system shall include all necessary gutters and down pipes from buildings, gullies, traps, manholes, lifting stations, retention basins and is to be laid to gradients sufficient to ensure self-cleansing velocities in the pipes.

Chemically soiled water shall be led to the neutralization pit and the neutralized water shall be directed to the drainage system.

### 5.1.10.18 Marine Works

Attention is drawn to the fact that the conditions on river coastline can make marine work particularly difficult. The Contractor will be deemed to have made full and proper allowance for this in assessing his programme of work and in allocating sufficient plant, supervision, etc., for the whole work to be executed in a responsible manner

### 5.1.10.19 Architecture

All buildings are to conform to the same architectural conception and shall be submitted for approval. All the buildings shall be provided with following materials and accessories as a minimum:

Roofing: up roofing on cladding or reinforced concrete.

Roof drainage: PVC or cast iron down pipes as per the requirement

Wall cladding: Gas Turbine Building above level + 2.5 m to Roof.

Exterior masonry: Gas Turbine Building ± 0 to + 2.5 m masonry walls with face bricks.

All other buildings ± 0 to roof.

Exterior masonry wall plastered inside and outside

Central Control Room ± 0 to Roof

All other buildings ± 0 to Roof

### 5.1.11 Embankments

Design calculations shall be submitted for the long-term stability of embankments or other soil improvements that will require.

## 5.2 Scope of Civil Engineering Works

### 5.2.1 General

The Contractor shall carry out demolition of all existing foundations and structures at the site and dispose to the satisfaction and approval of the Employer, removal of debris, backfilling and design, detail, procure, construct and commission the facilities given in the list below. Steel parts of the tanks should be handed over the Employer for later disposal. The facilities to be provided shall not be limited to the list given and the

Contractor shall ensure that all facilities required for the proper performance of the Works are provided by him. The Contractor shall also provide the other services listed under this sub-section.

The design shall comply with the codes and standards listed and both the materials and construction used shall comply with all the codes and standards listed in each sub-section.

### 5.2.2 List of Facilities

The Contractor shall design, detail, procure, construct and commission the following facilities in accordance with specification and standards listed elsewhere.

- Machine Foundation
- Control room building
- Canteen building
- Temporary Site Staff Office
- Emergency /Black Start Diesel Generator building
- Water Treatment Plant including modification to existing pump well of the old Steam Turbine Plant of KPS
- Exhaust stacks
- Transformer Bays
- Cable and pipe Trenches
- Water supply
- Surface Water Drainage
- Temporary fencing
- Roads and Surfacing
- Site Works

The Contractor shall design, detail, procure, construct and commission the following facilities in accordance with specification and standards listed elsewhere if applicable;

- Fuel Pump House
- Switchgear room
-
- Fire Pump House

### 5.2.3 Details of facilities

**5.2.3.1** Machine Foundation

The site area of the Machine Foundation shall be raised by1m from the existing ground level of Kelanitissa Power Station building.

The foundations shall be constructed of Sulphate resistant reinforced concrete on piled foundations. The foundation design shall be in accordance with the requirement and recommendations of the results of the soil investigations. The contractor shall take necessary approval before finalizing any design.

**5.2.3.2 Control room Building**

The Contractor shall design, construct and commission the control room building consisting of the following facilities. The building can even be a multi-storey with sufficient space for the facilities required.

- Central control room
- Engineers room for operation engineer with attached bathroom
- Meeting room
- Dining room
- bathroom for shift duty operators

The Central Control Room shall have a false floor covered by removable PVC tiles to enable easy routing of I&C, communication and power cables to the various workstations, computer peripherals etc. A matching PVC cover-type skirting shall be used in conjunction with the floor tiles.

**5.2.3.3 Canteen building/car park**

The existing canteen building should be demolished and new two storied canteen building shall be constructed with a minimum, total area of 2x400 square meters. Floor above the canteen area should be able as storage area of Kelanitissa premises in future. The area allocated for this building is marked on the "Map of the Kelanitissa Premises" Appendix-G where the existing car park is located. Ground level of the proposed building shall be capable of parking at least for ten (10) numbers of vehicles.

**5.2.3.4 Temporary Site Staff Office**

Two container offices shall be provided for a total 4nos. of occupants with safe accesses. It shall be completed immediately after the Contractor commences operations on the site, and available for Employer's use within one month after the award. The office shall be provided with electric lights, power points, two telephone sockets for CEB internal communication lines, Network sockets and approved quality air conditioning units of adequate capacity.

The office shall be installed and maintained at the contractor's expense until the Final Handing Over Certificate of the Power Station, when it shall be transferred to the CEB.

The Contractor shall maintain, repair the office equipment such as Photo copier/printer, fax, colour printer, personal computers etc. and allocate 2 employees for janitorial services throughout the duration of contract.

The Contractor shall provide in the offices the following equipment, to be approved by the Employer, and shall maintain it in good condition to the Employer's satisfaction:

Furniture of each office shall contain two office tables with lockable drawers, chairs, a full door cupboard and a First Aid Box.

Split type Air Conditioners of sufficient capacity shall be provided.

The facilities and all services specified above shall be provided and maintained to the Employer's satisfaction for such a period as the Employer may require, but not exceeding one month after the date of the final Handing over Certificate on the whole of the plant included in the Contract.

The offices and furniture shall become, upon completion of the Contract, the property of the Employer.



### 5.2.3.5 Emergancy /Black start Generator building

Steel framed building with infill panels of dense blockwork cavity wall. External wall face shall be completed with smooth finish of an approved colour. Internal walls shall be of fair faced of suitable thickness generally emulsion painted.

### 5.2.3.6 Water Treatment Plant including modification to existing pump well of the old Steam Turbine Plant of KPS

**Chemical Store**

Function: To store chemicals for the water treatment, capacity for the period specified in Section 07 of this specification.

Foundations: Sulphate resistant reinforced concrete on piled foundations. The foundations design shall be in accordance with the requirement and recommendations of the results of the soil investigations.

Superstructure: Reinforced concrete will be provided for all columns, floors and roof.

Floor: Reinforced concrete slabs with separate floor finish.

Roof: Built up roofing.

Floor finishes: Epoxy.

Walls: Masonry, plastered and painted.

Windows: Coated aluminium frame with single glazing.

Doors: Fire proof steel doors as required.

**Tanks**

Function: Specified in Section 07 of this specification.

Foundations: Sulphate resistant reinforced concrete on piled foundations as required for the components of the plant. The foundations design shall be in accordance with the requirement and recommendations of the results of the soil investigations.

Superstructure: Specified in Section 07 of this specification.

**Water Treatment Plant**

Function: To provide space for the water treatment plant equipment including, demineralization equipment, control room, electrical switchgear and toilet for WTP operators.

Foundations: Sulphate resistant reinforced concrete on piled foundations as required for the components of the plant. The foundations design shall be in accordance with the requirement and recommendations of the results of the soil investigations.

Superstructure: Reinforced concrete shall be provided for all columns, floors, and roof.

Floor: Reinforced concrete slabs with separate floor finish.

Roof: Built up roofing.

Floor finishes: Ceramic tiles, Acid proof ceramic floor tiles, non-skid ceramic tiles for office.

Walls: Interior masonry, plastered with acid proof tiles, or paint as required. Exterior masonry, plastered and painted.

Windows: Powder Coated aluminum frame with double glazing.

Doors: Steel and fire proof steel doors as required.

Crane: Monorail for maintenance.

**Modification to existing pump well of the old Steam Turbine Plant of KPS**

All necessary expansions, modifications or improvements shall incur minimum disturbance to the water supply of the existing IPP (Sojitz Kelanitissa Private Limited).

### 5.2.3.7 Fuel Pump House/ Fuel Treatment House

Floors shall be power floated treated with a skid and oil resistant paint.

Ventilation shall be by natural air flow. Adequate protection shall be given to the pumps and associated equipment from malicious damage.

#### 5.2.3.8 Exhaust Stacks

Exhaust stacks shall be provided to accommodate the exhaust flues from of the power station. The height of the chimney shall be according to the local EIA requirements but not less than 38m. The stacks structure shall be of steelwork designed with adequate structural stiffeners.

#### 5.2.3.9 Switchgear room

Foundations shall be reinforced concrete. Foundation pilling shall be provided if necessary. The building may have a reinforced concrete or a steel frame and air conditioned. High Level windows shall be provided and a number of these shall be opening lights, to provide adequate natural ventilation in the event of the air conditioning failing.

Cable trenches in the building shall have covers finished with the same material as adjacent floors.

Particular attention must be given in the design of the building and layout to fire prevention and safety of personnel at all times. The building shall be designed as far as practicable to exclude pollution under all likely weather conditions. Fireproof or flame - retarding materials are to be used for floor, wall and ceiling finishes.

A clearance of 1m between the top of equipment and any fittings suspended from ceilings shall be the criteria governing room heights.

#### 5.2.3.10 Transformer Bays

Transformers shall be surrounded by a low wall enclosing an area in which the oil content of the transformer will be contained and Chain link fences shall be constructed of PVC coated steel wire. The area shall be surfaced with depth of stone chippings supported on a steel grillage. The void thus formed below shall be drained to a central oil storage pit serving all transformers. Rainwater shall be removed independently of any oil spillage by means of siphons or other approved method which shall not contaminate surface water discharge. Fire wall to be included if the transformers are close by.

#### 5.2.3.11 Fire pumps and WTP intake Pump House

Steel framed structure located adjacent to existing fire pump. A shelter with monorail and hoist will be provided for weather protection and pump maintenance. The Contractor shall provide the deemed necessary modifications/ improvements to the existing pump well of KPS, that will require for the fire pumps installation specified under Clause 6.3 and WTP intake Pumps installation specified under Section 07 of this specification. These modifications shall incur minimum disturbance to the water supply of the existing IPP which is using the same water pump well.

#### 5.2.3.12 Cable,Pipe Trenches and Cable Pits

These shall be a minimum of 450mm deep by 700 mm wide with block- work of concrete walls on concrete floor slabs. The walls and bottom shall be treated with a waterproof membrane to prevent the ingress of water. Covers shall be precast concrete and shall have a lifting device for maintenance purposes to the approval of the Employer. Covers in rods or trafficked areas shall be heavy duty and capable of supporting any load likely to be imposed but in no case shall this be less than a point load of 40 kN. Provision shall be made for sealing the covers with a bitumen compound. All covers shall be anti-rock mounted and the means of allowing surface water to drain out and conducted to the surface water system shall be provided. In order to remove accumulated water, permanent submersible pumps shall be provided at intervals on bottom of the trenches.

Cable pits shall be provided at required connection points where necessary for maintenance and inspection with space for at least 10 people. Cable pits foundation shall be reinforced concrete.

#### 5.2.3.13 Water supply

The water supply to be installed using town water (National Water Supply & Drainage Board of Sri Lanka) supply for use of Employer's site office permanent washrooms etc. A town water connection pipeline shall be provided with proper sand bed, protection sleeves under road crossings, valves, isolating flanges, water metering instruments and pressure reducing valves.

#### 5.2.3.14 Surface Water Drainage

All surface water shall be collected from buildings, gullies etc. and discharged through a proper drainage system. It is the Contractors responsibility to determine whether the existing drainage system will be adequate for the additional flows. If there is a shortfall in the existing drainage capacity, it will be necessary to lay new drainage to discharge at a convenient point downstream of the site. Special consideration shall be given to the use of cut-off drains to embankments and cuttings to prevent erosion during heavy rains. This water shall form part of the surface water discharge system.

#### 5.2.3.15 Temporary Fencing

The section of the fencing structure required to be removed for transport of construction materials, mechanical and electrical equipment shall be rebuilt to match the existing works.

#### 5.2.3.16 Roads and Surfacing

Access roads will be required around the plant. The roads should be designed to be capable of carrying the heaviest vehicles that will need access to the station. All internal and external roads shall be concrete roads and external roads shall be overlaid by Asphalt Concrete.

#### 5.2.3.17 Site Works

Site clearance shall include removal of the existing foundations (Steel and the reusable materials shall be handed over to CEB), grubbing up of all bushes within the site boundary except where otherwise directed by the Employer. Areas to be subsequently landscaped shall have root holes filled, trimmed and levelled. The extent of excavation or boring required is dependent on the final configuration of the power house and the depth to the hard rock layer. If some rock will need to be removed, it should be noted that blasting will not be permitted due to the risk to the nearest working power stations and offices.

Excavated material may be removed from site or if suitable incorporated in the works. Before commencement of this work the Contractor shall submit a method statement for the approval of the Employer in accordance with Clause 8.6.

Any sound barrier required to meet the standard sound levels to be constructed by the Contractor. Perimeter lighting shall be provided.

## 5.3 Design criteria

### 5.3.1 General

The Contractor shall design, detail and draw all facilities to the appropriate standards and codes given below and also those standards has to be replaced with the new version where ever applicable.

### 5.3.2 Standards

| **Title** | **Subject** |
|---|---|
| BS 5950 | The structural use of steelwork in building |
| BS 2853 | Specification for the testing of steel overhead runway beams for hoist blocks |
| CP 3- Chapter 5 | Loading. Wind loads |
| CP 102 | Protection of buildings against water from the ground |
| BS 8110 | Structural use of concrete |
| BS 5628 | Use of masonry |
| BS 5268 | Structural use of timber |
| CP 143 | Sheet roof and wall coverings |
| BS 6262 | Glazing for buildings |
| BS 8301 | Building drainage |
| BS 6297 | Design and installation of drainage fields for use in wastewater treatment |
| BS 5720 | Mechanical ventilation and air conditioning in buildings |
| BS 5930 | Ground investigations |
| BS 6031 | Earthworks |
| BS 8004 | Foundations |

| | |
|---|---|
| BS 8005 | Sewerage |
| CP 2012 | Foundations for machinery |
| BS 8888 | Technical product documentation and specification |
| BS 1192 | Collaborative production of architectural, engineering and construction information |
| BS 6399 | Loading for Buildings |
| BS 5400 | Steel, concrete and composite bridges |

All design works, drawing and detailing shall use the SI Units. The sequence of submission of all drawings, data and samples shall be such that all information required for review shall be available. A letter of transmittal shall accompany each submittal. The Contractor shall allow at least 28 days upon receipt of drawings and calculations for review by the Employer unless otherwise stated in the Contract.

### 5.3.3 Drawings

The Contractor shall submit 3 hard copies and a 3 soft copies of all drawings in AutoCAD 2017 or later and Adobe Acrobat formats, prepared by him or his sub-Contractors, to the Employer for approval.

### 5.3.4 Calculations

All calculations related to civil, structural and services works shall be submitted to the Employer. Three (3) copies of all calculations under Contractor's letterhead shall be submitted by the Contractor. Such submittal shall be made not less than thirty (30) days prior to the time that the materials represented by such calculations are needed for incorporation into any work. Calculations shall be subject to review and material dependent upon such calculations shall not be incorporated into any work without any such review. Review period shall not exceed 21 days for a submission after comments.

Calculations shall clearly identify the subject of the calculations and shall include but not be limited to providing the following information:

Project name
Contractor's name
Contract number
Name of the item
Assumptions used in the design
Codes used
Loadings used
Date of Calculation
Calculation
Reference sources

Manufacturers' names and literature

Reference to the appropriate drawing

Technical specification section and paragraph number

Control register reference all as applicable.

If specific tests are required, reference to such test results shall be indicated.

All calculations shall be on A4 size paper and shall be bound in stiff-backed ring binders. The covers shall indicate the Project name, Contractor's name, the Contract name, the title of the calculations, the date of sub-mission and the revision letter of the calculations.

All printouts shall be bound into an appropriate binder with a cover which shall indicate the Project name, Contractor's name, the Contract name, the title of the subject, the date of submission and revision letter of the printout.

Where use is made of a computer, details shall be given of the programs used and any certification of approval by independent authorities shall be given for the programs used.

### 5.3.5 Drawing standards and level of detail

All drawings prepared by the Contractor shall be in accordance with BS 8888 or other approved standards and the following procedures:

Drawings and data sheets prepared by the Contractor shall include complete construction details. The drawings shall include but not be limited to the following information or detail as applicable: construction joints, bar bending details, details for unusual or special items for formwork, special trenching, structural steel detailing, architectural drawings for doors, windows, hardware and schedules.

Alphabetical revisions (A through Z) shall be used for drawings issued for construction. Specific changes shall be clearly designated on the drawings with the revision letter shown in an adjacent triangle. All revised portions shall be delineated by a cloud symbol.

All drawings shall be drawn, designed, checked, reviewed and signed by the Contractor before submittal.

All drawings shall be drawn in A1 size except detailed drawings. The Contractor shall submit 3 copies of all final drawings with 3 Soft copies.

All drawings produced by the Contractor shall use the same drawing number system. The system shall be consistent and logical and shall identify each drawing size, subject, discipline and revision.

Review of Contractor's submitted drawings or documents by the Employer shall not relieve the Contractor of any of his obligations to meet all the requirements of the Contract nor relieve the Contractor of the responsibility for the correctness of such drawings and documents. The Contractor shall make any changes which are necessary to make the Work conform to the provisions and intent of the Contract.

The Contractor shall maintain an up to date drawing register. This register shall list all drawings produced by him and shall contain the following information for each drawing

- Drawing title, number and revision
- Planned issue date for Employer review
- Estimated issue date for Employer review
- Actual issue date for Employer review
- Percentage completion
- Review status
- Planned issue date for Site
- Actual issue date for Site.

The drawing register shall be kept on A3 size sheets bound copies and soft-copy shall be delivered to the Employer each month throughout the contract or more frequently if required by Employer.

### 5.3.6 As-Built drawings

As-Built drawings shall be submitted to the Employer monthly as work proceeds. They shall contain details of all construction works completed to date and details of all changes to the facilities made on site and not yet incorporated into an approved revised drawing.

The Contractor shall use reproducible copies of approved drawings with soft-copy to convey the information. All drawings shall be dated and marked up as "AS BUILT".

### 5.3.7 Design loadings

The Contractor shall design each facility for the following minimum load conditions and the forces that arise from them.

(A). Dead Loads

All loads arising from the mass of the materials that make up the permanent works.

(B). Live Loads

All live loads arising from traffic, cranes, users of facilities, water storage etc. These shall be calculated using BS 6399: part 1 and shall represent a minimum load to be taken; where specific live loads are known then they shall be used if they exceed those determined by BS 6399: part 1.

For the machine hall and the mechanical and electrical installations the following criteria shall be used for the design of the suspended floors:-

1. Areas required to support plant are to be designed for the actual plant load or an imposed load of 10.0 kN/$m^2$whichever is greater.

2. Laydown areas/loading bay shall be designed for the maximum actual laydown load, or an imposed load of 10.0 kN/m$^2$whichever is greater.

3. Circulation spaces around plant and laydown areas are to be designed for an imposed load of 7.5 kN/m$^2$.

4. Control room floor shall be designed for an imposed load of 5.0 kN/m$^2$.

(C) Wind Loads

All loads arising from wind as determined by CP3 Chapter 5-Part 2. The basic wind speed shall be 40 meters per second.

- Factor $S_1$ (Topography): Due to significant local topography, to be within the range $1.0<S_1<1.36$, calculated (in accordance with Colombo Metrological Data & Weather Parameters for Design) of the above design code referred.
- Factor $S_2$ (Ground roughness, building size etc.); as appropriate for Category (2) —Open country with scattered windbreaks.
- Factor $S_3$ (Statistical) = 1.0

The above does not relieve the Contractor of his obligation to conform to any relevant local statutory regulations, by laws or orders currently in force.

(D) Earthquake Loads

Earthquake loads are to be calculated in accordance with American National Standard A58.1-1982 using the following:-

- Seismic Zone = 0
- Occupancy Importance Factor I = 1.5

(E) Road and Pavement Loads to BS 5400.

### 5.3.8 Fire Protection

To restrict the spread of fire and for the protection of escape ways, all solid floors and certain walls shall be designated as Fire Compartment Walls and shall have a minimum fire resistance of 1 hour.

All corridors and stairways shall be enclosed within Fire Compartment Walls. In addition, Fire Compartment Walls shall be provided between the following rooms and the main turbine hall.

(i) Relay Room

(ii) Control Rooms

(iii) Emergency /Black start generator

(iv) Switchgear Room

(v) Transformer area

All the window sets overlooking the main turbine hall from any of the above rooms shall be smoke and fire rated for at least one hour and provide suitable sound insulation properties.

All structural steel shall be protected or designed in accordance with good fire Engineering practice, to have a fire rating of 01 hour up to a height of 6 meters, and for hour above this level with the exception of the support steel to control room, switch rooms and offices which shall be designed to have a 01-hour fire rating.

All connecting door sets between the existing power station and the new power station shall be 01-hour fire rated and fitted with smoke seals suitable for the location.

All doors penetrating Fire Compartment Walls shall be 01-hour fire rated ad fitted with smoke seals suitable for the location.

All fire rated doors shall be fitted with automatic door closure devices.

All doors located on fire escape routes shall be fitted with signs on both faces of the door to BS 5499 and open in the direction of escape.

## 5.4 Setting out data and tolerances

### 5.4.1 General

The Contractor shall be responsible for all setting-out, irrespective of any checking by the Employer. The accuracy of all setting-out shall be better than ± 1 part in 4,500.

The Contractor shall advise the Employer within 24 hours whenever a new setting-out peg is established or an existing one destroyed, and shall regularly furnish the Employer 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 Employer.

The tolerances shown below shall rule on site unless the Contractor at time of tender proposed alternatives approved by the Employer.

### 5.4.2 Blockwork

(1) Position in plan

Fair-faced or specified side from
the designed position ± 15 mm

| | | |
|---|---|---|
| (2) | Length | |
| | Up to and including 5m | ± 15mm |
| | Over 5m up to and including 10m | ± 25mm |
| | Over 10m | ± 25mm |
| (3) | Thickness | |
| | More than one block | ± 15mm |
| (4) | Height | |
| | Up to and including 3m | ± 15mm |
| | Over 3m up to and including 6m | ± 20mm |
| | Over 6m | ± 25mm |
| (4) | Thickness | |
| | More than one block | ± 15mm |
| (5) | Level of bed joints | |
| | Length up to but not exceeding 5m | ± 10mm |
| | Over 5m but not exceeding 10m | ± 15mm |
| | Over 10m but not exceeding 20m | ± 20mm |
| | Add for every 5m | ± 5mm |
| (6) | Straightness | |
| | In any 5m (not cumulative) | 10mm |
| (7) | Vertically | |
| | In any 3m | ±15mm |

Load-bearing blockwork should not deviate more than 15mm from the vertical in their full height.

Walls which are not load-bearing, but are required to be built to this accuracy are especially specified as such.

**5.4.3 Permissible deviations on in situ concrete and on erection (Only for precast concrete)**

**5.4.3.1 Plant Foundations**

| | | |
|---|---|---|
| (1) | Position of centre line on plan from nearest building grid line | ± 10mm |
| (2) | Dimensions on plan | -5mm +20mm |
| (3) | Formation level | ± 25mm |

| | | |
|---|---|---|
| (4) | Surface level | -5mm +0mm |
| (5) | Sleeved bolt location | ± 15mm |
| (6) | Sleeved bolt plumbness | 1 in 100 |
| (7) | Cast-in bolt location | ± 2mm |
| (8) | Cast-in bolt plumbness | 1 in 300 |
| (9) | Bolt level | 0mm +20mm |

(N.B. - Where tolerances 5 & 6 conflict with 7 & 8 the latter shall govern.)

**5.4.3.2 Other - Foundations**

| | | |
|---|---|---|
| (1) | Position of centre line on plan from nearest building grid line | ± 25mm |
| (2) | Dimensions on plan | 35mm per m (maximum 35mm) |
| (3) | Formation level | ± 25mm |
| (4) | Surface level | ± 20mm |
| (5) | Cast-in bolt location | ± 10mm |
| (6) | Cast-in bolt plumbness | + 1 in 100 |
| (7) | Location of one bolt in a given group from any other in the same group | ± 5mm |

**Components above Foundations (Except Items Listed Below)**

| | | |
|---|---|---|
| (1) | Position of centre line on plan from nearest building grid line | ± 10mm |
| (2) | Vertically: Plumbness in height of | |
| | Up to 0.5m | ± 5mm |
| | Over 0.5m to 1.5m inclusive | ± 10mm |
| | Over 1.5m to 3m inclusive | ± 15mm |
| | Over 3m to 30m inclusive | ± 20mm |
| b. | Cross section and linear dimensions of beams, slabs, columns and walls Up to 300mm | ± 5mm |
| | Over 300mm to 600mm | ± 10mm |
| | Over 600mm to 1.5m | ± 15mm |
| | Over 1.5m to 3m | ± 20mm |
| | Over 3m | ± 30mm |
| c. | Level of specified surface relative to the nearest TBM | ± 10mm |

**Overall Dimensions of a Concrete Framed Building**

| | | |
|---|---|---|
| (1) | Length and width measured at external Ground level: | |
| | For dimensions up to and including 15m | ± 25mm |
| | For dimensions over 15m up to 30m | ± 50mm |
| | For each subsequent 30m | ± 20mm |
| (2) | Height to structural roof level with reference to the transferred bench mark | ± 25mm |

**Steel framed buildings:**

| | | |
|---|---|---|
| (1) | Position of first erected column | ± 10mm |
| (2) | Linear dimensions: | |
| | Up to 8m | ± 10mm |
| | From 8m to 15m | ± 15mm |
| | From 15m to 25m | ± 20mm |
| | Over 25m | ± 25mm |
| (3) | Plumb of columns in 30m height | ± 15mm |
| (4) | Level of base of first erected column | ± 5mm |
| (5) | Level of beam at junction with column measured from transferred bench mark | ± 15mm |
| (6) | Level of beam at junction with column measured from transferred bench mark of storey in which beam is located | ± 10mm |
| (7) | Levels of upper or lower surfaces of two or more beams meeting at a column | ± .5mm |
| (8) | Difference in level of ends of a beam: This sub clause is additional of BS 5606: 1990 Tolerances are: | |
| | Up to 8m long | ± ..5mm |
| | From 8m to 15m | ± 10mm |
| | From 15m to 25m | ± 15mm |
| | Over 25m | ± 20mm |

## 5.5 Site investigation

### 5.5.1 General

The Contractor shall execute all the necessary tests to provide adequate information to support his foundation design and the cost shall be allowed for in his tender price. The tests shall include but not be limited to:

- Borehole investigation
- Taking and Testing (in-situ) samples of soil, rock and water encountered in these boreholes.
- Carrying out in-situ cross-hole seismic tests.
- Carrying out electrical receptivity tests.
- Carrying out laboratory tests on samples of soil, water and rock taken from boreholes.
- Preparing and delivering preliminary reports on a weekly basis.
- Preparing Engineering analysis, making foundation recommendations and consulting with the Employer.
- Carrying out a detailed site topographical survey and delivering 3 copies of the site plan.
- Preparing and delivering 3 copies of the Final Report.

### 5.5.2 Underground Services

The Contractor is responsible for obtaining information regarding the position of existing services from the relevant authorities.

Great care shall be exercised in sinking boreholes for the first 2.0m any damage caused to existing underground services shall be covered by the Contractor's insurance.

### 5.5.3 Contractor's Labour

The boring operations shall be carried out by competent crews under qualified supervision.

### 5.5.4 Results and Samples

All results of the surveys and investigations shall be deemed to be the property of the Employer and shall not be divulged to anyone other than the Employer. All cores, samples and other materials recovered from boreholes shall also be deemed to be the property of the Employer and the Contractor shall not dispose of any material and samples except as directed by the Employer or its representative. The Contractor shall allow for storing all samples in a proper manner until the completion of the Contract, whereupon they shall be delivered to the Employer.

### 5.5.5 Standards

Except as otherwise specified, the works included in the Contract shall be carried out in accordance British Standards BS 5930:2015- Code of practice for ground investigations, BS 8004:2015- Code of Practice for Foundations, BS 1377-1:2016- Methods of test for soils for Civil Engineering purposes and BS 7430:2011**-** Code of practice for protective earthing of electrical installations.

### 5.5.6 Boreholes

(a) The accuracy of setting out the boreholes shall be ±0.5 metres in plan. Measurement of the depth of borings shall be taken from the level at which the casing enters the ground in addition to the ground level related to ordinance datum.

(b) Borehole shall be terminated at the depth shown on the site layout plans.

(c) Boreholes shall be made by:

i). Light percussive boring

ii). Mechanical continuous flight augers.

iii).Rotary open hole drilling in soils, rotary core drilling using casing and drilling mud where necessary in rock. The minimum diameter of extracted rock core shall be not less than 70mm.

(d) All boreholes shall be backfilled with excavated material except, where artesian water is encountered where grout shall be used. The type cement shall be ordinary Portland Cement.

### 5.5.7 In-Situ Samples

(a) For cohesive soils, undisturbed sampling using U100 or Denison samplers shall be carried out at 1.5m intervals and at changes in strata.

(b) For cohesion less soils, Standard Penetration tests shall be carried out at 1.5m intervals and at changes in strata. Where conditions permit split spoon samplers shall be used. When the SPT value is less than 20, the testing interval shall be reduced to 0.75m. The depth interval shall be from the top of one test to the top of the proceeding one.

(c) In cohesive soils in in-situ vane test to BS 1377 shall be carried out. Where site conditions or availability of equipment prohibits this test an alternative hand held vane will be acceptable. The rate of testing shall be as for cohesive soils.

(d) For rocks, continuous rotary coring shall be employed. The diameter of the resulting sample shall not be less than 70mm. Consideration shall be given to the use of liners in weak weathered rock.

(e) Samples taken from rock core runs shall be measured for:

- Total core recovery :- the length of the total amount of core sample recovered expressed as a percentage of the length of core run.

- Solid core recovery :- the length of core recovered solid cylinders, expressed as a percentage of the length of the core run.
- Rock Quality Designation :- the sum length of all core pieces that are 10cm or longer, measured along the centre line of the core, expressed as a percentage of the core drilled.

(f) Undisturbed cores shall remain in the sampler tubes and their ends shall be covered with 3 layers of melted wax. Disturbed samples shall be protected by two layers of muslin and three layers of wax.

(g) Rock core samples shall be carefully extruded and continually supported into a thin gauge polythene tube. The sample shall then be placed into a stout wooden core box divided longitudinally and placed in the sequence of extraction, suitably notated.

### 5.5.8 Ground water levels observations

(a) The phreatic water level shall be determined by dipping the boreholes. Where collapse of the boreholes occurs, casing shall be used and left in place until the water level remains constant for two consecutive days.

(b) Artesian water pressures shall be measured by the use of piezometers to be approved by the Employer.

### 5.5.9 Cross-Hole Seismic Test

Knowledge of the dynamic characteristics of the soil and rock is required and therefore the Contractor shall perform a cross-hole test.

This test is now well documented and the following is given as guideline only and shall not restrict the Contractor to alternative methods providing these are to the approval of the Employer.

The purpose of the test is to measure at different depths the compression and shear wave velocities. It is achieved by inputting an energy or excitation source in one borehole and measuring the time required for the primary and shear waves to travel to a sensing borehole. The boreholes are placed a set distance apart and knowing the time of travel the velocity may be calculated.

Excitation is achieved by striking a drill rod with a hammer which is electrically connected to the time base of the recording unit. A geophone (velocity transducer) is placed into the sensing borehole and this is also connected to the recording unit.

The recording unit shall be a seismograph which should have the following features.

i). Ability to —freeze the trace.

ii). Possess a moveable cursor

iii). Measure time in mil-seconds

iv). Signal enhancement

Particular requirements of the test are:

i). The distance between boreholes shall be not less than 5 metres.

ii). A minimum of three tests per depth shall be carried out.

iii). Depth interval shall be 1.5 metre.

iv). Maximum depth shall be 15 metres.

v). First and second arrivals shall be measured and recorded for each test.

### 5.5.10 Laboratory Tests

The Contractor shall transport samples to an approved laboratory for testing and shall require to provide the design information required. Laboratory test shall be carried out in accordance with BS 1377-1:2016.

#### 5.5.10.1 Unconsolidated Undrained Triaxial Compression Test

A minimum of three specimens shall be used. Each specimen shall be loaded to different cell pressures which are double the previous pressures.

The pressures chosen shall reflect the in-situ of the sol the imposed loads.

#### 5.5.10.2 Consolidated Undrained Triaxial Compression Test

A minimum of three specimens shall be tested. The consolidating pressure shall reflect the range of in-situ stresses. Consolidations shall be carried out against a back pressure. Pore water pressures shall be measured and recorded.

#### 5.5.10.3 Consolidated Drained Triaxial Compression Test

A minimum of three specimens shall be used. The consolidating pressure shall reflect the range of in-situ stresses and be carried out against a back pressure. The result shall be given as the cohesion and friction angle in terms of effective stress.

#### 5.5.10.4 Shear Box Test

For granular materials a shear box test shall be carried out. The range of normal stress shall reflect in-situ overburden stress.

A minimum of three specimens shall be used.

#### 5.5.10.5 Ring Shear Test

In order to determine the long-term residual strength parameters for over consolidated clays the ring shear apparatus shall be used.

#### 5.5.10.6 One Dimensional Consolidation Test

The deformation properties shall normally be determined by the one dimensional consolidation test (Oedometer). The sample shall be saturated and the range of applied pressure shall fully reflect the in-situ conditions of load.

Graphs showing void ratio (e) and applied pressure shall be submitted along with the Coefficient of Compressibility for the range of loading anticipated. Alternatively, the compression index may be quoted for normally consolidated clays.

The coefficient of consolidation shall be in $m^2$/year and shall be recorded for each load increment. The Casagrande construction shall be used to Determine the pre consolidation pressure which shall be recorded. A minimum of 4 tests shall be undertaken.

#### 5.5.10.7 Point Load Test

Rock samples shall be tested for compressive strength using the point load test. The result shall be recorded as the point load strength index Is.

### 5.5.11 Electrical Resistivity

The electrical resistivity of the soil shall be verified at three locations, as directed by the Employer. The test shall be carried out to BS 7430.

### 5.5.12 Site Survey

- The Contractor shall carry out a topographical survey of the sites to establish the plot boundaries and points of reference.
- The Contractor shall carry out a level survey on a 10 grid and levels shall be related to ordinance datum.
- The location of the boreholes and other test positions shall be shown.

### 5.5.13 Daily Field Logs

- Daily field logs shall be delivered to the Employer daily.
- Logs shall include:
- Size and depth of casing
- Method of boring and tools used

- Samples taken
- Soil or rock description to BS.5930:2015
- Water levels and water added (if any)
- Signature of driller/ supervisor

### 5.5.14 Final Report

- The final report shall be delivered within four of the date of completion of the site investigations.
- The Contractor shall submit either copies of the final report incorporating all data and interpretation of the data as a result of the survey in accordance with this specification
- The final report shall recommend appropriate forms of foundations and provide all necessary foundations design parameters and estimates of likely associated settlements. It should contain a list of probable construction difficulties and their solutions.
- Borehole records shall be submitted with the final report and shall Conform to BS.5930:2015 and shall include:

  i). Date on which hole was made and name of supervisor. ii). Total depth of hole.

  iii). Depth for which casing was used and diameter of such casing and of uncased hole.

  iv). Water Levels with full details of fluctuation.

## 5.6 Excavation and earthworks

### 5.6.1 General

The whole of the excavations shall be carried out to the widths, lengths and depths described or directed and no unlicensed or indiscriminate digging is permitted.

Before any excavation is begun the levels of the original surface shall be agreed between the Employer and the Contractor and such agreement recorded on drawings which shall be signed by the Employer and the Contractor. The Contractor shall provide all labour and instruments required to obtain and record these levels.

The Contractor may excavate by any method he considers suitable, subject to the Employer'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 shall be held responsible for protecting existing structures from settlement due to the new excavations, and shall, at his own expense, take any remedial action the Employer shall consider necessary, should this occur.

Before borrow pits are opened up the Contractor shall obtain the approval of the Employer for their location, depth, side batter, and drain-age proposals, etc.

The Contractor shall employ only that plant which is suited to the soils to be handled. He shall not at any time use any plant which damages or reduces the natural strength of the soil either in its in-situ state or during handling and placing or in its final compacted state.

The Contractor shall ascertain the location and nature of any existing substructures and services, and shall take every necessary precaution against damaging or interfering with them during excavations.

The Contractor shall provide all strutting and shoring necessary for the safe execution of the Works and shall allow for risk of meeting and excavating through any sort of material encountered, including rock.

### 5.6.2 Excavated materials

Materials from the excavation may, if approved by the Employer, be used by the Contractor in the construction of parts of the Works. Other excavated material shall be used as backfill where required or deposited where directed anywhere on site. Surplus material 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.

Where the excavation reveals a combination of suitable and unsuitable materials the Contractor shall, unless otherwise agreed by the Employer, carry out the excavation in such a manner that the suitable materials are excavated separately for use in the Works without contamination by the unsuitable materials.

### 5.6.3 Bottom layer of excavation

The bottom level of all excavations for foundations shall be inspected and approved by the Employer before foundations are constructed.

In excavations for foundations, a bottom layer of excavation 75mm 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. Alternatively, the excavation may be taken lower than structural foundation level and immediately protected by a layer of concrete blinding.

The bottom of all excavated areas shall be trimmed, leveled and well rammed if it is applicable.

If more than 24 hours elapse between the Employer giving approval to the foundation and the Contractor wishing to concrete over the bottom level then the Employer's approval must be re-obtained before foundations are constructed.

### 5.6.4 Removal of water

The excavated surfaces shall be kept dry and clean by pumping *or* any necessary method (including complete site de-watering systems). The proposed method shall be submitted to the Employer for his approval. The cost of pumping or other de-watering shall be covered by the Contractor in his tender. No concrete, masonry, brickwork or other materials shall be placed or built until the surfaces are properly drained. Special pre-cautions are to be taken to prevent water coming into contact with create or mortar whilst they are setting.

Water pumped from excavations shall not be allowed to enter any permanent drainage system without the sanction of the Employer.

In any lowering of water table, the Contractor shall pay due regard to the stability of all existing neighbouring structures.

### 5.6.5 Filling and reinstatement

Any fill material within 500mm of concrete structures or cement bound materials shall have a soluble sulphate content not exceeding 2.5g per when tested in accordance with BS 1377 unless special pre-cautions to the approval of the Employer are taken to protect the concrete or cement bound materials.

Filling for trenches, excavations, levelling and building-up of the site shall be deposited in layers not exceeding in thickness, each layer watered when necessary and well rammed or otherwise consolidated to within 95% of the maximum dry density obtained by the use of the British Standard compaction test. All equipment for determination of the specified density shall be supplied by the Contractor and all tests shall be carried out in the presence of the Employer.

Where excavations, whether in rock or other material, are made to a greater depth than shown on construction drawings, the intervening space shall be brought up to the proper level in Lean-mix concrete at the Contractor's expense. Excavations of greater width than required shall be filled and tightly packed with approved material at the Contractor's expense.

Any ground encountered in the excavations which, in the opinion of the Employer, is not sufficiently good to carry the loads which will be imposed on it shall be excavated and replaced with Lean-mix concrete or as directed otherwise by the Employer.

All equipment for determination and checking of the density of filled areas shall be supplied by the Contractor and all tests carried out in the presence of the Employer. The tendered price is deemed to include for this.

### 5.6.6 Slips and settlements

The Contractor shall supply and fix all necessary timbering, steel sheeting, strutting, shoring, etc. to support the sides of excavations so as to ensure the safety of workmen, freedom from damage of any structures or services and to prevent any movement of adjacent soil. All such supports shall be maintained until the constructional works is sufficiently advanced to permit the timbering, etc. to be withdrawn.

Where directed by the Employer or his Representative, timbering, sheeting or other excavation supports shall be left in to safeguard ad-joining structures. The Contractor will be paid the scheduled price for the materials used. Any timbering or sheeting not ordered to be left in by the Employer or his Representative but left in for the convenience of the Contractor will not be the subject of any additional payment.

Should any slips 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 form, and with such materials as the Employer shall direct, free of charge.

The Contractor shall make good all settlement of filling that may occur up to the end of the period of maintenance at his own expense.

### 5.6.7 Removal of topsoil

In areas of general excavation for site levelling all top soil shall be removed. In the areas shown on the drawings where excavated or imported fill material is required to raise the existing levels to a new formation level the top soil shall be removed prior to placing of the fill material. Top soil removed as described shall be deposited in dumps at a location approved by the Employer. Top soil shall be used as required for soiling slopes and grass areas and the remaining dumps shall be levelled and trimmed to stable slopes to the satisfaction of the Employer.

### 5.6.8 Areas of fill and embankments

The Contractor shall supply the Employer with fully detailed plans and programmes indicating precisely his proposed sequence of working in order that quality of fill may be efficiently monitored. Filling operations must be so planned that the areas of unfinished work left exposed to the elements is the minimum possible.

All earthwork top surfaces shall be finished level and regular and the sides of cuttings and embankments shall be properly trimmed to the de-tailed slopes as they become consolidated. Embankments and cutting slopes shall be well forked, raked and grass seed sown or turf laid, to stabilize the surfaces against erosion.

## 5.7 Piling work

### 5.7.1 General

The work to be carried out under this specification includes all labour, equipment, materials and auxiliary works as required.

Piling work shall be in accordance with the approved Drawings and as specified or as directed by the Employer.

The piles shall be designed to cater at least twice the working load and this shall be determined by normal design procedures and by the use of at least one preliminary test pile of each type.

The piles shall be adequately anchored into pile caps in accordance with Seismic design practice.

The contractor can propose any type of pile and method of installation approved by the Employer.

In addition to preliminary load testing of Test pile, 02 numbers or 2% of working piles, whichever is greater, shall be proof load tested in accordance with relevant standards.

### 5.7.2 Materials

Materials and equipment of the Contractor may be used but shall be in good repair to meet the requirements.

Materials which are to be permanently incorporated in the work shall be new and unused and shall be in accordance with the relevant standards.

For cement, water, additives, aggregates, and reinforcement steel, the regulations mentioned under Clause 8.8 shall apply. Minimum cement content 380 kg/$m^3$.

### 5.7.3 Execution of Work

#### 5.7.3.1 Cast-in-Place Concrete Piles

The Contractor can adopt any of the types given hereunder or propose an alternative type.

**Type A -** These piles shall be formed by driving a shell to the required bearing depth, leaving the shell permanently in place, and filling it with concrete. Shells shall have sufficient strength and rigidity to permit their being driven and not distorted by soil pressure or the driving of adjacent piles; they shall be sufficiently watertight to exclude water during placing of concrete. Piles may be tapered or cylinder. If tapered they shall increase uniformly in diameter or the diameter shall increase in uniform steps. The minimum diameter of tapered piles shall be 20 cm at the point and 35 cm at the head. The average diameter shall not be less than 28 cm. The minimum diameter of cylindrical piles shall be 30 cm. No concrete shall be placed until all piles in a cluster have been driven and approved.

**Type B -** These piles shall be placed by driving a heavy steel pipe casing with an interior core or point to the required depth, removing the core and inserting a permanent steel shell, filling it with concrete, and then withdrawing the driving casing. Shells shall have sufficient strength and rigidity not to be distorted by soil pressure or the driving of adjacent piles, and they shall be sufficiently watertight to exclude water during placing of concrete. Shells shall be cylindrical with a minimum diameter of 30 cm. No driving casing shall be withdrawn until all piles within 3.00 m, center to center, have been driven.

**Type C -** These piles shall be placed by driving a heavy steel pipe casing with an interior core or point to the required depth, removing the core, and filling the driving casing with concrete while withdrawing the casing. The inside of the driving pipe shall be at least 35 cm in diameter, and no driving pipe shall be withdrawn until all piles within 3.00 m, center to center, have been driven.

**Type D -** Bored piles shall be installed by advancing a steel casing down to the required depth, removing soil and rock from inside the casing and placing a reinforcement cage and concrete, and if conditions require where water is met by, underwater concreting technique.

Water or mud level inside the casing shall be kept high enough to prevent heaving of borehole bottom and loosening of soil around the casing.

#### 5.7.3.2 Steel Pipe Piles

Steel pipe piles shall conform to the relevant standards. Piles shall have a minimum inside diameter of 25 cm and a minimum shell thickness of 10 mm. They shall be driven without point but with open end or with cast-steel point. Specific construction of open ends for piles to rock or hardpan and for friction piles will be determined in accordance with soil investigation results. The pile shells shall be driven to required resistance, cleaned out and filled with concrete.

Piles up to 6.00 m in length shall be in one piece. Piles from 6.00 m to 12.000 m shall have not more than one splice. For longer piles, splices shall not be closer together than 6.00 m.

#### 5.7.3.3 Precast Concrete Piles

Precast concrete piles shall be of size and detail as shown on the Drawings. These piles shall be square or rectangular shaped in cross section with bevelled edges. No high-early-strength cement shall be used. Forms shall be tight and rigid. Piles shall be marked with casting date and shall be cured for 28 calendar days. During this period the lowest temperature allowed shall be 15 $^{o}$C.

The Contractor shall drive enough test piles to determine the length of pile required to secure the specified bearing and to determine required penetrations in the various areas of the work. These tests shall be made sufficiently in advance of the pile driving to prevent delay in the progress of work and so that the Contractor will have on hand, at all times, piles of proper length to meet any conditions that may arise.

#### 5.7.3.4 Steel Sheet Piles

Design of sheet piling and choice of steel sheet piles are subject to the Employer 's approval, which shall have to be obtained before work commences.

The steel sheets shall be regular in shape over their whole length and shall amply overlap or interlock neighbouring sheets during and after being driven in. Bulged or bent sheets shall not be used.

Steel sheet pile walls shall be fastened with dogs, straps, or walings. All parts shall be computed in such a manner that the permissible stresses and sagging are not exceeded.

If the sheets cannot be driven to the depth required to keep them in a stable condition, then special anchoring arrangements with all necessary materials shall be provided.

### 5.7.4 Piling Procedures

Piles shall be installed by methods and equipment that will ensure their installation without damage to the piles or reduction in their strength. The Contractor shall submit to the Employer description of the equipment, materials and procedures that will be used as well as complete structural computations of the proposed construction. For steel sheet piles, an anchoring arrangement shall be shown. The description shall include equipment specifications, including catalogue data, manufacturer's published specifications, loading capacities, hammer and sledge weights, protective devices, test apparatus, detailed installation procedures, test procedures, etc.

Piles and sheet pile walls shall be installed accurately in their required locations within a tolerance of 5 cm in the horizontal dimension in the case of concrete piles and 2 cm in the case of sheet piles, except as noted otherwise in the Specifications. In the vertical direction, pile shall not vary by more than two (2) percent of their length from the perpendicular.

Installation procedures shall be such that adjacent piles and sheets shall not heave or move laterally. All installation procedures shall be subject to the Employer's approval. Permanently installed shells shall be cut off at the pile cut off elevation. No pile driving shall take place within 48 hours of the concreting of any pile which is within a radius of 3 m.

#### 5.7.4.1 Records

The Contractor shall keep records of each pile driven or installed and shall submit these records in duplicate to the Employer daily. The records shall give the diameter, length, location, type, calculated safe load, penetration under the last five blows of the hammer and the result of any tests. The Contractor shall submit with his Tender detailed drawings and specification of the different types of piles upon which his Tender is based and a statement describing equipment he intends to use.

#### 5.7.4.2 Concreting

Each cast-in-place pile shall be filled with concrete G25 to its cut-off elevation. The space to be filled shall be free of mud, trash and other foreign material. After cleaning pile shell if water remains, concrete shall be placed by bottom-dump buckets or tremies, through a funnel by pump or other means, so that splashing or segregation will be avoided. The concreting of the piles shall be without any extra payment brought up to a minimum of 60 cm above the cut-off level of the pile to allow for complete removal of slush and other foreign material, etc., from the main pile and thus obtain sound and uniform concrete. The concreting procedure shall be sufficiently strong to withstand, without injury, all stresses and pressures to which the piles are to be subjected during placing, concreting or driving. Shells or pile sheets which are damaged or collapse during installation shall be replaced at the expense of the Contractor.

Once the pouring of precast concrete piles has started, it shall be carried out as a continuous operation until the pile is completed, beginning at the head of the pile and working towards the point. The concrete shall be thoroughly compacted and consolidated in the formwork and around the reinforcement by mechanical vibration, supplemented by rodding and spading, in such a way that honeycombing and voids are eliminated.

The top Surface of the pile shall be screeded and brushed to a uniform even texture, similar to that produced by the forms. On each pile, the casting date as well as lifting points and head cut-off point shall be marked.

#### 5.7.4.3 Handling and Storing

Piles shall not be handled or moved until the concrete has attained the specified 28 calendar days compressive strength determined by field control test cubes. Piles shall be handled and moved carefully to avoid dropping or severe jarring or bending. They shall be stored in a horizontal position supported on wooden blocks at least 20 cm wide, placed precisely under the correct support points. Piles shall not be stacked more than three deep and all piles in one stack shall be of the same length.

Cast-in lifting eyes will not permitted. Slings shall be installed only at the indicated lifting points. Steel wire rope slings or other tackle that might cause damage shall be padded.

Each pile shall be inspected as soon as possible after removal from formwork for any defects such as honeycombing, voids or movement of forms or reinforcement. The Employer shall be advised of any such defects and the pile shall either be repaired or rejected at his option.

### 5.7.4.4 Driving

The Employer's approval of the complete driving equipment shall be a requisite for commencing the pile driving work.

Piles shall be driven with a drop hammer or with a single-acting hammer, the weight of whose striking part times its fall shall meet the specified requirements for a certain energy per blow, to a safe bearing value or to refusal for piles driven to rock or hardpan. The double-acting steam hammer may be used when driving pile to refusal but shall not be used for other piles except with special permission of the Employer.

Driving shall be done fixed leads which will hold the pile firmly in position and alignment and in axial alignment with the hammer. Suitable anvils, cushions, or driving caps, depending on the type of the pile shall be used to prevent undue damage of the pile butts. Broken or shattered piles will not be accepted.

Driving of all piles shall be continuous without intermission until the pile has been driven to final resistance. The tops of piles shall be cut off true and level at the elevations indicated on the Drawings. All portions battered, split, warped, buckled, damaged, or imperfect in any way shall be removed.

Shells and casings shall have sufficient excess length to allow the complete removal of working tops.

After each group of casings is driven to the required resistance, all water and other material shall be removed and the shell shall be inspected with a light. The casings shall be free from water when the concrete is being placed. No piles in a cluster shall be filled until all piles in the cluster have been driven.

Piles shall not be jetted except with the approval of the Employer. After jetting, piles shall be driven to the required resistance.

Sheet piles shall be driven to obtain tight vertical panels in true alignment and, if not instructed otherwise, to a depth to reach compact subsoil, using suitable and approved pile driving equipment including pile heads.

Sheet piling which will later be withdrawn shall be driven at an adequate distance from structures in order not to disturb the surrounding soil when removing the piles.

Holes and openings of any description may be cut into the sheet piles only after approval has been given by the Employer. The Contractor shall later plug these holes or openings at his expense if the Employer thinks it necessary.

Any leaks in the sheet piling whether due to open joints or to bending of pile feet shall be tightened and maintained tight at the Contractor's expense during the entire construction period.

#### 5.7.4.5Redriving

Observations and measurements shall be made in the field during the process of driving piles, by any suitable method satisfactory to both the Contractor and the Employer, to determine whether a driven pile has been lifted from its original seat during the operation of driving adjacent piles. The Contractor shall provide the necessary tools, such as indicator pipes and instruments, to make these measurements. Such measurements shall be properly corrected for any temperature variations that might exist in the pile shell or instrumentation. Where such observations or measurements indicate that a pile has been unseated, it shall be redriven to the resistance specified under this chapter or elsewhere in these Specifications.

### 5.7.5 Damaged or Misdriven piles

Should any pile be damaged by overdriving or not conform to the tolerance of the specification, an extra pile or piles shall be driven in its place, at the Contractor's expense, unless in the opinion of the Employer the pile is out of place or plumb as the result of an underground obstruction.

Piles rejected after driving may remain in the ground at the discretion of the Employer, be filled with concrete, and be cut off as directed. when rejected piling is withdrawn, the space, if another pile is not driven into it, shall be filled solid with gravel or broken stone without payment.

### 5.7.6 Extraction of Sheet Piles

For extraction of the sheet piles, only properly equipped pile extractors shall be employed, in order to make full use of the pulling force. To allow proper fixing of the pulling jaw, suspension holes shall be provided at the top and the heads reinforced by welded plates or angles.

### 5.7.7 Obstructions

Where boulders or other obstructions make it impossible to drive certain piles in the location shown and to the proper bearing strata, the Contractor shall resort to all usual methods to install piles as required, including spudding, jetting, or other feasible means. If, in the judgement of the Employer, the Contractor is unable to complete properly any pile by resorting to such methods, the Employer may order an addition pile or piles driven. Piles abandoned because of obstructions encountered before reaching the accepted bearing strata shall be filled with concrete and be paid for as a completed pile for the length driven.

### 5.7.8 Tests and Properties

At the Employer's direction test piles shall be installed. These piles shall be subjected to load tests up to twice the design load and/or failure.

Other piles shall not be installed until the load tests have been conducted and the results evaluated, except at the Contractor's own risk.

2-5% of the working piles shall load tested to 1.5 times the design load.

In case of any pile failing in the test, the Employer will have more piles tested (such number not to exceed five (5) per cent of piles driven) at the Contractor's cost.

Reading of settlement and recovery shall be recorded up to an accuracy of 3 mm for each change of load. Increment of load shall be added after there has been no settlement for at least two hours after the previous increment. The test load shall remain in position until the settlement is less than 3 mm in 48 hours, after which the load may gradually be decreased.

Net settlement shall be defined as the distance from preloading elevation to final elevation after the specified test loads have been applied and removed.

All arrangements for tools, tackle, etc., as well as recording instruments and the compilation of reports shall be the responsibility of the Contractor.

### 5.7.9 Auxiliary Works

Unless otherwise specified, all and any kind of works, materials, services, safety measures, etc., required for the completion of the work as well as, and if so requested by the Employer, all tests and samples shall be included in the contract price.

The auxiliary works comprise, but are not necessarily restricted to, the following:

- procurement, furnishing, transport, erection, supplementation, maintenance, depreciation and removal of all equipment, tools, scaffolding, platform, etc.
- storing of piles
- removing of obstructions
- protection of existing structures
- welding, cutting. and sealing of sheet piles
- provision, installation and removal of all accessories such as stiffeners, anchors, structures, bracing etc.

## 5.8 Concrete work

### 5.8.1 Materials, design and workmanship

The standards of materials, design and workmanship are to be equal to those laid down in the latest amended editions of British Standard BS 8110.

### 5.8.2 Ready mixed concrete

Ready-mixed concrete as defined in BS 1926, off the Site, may be used only with the agreement of the Employer and shall 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 Employer. The time of such introduction shall be recorded on the delivery note together with the weight of the constituents of each mix.

When truck-mixed concrete is used, water shall be added under supervision, either at the Site or at the central batching plant, as agreed by the Employer but in no circumstances shall water be added in transit.

Unless otherwise agreed by the Employer, truck mixer units and their mixing and discharge performance shall comply with the requirements of BS 4251. Mixing shall continue for the number and rate of revolutions recommended in accordance with Item 9 in Appendix B of BS 4251 or, in the absence of the manufacturer's instructions, mixing shall continue for not less than 100 revolutions at a rate of not less than 7 revolutions per minute.

### 5.8.3 Cements general

The cements shall comply with all the requirements of BS 12, BS 1370 Part 2, BS 4027 and BS 4248.

Bidders shall indicate on the attached Schedule of Proposals the brand name, manufacturer 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 Employer's approval is obtained.

All cement of one type shall be obtained from the same source.

The Contractor shall not use varying from that used in the preparation of trial mixes until the permission of the Employer has been obtained and until any further trial mixes required by the Employer have been made and tested.

### 5.8.4 Cements – total alkali content

The cement shall be tested to determine the total alkali content in accordance with BS 4550 Part 2 or else A.S.T.M. C 114 (Chemical Analysis of Hydraulic Cement).

The equivalent weight of sodium oxide shall be calculated from the following formula: Equivalent weight of $Na_2O$ = Wt. of $Na_2O$ + 0.658 x Wt. of $K_20$.

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.

### 5.8.5 Cement delivery

The cement shall be delivered to site packed in sealed bags or proper containers, of which there shall be 20 tonnes, 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 Employer'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 required to be used.

### 5.8.6 Cement - storage

Cement in bags shall be unloaded under cover and stored in a ventilated and weatherproof building used exclusively for this purpose. The floor of the building shall be at least 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 shall be used. Cements of different types shall be stored separately.

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 of delivery.

Cement which is more than 12 weeks old from the date of manufacture shall be on site for fineness, settling time, strength and soundness in the presence of the Employer's Representative, and full test re-shall be submitted within 24 hours.

### 5.8.7 Cement test – certificates and samples

All cement shall be certified by the manufacturer as complying with the requirements of the appropriate specification.

For every 50 tonnes of cement delivered to site and whenever required by the Employer the Contractor shall take samples, under supervision, of the cement storage on, or delivered to the site. The Contractor shall test such samples as laid down in Clause 8.7.6 above.

### 5.8.8 Aggregates- general

Before the Employer can approve any aggregate source the Contractor shall furnish the following data:

- Petrological group of rock.
- Rock type within the group.
- Shape.
- Surface texture.
- Silt content.
- Grading curves.
- Specific gravity.
- Impact value.
- Water absorption.
- Soundness.
- Salt content.
- Alkali reactivity.

The fine and coarse aggregates shall comply with BS 882, unless exceptions listed by Tenderers in the attached schedule are approved by the Employer. The sources of all aggregates shall be approved by the Employer.

Marine aggregates may be used when their chloride content complies with Clause below and where the shell content does not adversely affect the workability of the concrete.

### 5.8.9 Aggregates – physical requirements

- The weight of voided shells in fine aggregate shall not exceed 5%.
- The weight of the clay and fine silt fraction (smaller than A.S.T.M. Sieve No.200) shall not exceed 1% by weight for coarse aggregates or 3% by weight for fine aggregates.

- The water absorption of fine and coarse aggregate as measured in accordance with BS 812: part 2 or similar standard not exceed the following values.
- Fine aggregates 2%
- Coarse Aggregate 2.5%
- The soundness of all aggregates shall be proved by a sodium sulphate test in accordance with A.S.T.M. C88-13, from the loss over 5 cycles shall not exceed 10% for fine aggregates or 12% for coarse aggregates.
- The apparent specified gravity of aggregates as determined by an approved test, such as in B.S. 812: Part 2, shall not be less than 2.5.
- The aggregate impact value as determined in accordance with BS 812: Part 3 shall not exceed 20%
- The aggregate crushing value as determined in accordance with BS 812: Part 3 shall not exceed 20%.
- The 10% fine value shall not be less than 50kN for aggregates for normal structural concrete or not less than 100kN for aggregates for concrete for wearing surfaces.
- The flakiness index shall not be greater than 35.
- All aggregates shall be washed mechanically to remove clay, silt, dust and adherent coatings.

**5.8.10 Aggregates – chemical requirements**

- Fine and coarse aggregates shall not be potentially reactive with alkalis, and shall be regularly tested in accordance with A.S.T.M. standard tests C227, C289, C342 & C586.
- Fine and coarse aggregates shall not contain more than 0.5% by weight of acid soluble sulphates (as SO3)
- Fine aggregate shall contain no more than 0.1% by weight of chlorides (as NaCl) and coarse aggregate not 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.
- Marine aggregates may be used provided that the content of chloride salt in the aggregate, expressed as the equivalent anhydrous calcium chloride percentage by weight of the cement to be used in the concrete, does not exceed but where the proportion exceeds by weight of cement, marine aggregates must not be used with alumina cement or for pre-stressed concrete in circumstances where calcium chloride admixtures are not permitted. In addition, in concrete containing embedded metal, calcium chloride must not be added in such proportion that the total anhydrous

- calcium chloride in the admixture, plus the equivalent value of anhydrous calcium chloride calculated from the chloride in the aggregate, exceeds 0.35% by weight of the cement. For the purposes of calculation, the anhydrous calcium chloride content may be taken as equal to the sodium chloride content or to 1.6 times the chloride ion content as appropriate.

### 5.8.11 Storage of aggregates

The aggregates shall be stored at mixer positions on drained concrete paved areas 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 Employer, it has drained sufficiently to ensure proper control of the water/cement ratio.

### 5.8.12 Aggregates – sampling and testing

The Employer shall have the right to require the Contractor, at any time, to draw samples of aggregates from stockpiles on the Site or any other location to be indicated by the Employer. All sampling and testing shall be in accordance with BS 812 or to American standards when no appropriate BS exists.

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 tests 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 1 sample per of aggregate to be used or 1 sample per month whichever is greater. Such testing shall include those tests from BS 812 as are considered useful by the Employer for comparison with the results of the initial set of tests but the Contractor shall allow for the full range to be carried out.

Testing shall be carried out at an independent laboratory approved by the Employer or else on the site in the presence of the Employer's Representative, where approved by the Employer.

### 5.8.13 Water

The water for mixing and curing concrete should be clean and free from harmful matter and should comply with the requirements of BS 3148.

### 5.8.14 Admixtures

Admixtures shall not be used without the approval of the Employer.

No admixtures shall be used until the contractor has demonstrated that all requirement of the specification are met when using the admixture. The contractor shall demonstrate that he has control over the rate of dosage of admixtures. Admixtures were applicable, shall conform to BS 5075. where not British Standard exists the manufacturer's recommendations shall be complied with.

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.

### 5.8.15 Reinforcing steel

Steel reinforcement shall be one of the following:

a). Hot rolled mild steel round bars complying with BS 4449 or equivalent standard, as approved by the Employer.

b). High tensile steel either (i) cold worked deformed bars or (ii) hot rolled bars complying with BS 4461 (or 4482) or as approved by the Employer.

c). Welded steel mesh reinforcement complying with BS 4483 or similar approved.

Bars, greater than 40mm diameter, shall not generally be used. Stocks of mild steel shall be stored separately from high tensile steel.

The Contractor shall supply the Employer with a certificate for 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 tonnes 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 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 $5^{o}C$ to $100^{o}C$.

High tensile steel shall only be heated or welded when the manufacturer gives written guarantees as to its subsequent performance. The shapes of the bends and lengths must comply with the applicable recommendations of BS 4466 or otherwise specified on the Drawings and Bending Schedules as approved by the Employer.

The Contractor shall provide bending schedules giving the location and bending of every bar shown on the drawings.

The Contractor shall provide any chairs or other subsidiary reinforcement which will not be shown on the drawings but may be 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 operations.

Mesh reinforcement shall be fixed flat over the whole of the areas indicated on the drawings. Adjoining sheets of mesh shall overlap by at least 300mm.

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 be of a type approved by the Employer. 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 of the concrete nor cause to deform locally. Concrete cover shall be in accordance with BS 8110.

Reinforcing bars shall be tied together at every intersection using 16 swg soft pliable annealed steel wire. When a F3 finish soffit is specified, stainless steel tying wire shall be used to prevent rust staining.

### 5.8.16 Testing - general

Testing methods are to be in accordance with the relevant BS or A.S.T.M. standard except as approved or requested by the Employer.

Tests required by the Employer will normally be carried out at an independent testing station. The cost of preparing, storing and trans-porting test specimens to the place of testing shall be borne by the Contractor. Where there is no independent testing station within a reasonable

distance of the Site the Employer may allow the Contractor to set up his own full laboratories.

The Employer shall have the right to order that any materials which do not meet with his approval shall not be used in the works. The Contractor shall have the right to sample test and give an opinion on such materials. If after this, the materials are rejected by the Employer they shall be immediately removed from the Site by the Contractor.

The Contractor shall provide the Employer 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 Employer's Representative, and whenever deemed necessary by the Employer.

### 5.8.17 Concrete composition and strength

All mixes shall be in accordance with the requirements of BS 5328 or similar approved and as designated on drawings approved by the Employer.

At least seven weeks before concrete construction is programmed to commence the Contractor shall submit for approval all the details listed in the Table of Concrete Composition for each proposed grade of concrete. No concrete construction drawings will be approved until this data is received.

Sampling rates shall comply generally with the Table of Concrete Sampling.

The Contractor shall carry out frequent tests to the satisfaction of the Employer to check the relationship of the strength of concrete cured under site conditions to that cured under laboratory conditions.



**TABLE OF CONCRETE COMPOSITION**

Form for scheduling the specified requirements of several different mixes to be used on one contract (refer to BS 5328)

| CONTRACT | Mix Descriptions used on Drawings |
|---|---|
| Type of mix | |
| Type of cement | BS no. |
| Type of aggregate | Coarse :<br>BS no. |
| | Fine :<br>BS no. |
| Normal aggregate maximum size (mm) | |
| TABLE OF CONCRETE COMPOSITION (continued) | |
| Grade | |
| Minimum Cement Content (kg/$m^3$) | |
| Sampling Rate ($m^3$) | |
| Workability | Slump (mm)<br>VB (s)<br>Compacting Factor |
| Maximum free-water /cement ratio | |

| | |
|---|---|
| Maximum Cement Content (kg/m3) | |
| Special cement | |
| Special aggregate | Coarse :<br>Fine : |
| Fine aggregate (%) | |
| Admixtures | Specified<br>Prohibited<br>Amount |
| Air Content | |
| Temperature of fresh concrete (ºC) | Maximum<br>Minimum |
| Density of concrete(kg/m3) | Maximum<br>Minimum |
| Additional requirements on attached schedule | |



### 5.8.18 Trial mixes

The Contractor shall submit not less than three weeks before the commencement of manufacture of preliminary trial design mixes the following information to the Employer in respect of each grade of concrete.

(a) Grade of concrete.

(b) Title of particular trial mix.

(c) The grading of the aggregates.

(d) The ratio by weight of all the constituents of the concrete.

(e) The expected compacting factor and slump.

(f) Full details of the proposed site quality control.

(g) 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. Should the proposals not be approved by the Employer, then the Contractor shall comply with the requirements included in this Clause.

At least six weeks before commencing any concreting in the Works, the Contractor shall make preliminary 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 to transport them a representative distance. The first batch shall be discarded.

Preliminary test cubes shall be taken from the proposed mixes as follows:

For each grade a set of six cubes shall be made from each of three 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 BS 1881. The test shall be carried out in a laboratory approved by the Employer.

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 two at 28 days to determine the likely effect of errors in dispensing.

Before commencing the Works, the Contractor shall submit to the Employer for his approval full details of the mixes he proposes to use which must be based on the satisfactory results of these preliminary tests.

The Employer shall if he so desires be present at all preliminary tests. The Contractor shall inform the Employer of his intention to carry out such tests and the time and place of the tests at least 24 hours before they take place.

### 5.8.19 Changes in materials or mix proportions

Neither the mix proportions nor the source of supply of materials shall be altered without the prior approval of the Employer, except that 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 Employer's satisfaction, of trial mix procedures set out herein.

### 5.8.20 Work test cubes

Before commencing any concreting in the Works the Contractor shall submit for approval his proposed testing regime for the Works concrete. Should the proposals not be approved by the Employer, the Contractor shall comply with the requirements of this Clause.

For the first 10 days that a particular grade of concrete is produced three samples shall be taken on each day and three cubes shall be made from each sample. shall be tested at 7 days and the other at 28 days.

After the initial 10 days, samples of designed mixes shall be taken at the reduced rate given in the Table of Concrete Sampling below, with the proviso that at least one sample shall be taken on each day that concrete of that grade is used. Three cubes shall be made from each sample, one being tested at 7 days and the remaining two at 28 days.

## TABLE OF CONCRETE SAMPLING

Sampling rates for design mixes after 10 day run-in of concrete grade
(3 Cubes shall be made from each sample)

| Rate | Tye of Structure | 1 Sample to be Taken every day or every |
|---|---|---|
| A | Critical Structures<br>e. g. Masts, cantilevers, columns | $10m^3$ |
| B | Intermediate Structures<br>Beams, slabs, bridge decks | $40m^3$ |
| C | Heavy Construction<br>Breakwaters, solid rafts, foundations | $80m^3$ |

The cubes shall be made, cured, stored and tested accordance with BS 1881 or equivalent. The tests shall be carried out in a testing a laboratory approved by the Employer. The laboratory must provide evidence that its equipment and procedures comply with BS 910 and BS 1881 and that its testing machines are regularly checked and adjusted for accuracy. Full details of the qualifications of all laboratory staff will be required by the Employer. Reports of all tests made shall be supplied direct from the laboratory to the Employer within

24 hours of the cubes being tested. The Employer's Representative 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 of positions in the works of every batch of concrete, of its grade and of all test cubes, cores, or other specimens taken from it. Copies of these records shall be supplied to the Employer at weekly intervals or upon request by the Employer.

### 5.8.21 Compliance of works test cubes with specification

When submitting proposed testing regimes, the Contractor shall also detail his proposed acceptance criteria for the Employers approval. When this is not forthcoming the Contractor shall comply with the requirements included in this Clause.

The rules of compliance for Works cubes are different to those in Clause for Trial Mixes. Compliance with the characteristic strength shall be assumed if the conditions given in both (a) and (b) are met: -

(a) The average strength determined from any group of four consecutive test results exceeds the specified characteristic strength by $3N/mm^2$ for concretes of grade C20 and above (i.e. characteristic strength = $20N/mm^2$)

$2N/mm^2$ for concretes of grade of grade C15 and below (i.e. characteristic strength = $15N/mm^2$)

(b) The strength determined from any test result is not less than the specified characteristic strength minus

$3\ N/mm^2$ for concretes of grade C20 and above

$2\ N/mm^2$ for concretes 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 (b), only the particular batch from which the sample was taken shall be at risk.

### 5.8.22 Lapse in Batcher Operation

Where there is a lapse of two weeks or more between successive pour of the same grade of concrete the mix must be subjected to more frequent sampling as per Clause 8.7.20.

### 5.8.23 Different Rates of Sampling

Compliance criteria remain the same irrespective of varying rates of sampling of the same grade concrete in different structures.

### 5.8.24 Cement Content of Designed Mixes

Where a minimum or maximum cement content of a designed mix is specified and compliance is assessed by observation of the batching or from autographic records, the cement content shall not be less than 95% of the specified minimum or more than 105% of the specified maximum.

Where compliance 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.

### 5.8.25 Failures to meet test requirements

If the strength of test cubes, the mix proportions of prescribed mixes, or the limits on cement content, do not comply with clause 8.7.21 or if, in the opinion of the Employer, the concrete fails to meet the specified requirements in other respects, the concrete in that part of the works from which it is a sample will be considered not to comply with the specified requirements.

As and where directed by the Employer cylindrical core specimens of 150mm nominal diameter shall be cut from the hardened concrete in the Works for the purpose of examination and testing. The cutting equipment and the method of doing the work shall be approved by the Employer. The specimens shall be dealt with in with BS 1881. Prior to preparation for testing the specimens shall be made available for examination by the Employer. The results of such tests shall not nullify the fact of non-compliance with the Specification.

Recourse also be made by the Employer 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 Employer's satisfaction and approval. If no satisfactory remedial measures are proposed by the Contractor and approved by the Employer, then the Employer shall order the removal of all work not complying with the Specification at the Contractor's expense. Before proceeding similar work, the Contractor shall submit to the Employer for his approval details of action proposed to ensure future concrete to be placed in the Works will comply with the Specification.

### 5.8.26 Supervision

A Material Employer shall be employed to supervise the testing of aggregates, quality control etc. The Contractor shall submit details of his experience in this field to the Employer for approval.

### 5.8.27 Plant

The Concreting Plant shall be suitable in type, capacity and design for its purpose. The performance of the plant and its disposition shall be to the satisfaction of the Employer.

### 5.8.28 Concrete mixing

All concrete except where specifically permitted by the Employer in writing shall be mixed in weigh batch mixing machines. The machine shall have a large water storage tank with a gauge so that predetermined quantity of water can be injected into the mixer drum. The machine shall be in full working order when in use and shall be calibrated at regular intervals and when deemed necessary by the Employer.

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 2 minutes or until a uniform colour is achieved.

During mixing of the concrete due account must be taken of the water contained in the aggregates. The total water in the mix shall not exceed the amount used in the trial mix.

The Contractor shall take all precautions to the satisfaction of the Employer to protect the concrete from the injurious effects of the elements.

### 5.8.29 Workability

The concrete shall be of such consistency that it can be readily worked into the corners and angles of the and around reinforcement without segregation of the materials or bleeding of free at the surface. On striking the formwork it shall present a face, which is uniform, free from honey-combing, surface crazing or excessive dusting, and which shall not, in the opinion of the Employer, be inferior to the standards laid down in later clauses in this section. In order to satisfy the Employer that the workability of the proposed mixes is 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 or such other procedure as may be approved by the Employer.

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 formwork 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 shall be at least half a of concrete but in any case not less than the shall comply with the requirements of this Specification for formwork. The mould shall be filled in the presence of the Employer with concrete of the same mix and batch from which the preliminary test cubes are made and shall be compacted in the same manner and 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 Employer, after which it shall be used as the standard for that grade.

When a specific workability is called-for on the drawings or in the Table of Concrete Composition a check shall be maintained by measuring slump at the rate of one test for each cubic metres of concrete or three tests for each day of concreting.

### 5.8.30 Transport and placing

The method of transporting and placing concrete shall be to the approval of the Employer. Concrete shall be transported and placed, that contamination, segregation or loss of the constituent materials does not occur.

All reinforcement contained in it shall be clean and free from standing water immediately before placing concrete.

The Employer shall be given 24 hours notice in order that he may check the work and no concrete shall be placed in any part of the structure until the Employer's approval has been given.

Upon arrival at the place of deposition the concrete truck driver must present to the Employer's Representative a chit from the concrete stating (a) the grade of concrete, (b) workability (c) aggregate size (d) type of cement and 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 Employer. Concreting shall then proceed continuously over the area between construction joints. Fresh concrete shall not be placed against in-situ concrete which has been in position for more than 30 minutes unless a construction joint is formed in accordance with Clause 9.6.29 When in situ concrete has been in place for 4 hours, or less as directed by the Employer 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 and not more than 32°C. It shall be compacted in its final position within 30 minutes of discharge from the mixer unless carried purpose-made agitators, operating continuously, when the time shall be within 2 hours of the introduction of cement to the mix and within 30 from the agitator.

Except where otherwise agreed by the Employer, concrete shall be deposited in horizontal layers to a compacted depth not exceeding where internal vibrators are used or in all other cases.

Unless otherwise agreed by the Employer, concrete shall not be dropped into place from a height exceeding 2 meters. When trucking or chutes are used they shall be kept clean and used in such a way as to avoid segregation.

No concrete shall be placed in flowing water. Underwater concrete shall be placed in position by tremie tube, or by pipeline from the mixer. Full details of the method proposed shall be submitted in advance to the Employer and his approval obtained before placing begins.

Where the concrete is placed by a tremie tube, its size and method of operation shall be in accordance with British Standard Code of Practice, BS 8004: Foundations. During and after concreting under water, pumping or de-watering operations in the immediate vicinity shall be suspended until the Employer permits them to be continued.

### 5.8.31 Construction bays and formed joints

The Contractor shall agree with the Employer, 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.

Some constructions such as machine foundations require to be poured in one continuous operation.

In general, except as modified below, slabs in excess of 13 metres in length and/or width and walls exceeding 13 metre in length shall not be poured in one operation and subsequent adjacent bays shall not be concreted within 2 days. The maximum area of any pour shall be $100m^2$.

In the light of experience, the Employer 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 1 metre in width may be left at 13 metre 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 fibre board to full depth and width. The infilling will be permitted to be used as permanent only for the second casting. Where the fibre board is exposed it shall be cut back for a depth of at least 2cm. from the chamfered 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 with BS 4449; they shall be straight and coated at one end with approved bond breaking compound, which shall consist essentially of

66% of 200 pen bitumen blended hot with 14% light creosote oil and, when cold, brought to the consistence of paint by the addition of 20% solvent naphtha, or other app-roved 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.

### 5.8.32 Construction joints

Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated on the Drawings or approved by the Employer. When not indicated on the drawings the following general rule shall apply:-

<u>Columns</u>: Joints in columns are to be made at the underside of floor members and at floor levels. Haunches and column capitals are to be considered as part of and continuous with the floor or roof.

<u>Floors</u>: Joints in the floor system are to be located at or near the quarter points of the span in slabs and beams, except where other-wise instructed.

<u>Walls</u>: Vertical joints away from corners. Horizontal joints above splays 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 off-setting of the joint and to ensure water tightness. The joints shall in every way satisfy the requirement of the Employer, and be fully detailed on drawings prior to submission for approval.

At construction joints, the laitance film and porous layer of the already set concrete shall be removed and the surface keyed by hacking and then wire-brushed and thoroughly cleaned.

### 5.8.33 Joining new concrete work to existing

Existing concrete shall be broken out as described or directed and to form a key for the new concrete. The applicable of and 9.6.29 shall be complied with.

Where necessary the reinforcement in existing concrete shall be exposed, cleaned and bent to its correct shape.

Immediately before new concrete is poured, an approved cement grout shall be applied to the existing concrete faces.

New reinforcement shall be securely wired to the existing.

### 5.8.34 Compaction of concrete

All concrete shall be compacted to produce a dense homogeneous mass. Unless otherwise agreed by the Employer, 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 or disturbance on partially harden concrete. Unless otherwise directed by the Employer, 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 is satisfactorily and uniformly compacted.

The Contractor shall ensure that a sufficient number of vibrators are on hand at all times including allowance for breakdown of vibrators. As a general rule, one working vibrator shall be available for each $6m^3$/hr of concrete being placed.

Vibrators shall penetrate the full 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 shall be avoided. Immersion vibrators shall be withdrawn slowly to prevent the formation of voids. Vibrators shall not be used to work the concrete along the forms, or in such a way as to damage 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 cycles per minute and external vibrators not less than 3,000 cycles per minute.

**5.8.35 Air bubbles**

The formation of air bubbles against vertical or sloping shall be prevented and the finished surface shall be at least as good as that of the approved standard called for on the drawings.

**5.8.36 Curing**

Concrete shall be protected during the first stage of hardening from the harmful effects of sunshine, drying winds, cold, rain or running water. The protections shall be applied as soon as practicable after completion of placing by one or more of the following methods:

a). The concrete shall be covered by a layer of sacking, canvas, hessian, straw mats, or similar absorbent material, or a layer of sand wet.

b). Alternatively, after thoroughly wetting, the concrete shall be covered with a layer of approved waterproof paper or plastic membrane kept in contact with the concrete.

c). Except in the case of surfaces to which concrete has subsequently to be bonded, the concrete may be cured by the application of an app-roved coloured liquid curing membrane. Application shall be made by low pressure spray in accordance with the manufacturer's instructions. On vertical surfaces, the curing membrane shall be applied immediately after removing the formwork. The curing of the concrete shall be maintained for at least one week or as long as directed by the Employer depending on weather and sufficiency of the protection provided.

**5.8.37 Additional requirements in hot weather**

**5.8.37.1**General

In hot weather concreting shall be generally in accordance with A.C.I standard 305-72, "Recommended: Practice for Hot Weather Concreting". The Contractor shall present for the Employers approval his proposals for dealing with the following problems:-

(i) Reduced workability

(ii) Excessive plastic shrinkage

(iii)Rapid strength gain but possible low final strength.

(iv)Rapid drying-out of concrete.

#### 5.8.37.2Concrete Mixing

Aggregate stock piles 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 exceed 32°C.

With the approval of the Employer admixtures may be employed to retard setting time or enhance workability, or induce early bleeding etc.

Concrete batched off--site shall be transported by truck mixer with 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 practcable.

#### 5.8.37.3Concrete Placing

Placing shall not commence until sufficient standby pumps and vibrators are on site to cope with breakdowns.

No concrete shall be batched until is ready and all reinforcement fixed in place.

The area of each concrete pour frontage shall be kept wet by suitable means shall be provided to avoid premature stiffening at concrete placed in contact with hot dry surfaces. The surfaces, including reinforcement, against which the concrete is to be placed shall be shielded from the rays of the sun and shall be sprayed with water to prevent excessive 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 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.

#### 5.8.37.4Curing

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 10° C of that of the concrete. Air shall not be permitted to between concrete and curing materials.

#### 5.8.37.5Testing

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 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.

### 5.8.38 Additional requirements for machine foundations

The design and construction of the machine foundations require additional attention, to reduce the occurrence of cracks.

#### 5.8.38.1Design

Consideration shall be given to stresses arising from shrinkage and thermal effects. Minimum reinforcement over all faces of the foundation should be 9mm diameter bars at centres horizontally and vertically but in the vicinity of pits in the foundation the longitudinal reinforcement should be doubled. Minimum reinforcement in the body of the foundation should be 9mm diameter bars at centres in three directions.

The ends of all reinforcement should be hooked.

#### 5.8.38.2Construction

The top of the blinding concrete should be painted with three coats of bituminous paint. Water shall be of drinkable quality. Aggregates are to be dense, naturally occurring and inert.

Thin concrete sections are to be additionally protected by insulating the formwork. Consideration could be given to lining the with polythene sheeting to prevent premature drying out of the surface.

All formwork for pits, duct and holding down bolt holes must be so constructed that it can be easily collapsed to facilitate withdrawal after the initial set of the concrete. The Contractor shall submit a working drawing of the method he intends to use to the Employer for approval before construction. The top of the shuttering for the holes shall be covered to prevent entry of excess grout, materials used for curing etc.

Solid timber shall not be used for forming holding-down bolt holes

Exposed surfaces of the foundation and the surface in the vicinity of the holding down bolts shall have a finish Type U.3 as described.

All formwork shall be to the approval of the Employer, and shall be constructed to the tolerances described elsewhere and adequately supported to prevent any movement during concreting.

The concrete shall be machine mixed and pouring of the price begun shall be carried out continuously and be completed within 9 hours. The cement content shall not exceed 350 kg/$m^3$ and the total water/cement ratio should not exceed 0.55.

In the event of construction joints proving necessary for slow speed engine foundation only, they shall be horizontal and not vertical unless approved by the Employer.

The Contractor shall submit to the Employer full details of how he proposes to carry out the pouring.

The details shall include such items as number, description and output of concrete mixers employed; number and description of vibrators; standby arrangements; details of labour force and shift times, volumes of aggregate and any other information the Employer may require.

A temporary cover or other suitable means shall be erected over the area of the pour prior to concreting to avoid dehydration of the concrete.

Foundations are to be covered with approved absorbent material and constantly wetted by a

continuous spray of water, including the vertical faces of the foundation. Curing shall be commenced immediately on completion of concreting and to be maintained for at least ten days. Thereafter, the curing process can be gradually reduced until, after a period of one month after casting, no further protection should be required. The whole curing process must ensure that the mass of concrete is subjected to the lowest practicable temperature and moisture content variations.

Where base plates are to be grouted after erection of plant, the top surface of the foundation shall be left rough as directed (except in the vicinity of holding down bolt-holes) to make a good key for grouting.

Where instructed, the Contractor shall clean and wire brush the areas specified to remove all dust and grease and shall form a grout barrier and grout as directed.

**5.8.39 Formed finishes for concrete**

**Type F.1:** This finish is for surfaces against which backfill or further concrete will be placed. shall consist of sawn boards, sheet metal or any other suitable material which will prevent the loss of grout when the concrete is vibrated.

**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 thicknesses boards 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 boards and panels shall be horizontal and vertical unless other-wise directed. This finish shall be such as to require no general filling of surface pitting, but fins, surface discolouration and other minor defects shall be remedied by methods approved by the Employer.

**<u>Type F.3:</u>** 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 work shall be faced with plywood or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible joints between sheets shall be arranged to with architectural feature, sills, window heads or changes in director 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. Un faced wrought boarding or standard steel panels will not be permitted for Type F.3 finish. The use of internal metal ties shall not be allowed.

**<u>Type F.4:</u>** This finish is identical to Type F.3 except that internal metal ties are permitted.

**<u>Type F.5:</u>** This finish is a special moulded finish with a surface finish equivalent to F.4, but to the shapes outlined on the Drawings.

### 5.8.39 Unformed finishes to concrete

**<u>Type U.1.</u>** This is a screed finish for surfaces of roads or of foundations, beds, slabs and structural members to be covered by backfills, subsequent stages of construction, bonded concrete, topping or cement mortar beds to receive pavings and on exposed surfaces or paving where superior finish is not required. It is also the first stage of finishes Type U2 and U3. 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.

**<u>Type U.2.</u>** This is a floated finish for surfaces of beds and slabs to receive mastic paving or block or tile paving where a hard smooth steel-trowelled surface is not required. Floating shall be done only after the concrete has hardened sufficiently and may be done by hand or machine. Care shall be taken that it is worked no more than is necessary to produce a uniform surface free from screed marks.

**<u>Type U.3.</u>** This is a hard, dense, smooth steel trowelled finish for surfaces of concrete paving, tops of walls, copings and other members exposed to weathering, surface beds and slabs to receive thin flexible sheet and tile paving bedded in adhesive and seating 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.

### 5.8.41 Formwork and its removal

Forms shall be designed and so constructed that the concrete can be properly placed and thoroughly compacted and that the hardened concrete shall conform accurately to the required shape, position and level, subject to the tolerance and to the standards of finish specified.

When concrete is vibrated, special care shall be taken to maintain the stability of the and the rightness of the joints during vibrating operations.

The material and position of any ties passing through the concrete shall be approved by the Employer. The whole or part of the tie 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 directed by the Employer with concrete or mortar of approved composition. Through-ties shall not be permitted for water retaining structures.

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 Employer.

The Employer shall be informed in advance when the Contractor intends to strike any formwork.

The time at which the formwork struck shall be the Contractor's responsibility. The may be struck when the concrete has in the opinion of the Employer attained a compressive strength of not less than10N/mm$^2$ or twice the stress to which it will then be subjected whichever is the greater.

In the absence of cube test results the periods before striking given in the table below may be used for Ordinary Portland Cement:-

| Location | Time Period |
|---|---|
| Beam sides, wall and columns | 9 hrs |
| Slab, soffits (formwork props Undisturbed) | 4 days |
| Formwork pops to slabs | 11 days |
| Beam soffits (formwork props Undisturbed) | 8 days |
| Formwork props to beams | 15 days |

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.

### 5.8.42 Grouting of bolts and plant

No grouting shall commence without the written approval of the Employer and Contractor shall submit full details to the Employer for his approval.

Before plant grouting commences the Civil Contractor shall check the relevant Plant Contractors that the proposed methods and materials are acceptable, and that no special resin additives or similar are necessary.

The surface of concrete shall be thoroughly scrabbled to remove all laitance to provide a clean rough surface. The bolt pockets and surface of the concrete foundation shall be cleaned immediately before the base plate is placed in position. Immediately before grouting, the space between the concrete and base plate shall be cleaned again and thoroughly wetted. All excess water shall then be blown away by means of a com-pressed air jet. Bolt pockets must be free of water before grouting.

The grout or concrete shall be transported from the mixer to the placing point quickly and in such a way that the materials do not segregate and shall be placed within 45 minutes of being mixed.

The grout or concrete shall be poured into the and worked into position with chains, bolts, rods or other suitable instruments, until the whole of the space is completely filled with the concrete. The use of the expanding grout admixture shall in all ways be according to the specification of the manufacturer. Expanding grout shall not be vibrated. In the case of packing under a base plate the grout shall be worked from one side and in one direction only, so that there is no possibility of air being trapped in the middle.

Where grouting holes are provided in large base plates, grout may be introduced at these points and allowed to spread radially. The sequence of grouting must, however, be such as to avoid the formation of air pockets.

The main grouting and the grouting of bolt sleeves and pockets should normally be executed at the same time. If separate operations are advisable bolt sleeves and pockets shall be grouted up to approximately 50mm of the level of the concrete foundation before the main grouting.

Grout or concrete shall not be placed when the air temperature or the temperature of the concrete is lower than 5°C.

Dry packing mortar shall consist of cement and fine aggregate pro-portioned by weight in the ratio one part cement to two parts fine aggregate. Water shall be added such that the slump of the mix does not exceed 6mm. Mixing, placing and protection shall be in accordance with appropriate preceding clauses.

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 Employer. The clearance space between the formwork and the base plate shall normally be 75mm but exact clearance shall be decided on the site for each operation. On the side from which the grout is to be poured forms shall be at least 150mm high in order to provide a head to ease 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 not be struck without the approval of the Employer, and normally this will not be given within 24 hours of grouting.

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 an oil and alkali resistant coating.

### 5.8.43 Waterstop

Waterstop shall be either PVC or rubber.

The contractor shall submit the following information to the Employer for approval any propose waterstops.

- Manufacture
- Type of material
- Density
- Hardness
- Tensile strength
- Elongation at break

### 5.8.44 Polythene Sheet

When binding is of materials other than concrete or when required, 0.5 mm thick polythene sheet shall be laid on top of the building before pouring any concrete. The polythene sheet shall conform with all the requirements of BS 3012.

### 5.8.45 Pre-Cast Concrete

The Contractor is required or proposes to pre-cast structural elements for in-situ construction then drawings, calculations and details of arrangements, cast-in fittings and fixings shall be submitted by the Contractor to the Employer for review.

### 5.8.46 Drawings

Each drawing showing construction in concrete shall detail the following:-

i). Type of cement

ii). Minimum cover to reinforcement

iii). Maximum size of aggregate.

iv). Characteristic cube or cylinder strength at 28 days.

v). Type of reinforcing steel and cross section of bars.

vi). Reference to bar bending schedules.

vii). Workability of concrete.

viii). Concrete finishes

ix). Minimum cement content

x). Maximum

xi). Volume of concrete represented by the drawing.

xii). Proposed locations and details of construction joints.

xiii). Proposed locations and details of expansion joints.

xiv). Full details of any grout required.

## 5.9 Structural steelwork, Cladding and Welding

### 5.9.1 Structural steel

Structural steel and bolts shall in all respects comply with an approved standard and shall be fabricated from new sections unless otherwise specified and agreed in writing by the Employer.

### 5.9.2 Connections

Shop connections shall generally be electric arc welded or bolted. The connections shall be shown as bolted on the drawings unless specifically approved by the Employer.

### 5.9.3 Design

The design shall meet the requirements of BS 5950 or other approved standard, and the design calculations shall include the computation of stresses in all structural components and shall show how all loads are transferred to the foundations.

Consideration shall be made in sizing members to eliminate excessive deflection or vibration during service. Suitable stress reductions shall be applied to slender compression members in accordance with the approved standard.

### 5.9.4 Materials

Samples of all materials shall be tested and copies of the test reports giving physical and chemical properties shall be submitted to the Employer 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.

### 5.9.5 Foundations

The foundation bolts shall be of an approved manufacture and shall be fitted with tubes, washer plates, anchor angle, flats and nuts, etc. Drawings showing the foundation bolt arrangement shall be approved by the Employer and sent to site with the foundation bolt assemblies and templates in good time for being built into the foundations.

### 5.9.6 High strength friction grip bolts

The manufacture and use of high strength friction grip bolts shall be in accordance with an approved standard. 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 Employer's approval must be used in accordance with the manufacturer's instructions and recommendations. If required, the Employer may call for tests to prove the adequacy of the washers proposed.

### 5.9.7 Workmanship

Fabrication and erection shall conform at all stages to the standard approved by the Employer and allowance should be made for the Employer 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 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.

### 5.9.8 Welding

Welding of structural steelwork shall be by an electric arc *process.* The procedure to be followed, plant and equipment to be used and the testing and inspection to be applied, shall

all be to the satisfaction of the Employer and shall conform generally with the relevant approved standard with further details contained in this Specification.

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 Employer approves site welding, this shall not be done under whether or other conditions which might adversely affect the efficiency of the welding and, where necessary, effective protection and other safeguards, as shall be agreed with the Employer, shall be provided.

### 5.9.9 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 Employer 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 minimizing 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 slag and other inclusions, all adhering slag being carefully removed from the exposed faces immediately after each run.

i). Fusion Faces

Fusion faces, angle of bevel, root radius and the like shall be properly prepared to give the approved weld 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 thicknesses not greater than fusion faces shall be prepared by machining, or where approved, by use of special flame cutting apparatus. Faces shall be kept clean and protected.

ii). 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 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.

iii). Intermittent Welds

Intermittent welds shall not be permitted without the approval of the Employer.

### 5.9.10 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.

### 5.9.11 Steel work protective coating system

The steelwork shall be protected against corrosion by an approved protective coating system which shall comply with the relevant requirements of BS 5493:1977, or other approved standard. The protective coating system shall have a proven life to first maintenance of at least fifteen years under similar environmental conditions to those prevailing on the site which shall, for purposes of classification by B.S. 5493:1977, be taken to be:

External - Exterior exposed non-polluted inland atmosphere. (Table 3, Part 1)

Internal - Interior (of building) normally dry. (Table 3, Part 6).

The Contractor shall submit for the Employer'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 thicknesses, remedial treatment for damaged surfaces, etc.

Where possible and practicable, coatings shall be applied under con-trolled, 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 pro-vide such a finish using paint materials which are compatible with the protective coating system. Full details of any decorative paint finishes shall be submitted to the Employer 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 followings :

- Swedish Standard SIS 05 59 00 - SA 2.5
- British Standard 4232 - Second Quality
- U.S. Standard - near white blast cleaned surface finish; SSPC-SP-10-63T

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 area, except as recommended by the manufacturer of the paint system approved by the Employer. 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$^{o}$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 galvanizing is used, the whole of the fabricated steelwork shall be blast cleaned, treated in an acid pickling bath and then hot dip galvanized in accordance with BS 729, or other approved standard. The thickness of zinc coating shall be at a rate of not less than 610 g/m$^2$.

To check on the galvanizing, 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.

### 5.9.12 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 50mm 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 arid the edges of site joints shall be cleaned down, primed and painted all in accordance with the standards specified.

### 5.9.13 Transportation and storage of steel work

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 will not be used in contact with the steelwork. The position of lifting points used on sections shall be such that the stresses induced in the sections do 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.

### 5.9.14 Erection

The Contractor must provide all temporary works, of any kind whatsoever, as 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.

### 5.9.15 Hoists, slings etc. for painting

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 Employer.

## 5.10 Metal work

### 5.10.1 Tubular hand railing

Tubular hand-railing where used shall be 25mm nominal bore tube and handrail standards shall be 25mm nominal bore "heavy" tube. Handrails and standards shall be delivered to site unpainted.

### 5.10.2 Ladders

Access ladders are to be mild steel and conform to BS 4211: 2005.

### 5.10.3 Chequer plate

Chequer plate trench covers shall be 6mm thick mild steel and galvanized after cutting to size.

### 5.10.4 Open Steel Flooring

Open steel flooring and stair treads shall comply with BS 4592, shall be of the square grid type and shall have a galvanized finish.

### 5.10.5 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 Employer. Opening windows shall be sliding type preferably and fitted with external fly-screens which shall be removable for maintenance. If hinged windows are used, there shall open inwards with the fly-screens fitted externally.

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 may occur on the aluminium during the period shall be immediately cleaned off.

Particular care shall be taken during dispatch and storage on site to damage to the windows and doors, and to this end they should be kept in protective wrapping until fixing.

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.

### 5.10.6 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 in generally used in first class work. The Employer 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.

## 5.11 Brickwork, Blockwork & Masonry

### 5.11.1 Materials

The Employers approval shall be obtained for all proposed manufacturers and suppliers of all bricks, blocks, air bricks, damp-proof courses other materials.

Manufacturers or suppliers may not be subsequently changed without the approval of the Employer.

<u>Concrete Blocks</u>

Precast concrete shall be manufactured using an approved machine or vibrating table. Blocks shall be true in shape, even in size, square with sharp arises and free from flaws and holes.

After removal from the machine the blocks shall be laid out on their pallets under cover in separate rows one block high for a minimum of 24 hours and kept wet by watering with a fine spray. The blocks may then be removed from their pallets and shall remain under cover and be kept wet by watering for a further period of six days after which they may be stacked not more than five meters high until required for use. Blocks shall not be built into the Works until they are at least 21 days old.

Block shall generally be nominally 390mm long and 90mm high and 100mm, 150mm or

200mm thick (nominal). Blocks 100mm thick shall be solid and other blocks shall normally be hollow. Where blocks are to be used in work to be plastered or rendered the faces shall be scored whilst the blocks are still "green" to provide a key.

Drawings of load bearing blockwork walls shall stipulate the average and minimum strengths required of blocks, and the mortar mix. The Contractors shall submit for approval at least 4 weeks prior to construction his proposed quality control procedures.

<u>Samples</u>

Separate samples of each type and size of brick or block, taken at random from the load, shall be deposited with and approved by the Employer before being used and subsequent deliveries shall be up to the standard approved.

Manufacturer's test certificates shall be produced in respect of each type of concrete block employed, and the manufacturer must give a written warranty that all blocks are properly cured and dried before delivery to site.

<u>Cements</u>

Generally, cement shall be as specified under Clause 8.7.3 of this Specification.

Masonry cements may only be used with the approval of the Employer. Where they are permitted, they shall be used strictly in accordance with the Manufacturers recommendations.

<u>Lime</u>

Lime for mortar shall generally be hydrated grey-stone lime in accordance with for hydrated calcium limes. Magnesium lime shall not be used in mortar for brickwork below the damp-proof course.

The Contractor shall forward copies of Manufacturers certificates to the Employer, which in addition to certify compliance with BS 890, shall give details of the type of lime. If lime is delivered as lime putty, the certificate shall state whether quick lime or hydrate lime was used in its manufacture.

All time shall be efficiently protected against deterioration out transport and whilst stared on site. Different types of brands of lime shall be stored in dry conditions in a manner that allow it to be used in the order of delivery.

When lime putty is used the Contractor shall obtain the approval of the Employer of his arrangement for handling and storage. Precautions shall be taken to prevent and contamination and drying out of lime putty stored on site. Lime putty made from quicklime should mature for at least 14 days before being used. Where it is lime (powder), lime putty should stand for at use.

Sand

Sand for mortar shall be naturally occurring material complying with BS 1200 or similar approved. It shall be stored on faces in such a manner as to allow adequate drainage, and to contamination by other materials.

Test results and details shall be included on the Suppliers of compliance with BS 1200, copies of such, being supplied to the Employer. The Contractor shall also supply to the Employer the details called for in BS 1200 -Clause 7. Should control charts and not be available the Contractor shall carry out his own satisfaction of the Employer.

Sea sand shall not be used.

Water

Water shall be as specified under Clause 8.7.13 of this Specification.

Aggregates

Aggregates for forming blocks shall be natural aggregates from natural sources to BS 882 or as specified for block type A or B in BS 2028,1364 or similar approved.

Pigments

Pigments for colouring mortar shall comply with BS 1014 and shall only be used where called-for by the Employer.

Where carbon black is a constituent of the colouring compound the proportion of compound added to the mortar shall be such that the resultant proportion of carbon black is less than 3 per cent of the cement by weight.

Damp Proof Course

Lead and Copper damp-proof course shall comply with the requirements of BS 743.

Bitumen damp-proof course shall be asbestos base bitumen damp-proof course complying with the requirements of BS 743, Type C.

Metal cored damp-proof course shall be asbestos base, lead cored bitumen damp-proof course complying with the requirements of BS 743, Type F. Copper or aluminium cored damp-proof course shall only be used where its substitution and gauge is approved by the Employer.

Asphalt damp-proof course shall comply with the requirements of BS 743 with the exception that mastic asphalt for damp-proof courses shall comply with BS 1418. Polythene damp-proof course shall comply with the requirements of BS 743.

Expansion Joints

The Contractor shall submit for approval his proposals for expansion joint materials before placing any orders. All expansion joints shall be sealed against the ingress of water.

Airbricks

Airbricks are to comply with for terra-cotta or clay and shall be to approved colour. They are to be set flush with the wall face and internally fibrous plaster vent units are to be set flush with the finished plaster surface.

Over openings formed for air bricks the brickwork or blockwork shall be supported with a roofing slate or similar. Slates shall have a minimum bearing of 50mm at each end. Cavities around air bricks above the damp-proof course in cavity walls shall be closed with brickwork and an approved vertical damp-proof course shall be built in between the inner and outer skins.

Ducts of glazed stoneware where used in cavity walls for forming the openings shall comply with BS 65 or similar approved.

Sills and Thresholds

Sills are to be of approved natural grey slate, tile, or pre cast concrete and are to comply with

BS 4374 or similar. Bedding surfaces of slate sills are to be tooled to give a good key.

Built-in continuous sills and thresholds shall be laid on sand and embedded with mortar only below stoolings. When approved by the Employer, the sand shall be raked out and the joint subsequently filled with mortar and painted to match the surroundings.

Lintels

Lintels are to have a fair smooth surface and be set flush with the wall face in fair-face walls, when the wall is plastered or rendered. The concrete mix and dimensions will be shown on the drawings. Design calculations must be approved by the Employer prior to manufacture.

Wall Ties

Wall ties for cavity walls or for tying walls to concrete casings shall be Butterfly type, long manufactured from steel wire, in accordance with BS 1243. Wall ties for cavity walls shall be built into the bed joints of the walls during erection with a slight fall to the outer leaf and shall be spaced not more than apart horizontally and apart vertically. Wall ties for bonding brickwork to concrete casings shall be spaced not more than apart vertically and be properly cast in the concrete. Alternatively, where approved, masonry slots may be employed.

Sealing Compounds

Single-part polysulphide based sealing compounds shall be supplied by a manufacturer approved by the Employer. Two part polysulphide based compounds shall comply with BS 4254.

Pouring grade compounds shall be used for joints open on the top surface; and for those open in vertical or sloping faces the compounds used shall be of gun applied grades.

Surfaces of joints shall be primed with paint complying with the recommendations of the

Manufacturer of the sealing compound.

**5.11.2 Mortar mixes**

Proportioning Materials

Materials shall be accurately by weight or volume.

Volume batching shall be by means of gauge boxes approved by the Employer and allowance shall be made for sand bulking.

Weigh batching shall be by equipment accurate to within 2 ½ % which has been approved by the Employer. Each material shall be weighed individually.

Hydrated lime (powder) shall not be mixed with the cement and sand unless approved by the Employer. Lime putty shall first be made by the addition of water to the lime, or alternatively coarse stuff may be made-up with hydrated lime. Coarse-stuff or lime putty made from hydrated lime shall stand for at least 16 hours before cement is added.

Sufficient water shall be used to give the mix adequate workability. Calcium silicate bricks shall not be wetted before being laid and the consistency of the mortar shall be adjusted to suit by varying the water content.

Containers used for storage and transport of coarse-stuff and lime-putty shall be cleaned regularly.

Mixing

Where matured lime putty is used, the cement and sand shall be first mixed dry, then the lime putty mixed in, with further water being added to attain correct consistency.

Where coarse-stuff is made from hydrated lime (powder), the sand and lime shall be first mixed dry. Water shall then be added to give a paste of uniform consistence and colour.

Cement shall be added to coarse-stuff immediately before the mortar is required. Further water may then be added to give the correct consistence.

Where the Employer approves the use of mortar mixed from cement, hydrated lime (powder) and sand, the materials shall be first mixed dry before the addition of water.

Generally, mortar shall be mixed in a power mill unless otherwise approved by the Employer. Hand mixing will only be permitted where small quantities of mortar are required. In such cases the materials will be mixed on a clean watertight platform, being turned over twice dry and twice wet whilst water is added through a rose.

All mortar shall be used within 60 minutes of the cement being added.

In no circumstances will admixtures to mortar be permitted without prior approval from the Employer.

Manufacturers recommendations shall be strictly followed when masonry cement/sand mortars are employed, and over mixing shall be avoided.

<u>Classes of Mortar</u>

Every Contractors drawing showing blockwork or brickwork shall stipulate the required mortar mix.

Where the use of hydrated lime (powder) mixed with sand and cement for immediate use is approved by the Employer, then the volume of hydrated lime shall be 50% more than that applicable to lime putty.

**5.11.3 Setting out**

The Contractor shall provide proper setting-out rods and set out on the same, all work showing openings, heights, sills and lintels, the brick-work and blockwork being built to the thickness, widths and heights shown on the drawings.

The walls are to be taken up, level as far as possible, and no lift shall be greater than 1.2 metre above the adjoining walls. Joining of lifts shall be made by long steps and not by teething. Corners be raised first and these shall be laid to a gauge rod and racked back to the main wall.

All blockwork must be built in level courses.

The blockwork shall be built 3 courses to 600mm.

Single block walls shall be built of selected blocks to keep an *ever,* face on both sides. The header blocks used in double block wall shall also be carefully selected and the wall built so as to preserve an even face on both sides.

### 5.11.4 Workmanship & samples

All work shall be carried out in accordance with the recommendations of British Standard Codes of Practice CP 111, CP 121: Part 1 and CP 122.

The Contractor shall erect a sample panel of not less than two sq. meters of each class of blockwork being employed, in the mortar, gauge and pointing specified, for the approval of the Employer and shall amend and rebuild as directed until each sample has been approved. All blockwork shall conform in character and quality with the approved sample.

### 5.11.5 Laying & jointing

Every Contractors drawing shall define the bond pattern for every leaf shown.

All piers, intersections and angles of walls shall be properly bonded together and no bats shall be used except where required for the bond. Any proposals for block bonding shall be approved by the Employer.

Blockwork shall be carried up in a uniform manner. All faces and quoins shall be truly plumb and in facings and fair face work all perpends shall be accurately kept and the whole plumbed and levelled at each course.

Walls shall be constructed with an approved expanded metal reinforcement every second course.

Jambs of all openings in hollow concrete blockwork shall be filled with weak concrete, well compacted and carried from base slab to top of such openings.

All blocks shall be kept damp during building and shall be laid in full bed of mortar. All joints shall be completely filled with mortar. The thickness of the horizontal mortar joints shall be completely filled with mortar. The thickness of the horizontal mortar joints shall not exceed 40mm to every four joints.

Where the walls are specified to be plastered, the blockwork face shall be left rough and the joints raked out to a depth of 12mm while the mortar is green to form an adequate key for the plaster.

Newly laid blockwork and brickwork shall be protected from the harmful effects of sunshine, rain, drying wind, running or surface water and shocks, during the day of laying and the following day. The Contractor shall 'include for and provide a sufficient amount of cheap cloth material which shall be kept wet, and used for this purpose. Any work that may be damaged shall be taken out and rebuilt as directed by the Employer. Any costs incurred in carrying out such remedial works shall be borne by the Contractor.

Unless shown otherwise on drawings, pointing to external facings shall be rounded hollow as the work proceeds and that to internal facings, basements and manhole walls shall be flushed joint as work proceeds.

Holes and chases shall preferably be left in the walls where required, conduits and pipes shall be built in. Under unavoidable circumstances holes and chases may be cut out and provision shall be made for ―making good‖ to the satisfaction of the Employer.

Weep holes shall be built into the external skin of cavity walls form of sand filled vertical joints at 1m centres and are to be raked out completion. Weep holes shall be placed over all lintels, or other significant obstructions to the cavity.

The top courses of hollow concrete blockwork walls shall be laid in solid blocks unless otherwise indicated.

The tops of all non-load-bearing walls shall be laid in solid blocks unless otherwise indicated.

The tops of all non-load-bearing walls and partitions shall be pinned up to the soffits of beams, joists, purling or slabs above them.

Precautions During Warm Weather

In warm dry weather blockwork shall be protected from the effects of hot sunlight and drying winds until the mortar has sufficiently matured. Very absorbent blocks shall be wetted before they are laid.

### 5.11.6 Cavity walls

Cavities shall be kept clear of mortar droppings or other debris by the use of lifting boards and temporary openings at the foot and other locations where rubbish can collect in the cavity. Mortar droppings shall be cleaned from the ties and the inside mortar joints flushed up as the work proceeds. Rubbish and mortar droppings shall be removed from the cavities daily. After the wall has been completed the openings shall be closed with bricks and mortar matching the surrounding wall.

Reveals to all openings in cavity walls unless otherwise shown shall have vertical D.P.C. between the external and internal skins returned at the joints. Where such DPC's prevents bonding of the two leaves, a vertical line of additional wall ties shall be used on every fourth course of brick walls or at maximum intervals of for block walls.

Except where shown otherwise, cavity walls shall be constructed with 50mm cavities. During construction one leaf shall never rise more than above the other.

### 5.11.7 Movement joints

External skins of cavity walls shall have 10mm wide straight vertical movement joints at maximum of 6 metre intervals. The separated portions of the walls shall be tied together with galvanized hoop iron or similar while still allowing for movement.

Gaps in movement joints shall be filled with an approved joint sealing compound.

### 5.11.8 Concrete abutting blockwork

Where concrete abuts external block work it shall be coated with bituminous paint.

Where facing blocks are to be tied back to concrete surfaces, this shall be done by means of galvanized steel adjustable ties and slots, the latter cast into the concrete.

### 5.11.9 Building in frames

Openings in masonry for doors, windows, air conditioning units, ventilators and fans, etc. are to be properly marked out and left un-built until the wooden frames have been fixed in position.

All timber frames are to be built in as the work proceeds and propped or strutted, and the back of same coated with an approved wood preservative before fixing.

All door frames, window frames, vent and shutter frames are to be bedded in 1:3 cement mortar, 12mm thick.

All frames are to be securely fixed in position with approved anchors built into the walls.

### 5.11.10 Damp - proof course

A damp proof course of approved lead cored bitumen shall be laid under walls above ground level so as to exclude rising moisture.

### 5.11.11 Protection against damage

Architectural features, finished surfaces and quoins shall be protected against damage during the progress of the works. Sills, jambs and heads shall be protected by basings as soon as built.

Freshly completed work shall be covered with waterproof sheets in locations where rain damage is likely.

Door and window frames and other items built-in shall be fully protected by boards, sheets, or other measures which are to the approval of the Employer.

### 5.11.12 Defective work

Any defective blocks found in the work after completion are to be cut out and replaced and defective workmanship shall similarly be remedied, all at the Contractor's expense.

### 5.11.13 Stacking and storage of blocks

All blocks shall be stacked by hand on approved hard standings. They are to be stored in orderly stacks so arranged that they are used approximately in the order in which they are delivered. The stacks are to be clear of standing water and the blocks are to be protected from splashing by mud or contamination by other materials.

Blocks shall be stored either on pallets or by other methods to the approval of the Employer, in order to prevent absorption of moisture from the ground which may contain dissolved sulphates or other soluble salts.

#### 5.11.14 Reinforced blockwork

Expanded metal reinforcement strip shall be built into blockwork as follows:

- 64mm wide for 100mm block
- 114mm wide for 150mm block
- 150mm wide for 200mm block

The reinforcement shall be kept back at least 18mm from the face of the wall. Generally, unless shown otherwise the blockwork shall be reinforced: -

Over internal door openings, build in reinforcements in one course over lintel and at bearing to head to lap beyond the jamb.

To all block partitions over 6 metres long, build in reinforcement every alternate course, to full height of partition.

At corners and junctions of partitions, build in 300mm length of reinforcement to alternate courses.

### 5.12 Floor Laying

#### 5.12.1 Screed beds

Concrete floors which are required to be surfaced with screed shall have a roughened surface, produced by hacking and wire brushing. The roughened concrete floor shall be cleaned, wetted preferably overnight, the surplus water removed and 1:1 cement/sand grout brushed into the surface, keeping just ahead of the screed bed. The screed bed shall be 40mm thick and shall be well compacted and levelled with a screed board and steel trowelled smooth.

The screed shall be mixed in the proportions of 1:2:3 (cement; sand; 10mm pea shingle) by volume with the minimum quantity of water necessary to give a good hard smooth, steel trowelled finish. The section hereof concerning concrete applies.

The screed shall be reinforced with 50mm GI mesh and divided into panels approximately 3 metres square by aluminium strips.

Where the floor surface is not screed finished and where specified a power float finish shall be employed and the surface treated with a proprietary hardener that is both oil resistant, skid resistant and anti-dust resistant.

### 5.12.2 PVC flooring ( control room false floor)

PVC flooring shall be flexible PVC tiles obtained from an approved manufacture. PVC vinyl asbestos tiles will not be accepted. The tiles shall be laid by a specialist and the jointing layout shall be approved by the Employer. A matching PVC cover-type skirting shall be used in conjunction with the floor tiles. The tiles and skirting shall be laid on a flat, clean screed, in strict accordance with the manufacturer's instructions.

### 5.12.3 Damp-proof membrane

An approved bitumen/PVC water-proof membrane shall be placed on the blinding concrete under concrete floor slabs, to exclude rising moisture. The membrane shall be lapped at joints; and taken up walls and lapped 75mm with the wall D.P.C.

### 5.12.4 Acid Resisting Tiles

Acid resisting tiles shall be 150 x 150 mm 22 mm ribbed (non-slip) ceramic quarry tiles.

The separating layer shall consist of either bituminous felt to BS 747, building paper to BS 1521 or 500 gauge polythene film.

The separating layer shall be laid flat in a continuous layer over the screed base, with 100 mm lapped joints between adjacent sheets and shall not be stuck down.

The bedding mortar and grouting joints shall be formed from materials that will resist the environment as satisfactory as the tiles.

Movement joints shall be provided in accordance with the recommendations of BS 5385. Each movement joint shall be at least 6 mm wide and of a depth equal to the combined thickness of tiles and bedding mortar.

### 5.12.5 Protection

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 Employer.

### 5.12.6 Defects

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 Employer.

### 5.12.7 Raised Modular Floors.

Raised modular flooring shall be provided for the Local Control Room and Relay Rooms. Panels in these rooms shall be supported from the structural floor on independent sub-frames. The modular flooring shall be designed to fit flush with the face of the panels to ensure that all floor panels are removable.

Raised modular floor shall be of high quality proprietary manufacture of the prop and panel type to the Employer's approval.

The floor shall generally be of the raised modular type providing full access to the void beneath.

The whole of the raised access flooring shall be made of non-combustible materials. Panels shall meet the fire rating requirements of BS 6266.

The load capacity of the floor shall be appropriate to foreseeable usage of the area concerned.

A full range of accessories shall be provided with the flooring, where appropriate these shall include;

- Ramps or steps to adjacent areas
- Perforated panels where floor void is used as a plenum
- Outlet boxes
- Lifting grips for removable panels
- Fire and smoke stops
- Skirting

The panel shall be of galvanized steel with a core of special purpose high density processed timber.

The flooring panel shall be finished with PVC, anti-static vinyl, or plastic laminants, edged on all four sides with carbon loaded rigid PVC lipping.

## 5.13 Drainage and Ducts

### 5.13.1 Scope

This Clause specifies the materials and workmanship for drainage works in general and cable ducts and trenches. It does not include pressure pipelines or sanitary and rainwater pipework above ground level.

For the purposes of this section the definitions given in section 02 of BS 8005: part 0: 1987

### 5.13.2 Standards

The following British Codes of Practice shall apply unless other equal Standards are proposed and approved:

| | | |
|---|---|---|
| **5.13.2.1** | BS 8301 :1985 | Building Drainage |
| **5.13.2.2** | BS 6297 | Small Sewage Treatment Works |
| **5.13.2.3** | BS 6367 :1983 | Drainage of Roofs and Paved Areas |
| **5.13.2.4** | BS 8313 :1997 | Accommodation of Building Services in Ducts |
| **5.13.2.5** | BS 8005 | Sewerage |

### 5.13.3 Materials

Unless Bidder list proposed deviations in the attached schedule and these are approved by the Employer, then materials shall comply with the appropriate British Standards or approved equivalent, in addition to the following requirements: -

**Pipes and Fittings**

Two copies of the certificates verifying that the pipes and fittings comply with the Specification shall be given by the Contractor to the Employer for each delivery.

Pipes and fittings shall be obtained from the manufacturer or his accredited stockist and be marked with the manufacturer's name or mark.

Pipes and fittings shall be to the class or strength shown on the Drawings.

Contractor's drawings shall state whether joints are to be rigid or flexible, and when flexible joints are specified the components shall be those which are recommended by the manufacturer and which have received the approval of the Employer.

Steel ladders shall be manufactured from steel which complies with grade 43A of BS 4360. After fabrication ladders shall be galvanized to comply with BS 729. The Contractor shall prepare fabrication drawings as specified.

**Glazed Vitrified Clayware Pipes and Fittings**

Salt glazed vitrified pipes, bends, junctions and tapers shall be of British Standard quality complying with BS 65 traps, gullies and fittings of similar material to generally with the types and dimensions laid down in BS 65.

All joints shall be of the flexible coupling type.

**Cast Iron Pipes and Fittings**

Cast iron pipes and fittings where used below ground shall comply in all respects with BS 4622, BS 437 and/or BS 4772. The pipes shall be coated internally and externally with an approved tar base composition and shall have spigot and socket joint unless otherwise described or directed.

**Concrete Pipes and Fittings**

Concrete pipes, fittings and street gullies shall comply with the requirements of BS 5911 parts 1 to 3 and be supplied by an approved manufacturer. The pipes shall have spigot and socket joints and manufactured using Sulphate Resisting cement.

Alternative types and methods of jointing may be used subject to the Employer's approval.

**PVC Pipes**

PVC pipes and fittings shall be manufactured from unplasticised polyvinyl chloride and shall comply with BS 3505 and/or BS 3506. The pipes shall have spigot and socket flexible joints.

**Clay ware and Porous Concrete Pipe**

Clay ware and porous concrete pipes shall comply in all respect with BS 1196 and BS 1194 respectively. These shall be used for field drainage only.

### 5.13.4 Setting out

Setting out shall comply with section 12.1 of BS 8005: part 1. Levels shall not be transferred by straight edge and spirit level. Invert levels shall be accurate to 5mm.

### 5.13.5 Excavation

Excavation shall comply with Clauses 12.2 to 12.5 of BS 8005: part 1 and also to Clause 8.6 of this Specification.

All main drains shall be commenced at the point of the necessary junctions for the branch mains being inserted as the work proceeds until the main drains are completed. The branch drains shall then be laid commencing from the junctions in the main drain.

Trenches for pipelines shall be excavated to an even gradient between access chambers and to the depth required for the bedding.

### 5.13.6 Laying and jointing pipes

Pipes shall be inspected, laid and jointed to comply with section 12.6 and 12.7 of BS 8005: part 1 or similar approved and drawings shall comply therewith and also state whether joints are to be rigid or flexible.

Pipes shall be laid in straight lines to even falls from manhole to manhole, and in the uphill direction. With the prior approval of the Employer pipes may be laid to slow and even curves on plan to obstruction provided that upon completion a true record of the is made by the Contractor and given to the Employer.

**5.13.7 Manholes General**

Manholes constructions shall comply with BS 8005 part 1: section 2 and shall only be constructed after the connecting drains have been laid.

Manholes shall be watertight.

In situ concrete bases, shafts and cover slabs shall be cast in 20N/mm$^2$ concrete.

Curved channel inverts shall have the largest possible radius.

Main channel inverts shall be made of the same material as the pipe. When this is not practicable channels shall be formed in concrete with a semi-circular invert, vertical sides up to the crown of the outlet pipe and with a small radius curve between the sides and the benching and levelled smooth.

**Blockwork Manholes**

Concrete blocks for the construction of manholes, inspection chambers, catchpits etc. shall conform to Specification Clause 8.7.

Beds and vertical joints shall be completely filled with mortar as the blocks are laid and joints shall be flush cut as the work proceeds.

Step irons shall be properly staggered and lined.

Blockwork manholes for foul drainage shall be rendered internally with 2 coat cement render to a minimum thickness of 15mm.

**Precast Concrete Manholes**

Inverts shall be shaped to form the foundation for the chamber section.

The sections shall be bedded in mortar and flush pointed internally. The bed of mortar under the lowest section shall be at least 10 mm thick. When the joints between sections are not to be surrounded in concrete they shall be sealed externally with joint sealant in accordance with the manufacturer's instructions. The step irons shall be properly lined vertically and shall not be used for hoisting or lowering components.

When a manhole is surrounded in concrete horizontal construction joints shall not be formed in it within 150 mm of a joint between sections. This concrete shall support the cover slab with a space of 25 mm between it and the top of the highest section.

### 5.13.8 Sealing, marking and cleaning

When a pipe line is completed and when construction is delayed the open ends of the pipes shall be plugged or sealed off until the pipeline is required to operate or work recommences. At each point where a pipeline is temporarily terminated a marker shall be attached to the end of the pipeline and fixed at ground level.

The interior of all pipelines shall be clean when commissioned.

### 5.13.9 Testing of drains ducts

**General**

The Contractor shall give adequate notice to the Employer of the times and places at which all final tests are to be held. When backfilling and the reinstatement of surfaces has been completed each drainage system shall be inspected and tested generally in accordance with BS 8005: part 1 Section 5, BS 8301 or other recognized approved standard.

When the test is hydraulic, clean water shall be used and promptly removed upon completion of the test.

Upon completion of the tests two copies of the complete records shall be given to the Employer for his retention.

**Drain Testing**

Drains shall be tested with water generally in accordance with BS 8005: part 1. After an absorption period of 30 minutes the rate of loss of water in the next hour shall not exceed 0.5 litre per hour per linear metre per metre of nominal diameter.

**Cable Ducts**

All conduits and also drains shall be gauged by having pulled through them a gauge not less than long and of a diameter 6 mm less than the conduit diameter. After drawing through the gauge, the ends of pipes shall be plugged to exclude dirt and vermin.

### 5.13.10 Cable trenches

Cable trenches shall be cast in lengths not greater than 10 metres with alternate lengths cast at one time. Joints between succeeding lengths are to be sealed. The trenches are to be reinforced. Trenches are to be cleaned out on completion and all drainage left clear and working. Cable trenches shall be adequately drained.

Where applicable the Contractor shall submit for the Employer's approval a schedule of trench covers including details of supporting steel-work at trench intersections.

The Contractor shall provide cable trays, including any necessary supports, as directed by the Employer.

The covers to trenches outside building areas shall generally be made of precast concrete. Where crossing roads, trench covers shall be heavy duty, capable of carrying loads expected to pass over them and conforming to the appropriate specifications.

#### 5.13.11 Soakaways

Soakaways shall conform to the recommendations of CP 301 or other approved Standard with a cover slab, frame and cover. The size of the soakaway will depend on the amount of surface water it receives and the rate of percolation. The minimum size will be that its storage capacity is equal to 13mm of rainfall over the contributing impermeable area.

## 5.14 Waterproofing

### 5.14.1 General

The scope of work covered by this sub-chapter shall be deemed to comprise damp-proofing against non-pressurized water; damp-proofing against lateral and rising moisture; damp proofing against seepage water, surface water and the like in the open air and indoors. Also included is all labour, equipment, and the supply of materials and building components connected therewith, including unloading and storage on the site, unless stated to the contrary in the Contract Documents.

The Contractor shall provide descriptions and methodologies to be adopted in prevention of ingress of ground water to power house basement (if applicable) with the bid.

It does not apply to damp-proofing against pressurized water; to asphalt floorings, water repellent concrete, or roof coverings; to damp-proofing of steel bridges, similar steel structures, or structural members.

### 5.14.2 Materials

Materials and building component which the Contractor provides but which do not become a part of the permanent structure, may be used or unused, at the Contractor's discretion, unless otherwise stated in the specifications.

Materials and building components which the Contractor has to supply and which are incorporated into the permanent structure, shall be new and unused, unless otherwise stated in the specifications. They shall comply with the standards and quality and dimension regulations. Officially approved but unstandardized materials and building components shall be used only with the approval of the Employer.

For unstandardized materials and building components, the Contractor shall supply samples upon request and name the manufacturer.

Bituminous material shall possess the following properties: the residue remaining when the solvent or the water of the emulsion has evaporated normally or been removed in some other way, is regarded as the solid. Fillers must neither swell nor dissolve in water. Damp-proofing bituminous materials with fillers which must be acid-resistant may contain only filler materials which dissolve in a 5% hydrochloric acid solution at 120 °C (permissible variation +1 degree) within 24 hours to a maximum of 10% by weight.

**Undercoating Materials**

Bituminous solution: Bitumen content 30 to 45% by weight; softening point of the solid 55 to 70 °C.

Bituminous emulsion: Bitumen content not less than 30% by weight; softening point of the solid not less than 45 °C.

**Top-coating Materials, to be worked Cold**

Bituminous solution without filler: Bitumen content not less than 50% by weight; softening point of the solid not less than 60 °C.

Bituminous solution with filler: Bitumen content not less than 30% by weight; softening point of the solid not less than 60 °C.

Bituminous emulsion without filler: Bitumen content not less than 45% by weight; softening point of the solid not less than 45 °C.

Bituminous emulsion with filler: Bitumen content not less than 30% by weight; softening point of the solid not less than 50 °C.

**Top-coating Materials, to be worked Hot**

Bitumen without filler: Softening point of the bitumen without filler not less than 54 °C.

Bitumen without filler: Bitumen content not less than 54% by weight; softening point of the bitumen with filler not less than 60 °C.

**Mastics, to be worked Cold**

Mastics with a bitumen base, bitumen as solution, with filler: Softening point of the solid not less than 90 °C.

Mastics with a bitumen base, bitumen as emulsion, with filler: Softening point of the solid not less than 90 °C.

**Mastics, to be worked Hot**

Mastics with a bitumen base, with filler (e.g. mastic asphalt): Bitumen content not less than 16% by weight.

**Adhesives, to be worked Hot**

Bitumen without filler: Softening point of the bitumen without filler not less than 54 ºC.

Bitumen with filler: Bitumen content not less than 50% by weight; softening point of the bitumen with filler not less than 60 ºC.

**Felts**

Unbacked bitumenized felts: bitumenized roofing felts with bitumen coating on both sides.

**Building Paper, Factory-finished**

Building paper, factory-finished, shall consist of an inlay and outer layers which are applied to both sides of the inlay; the outer layers shall be sprinkled with fine sand. Softening point of the outer layers, 55 to 90 ºC.

The inlay and the outer layers shall be closely bonded to each other. The sanding of the outer layers shall adhere well.

Impregnated inlays shall not have visibly unimpregnated places, woven glass inlays in building paper are exempted.

The building papers shall be water-proof. It shall lie flat on an even bed and shall not have any unevenness (e.g. bulges, depressions). It shall have a regular surface and thickness and be free from faults, such as cracks, folds, etc.

Building paper with an inlay of impregnated 500 g/sq.m crude felt, with bitumen outer layers on both sides, shall have a thickness not less than 3.5 mm. Longitudinal and transverse breaking strength (breaking load), not less than 30 kp. Longitudinal and transverse ductility, not less than 2%.

Building paper with an inlay of impregnated 300 g/sq.m jute fabric, with bitumen outer layers on both sides shall have a thickness not less than 3 mm. Longitudinal and transverse breaking strength (breaking load), not less than 60 kp. Longitudinal and transverse ductility, not less than 5%.

Bui1ding paper with an inlay of impregnated 300 g/sq.m woven fibre glass shall have bitumen outer layers on both sides.

Building paper with an inlay of 0.1 mm thick copper foil with bitumen outer layers on both sides shall have a thickness not less than 3 mm. Longitudinal and transverse breaking strength (breaking load), not less than 50 kp. Longitudinal and transverse ductility, not less than 5%.

The copper foil shall possess the following properties: copper content not less than 99.88% Oxygen free copper soft quality, (Brinell hardness about 40 kp/sq.mm), pore-free, stretched 3 flat and straight.

Building paper with an inlay of 0.2 mm thick aluminium foil with bitumen outer layers on both sides shall have a thickness not less than 3 mm. Longitudinal and transverse breaking strength (breaking load), not less than 50 kp. Longitudinal and transverse ductility, not less than 5%.

The aluminium foil shall possess the following properties: degree of purity not less than 99.5%, finely figured surface, soft quality (Brinell hardness about 20 kp/sq.mm), pore-free, stretched flat and straight.

Building paper with an inlay of polytere phythalic acid ester foil not less than 0.03mm thick with bitumen outer layers on both side shall have a thickness not less than 2.5 mm. Longitudinal and transverse breaking strength (breaking load), not less than 25 kp. Longitudinal and transverse ductility, not less than 15%.

**Metal Strip without Outer Layers**

Copper strip: copper content shall not be less than 99.88% oxygen-free copper; cup-fluted depth of cup 1.0 to 1.5 mm; soft quality (Brinell hardness about 60 kp/sq.mm); drawing depth about 5 by the Erichsen test; foil thickness 0.1 mm, width of the strip not more than 60 cm; pore-free, stretched flat and straight.

Aluminum strip: degree of purity shall not be less than 99.5%; cup-fluted, depth of cup 1.0 to 1.5 mm; soft quality (Brinell hardness about 20 kp/sq.mm); drawing depth about 5 by the Erichsen test; foil thickness 0.2 mm; width of the strip not more than 60 cm; pore-free, stretched flat and straight.

**Thermoplastic Plastic Sheeting**

Thermoplastic plastics sheeting shall be impervious to water and moisture-resistant and shall not swell in water. It shall remain unaffected by the action of natural acid ferrous, alkaline, or saline groundwater, stagnant water, or seepage, water and the normal chemical action of the adjoining structural members. It shall be proof against aging and rotting.

It shall not alter its essential properties in constant temperatures ranging from -20 to 170ºC and, moreover, shall retain its homogeneous state: small bubbles, for example shall not form.

The plastics sheeting shall be resistant to perforation (e.g. through loose sand grains or roughness of the bed associated with building). It shall not form bubbles, not alter chemically, and shall be dimensionally stable even when bitumen at a temperature of 200 ºC is applied as adhesive or outer coat. It shall roll out straight-edged and keep an even width on level bed and lie flat on the bed. The thickness of the plastic sheeting shall at no point fall below the nominal by more than 10%. The sheeting shall be capable of being bonded (e.g. by solution welding) in such a manner that the sheet-joint (seam) makes a nonporous seal and is as resistant as the sheeting itself.

Thermoplastic sheeting shall be of polyisobutylene (unlaminated) with nominal thickness not less than 1.5 mm.

**Solution Welding Compounds for Thermoplastic Sheeting**

Benzin with a low aromatic content (not more than 5%) with additions of more than 0.5% and boiling range from 80 ºC to 110 ºC shall be used.

**Execution of Work**

Prior to the start of his operations under this sub-chapter, the Contractor shall verify that all conditions are suitable for the timely and effective carrying out of his work. Where unsuitable conditions are found, they shall be reported in writing to the Employer and under the Employer's direction immediately corrected. In particular, the Contractor shall verify that such conditions as the following do not exist:

- extensive unevenness of the bed
- too rough, too porous, too smooth surfaces
- sharp edges of boarding and ridges
- variations from the horizontal or the fall stipulated in the specification or dictated by circumstances
- incorrect level of the surface of the bed
- unrounded corners, edges and channeling
- stress and settlement cracks, holes
- too moist surfaces
- too strongly absorbent surfaces
- non-sealing of voids (e.g. in lightweight concrete)
- inadequate firmness of the bed
- gypsum, magnesium oxychloride and like surfaces
- oily surfaces, paint residue

- unsuitable type or position of penetrating structural members
- lack of parts for connecting to structural members which penetrate the damp-proofing
- concrete or brickwork surfaces not, or insufficiently, levelled.

In weather conditions which could detrimentally affect the damp-proofing, damp-proofing works may be carried out only if the damaging effect can be safely prevented by special precautions. Such weather conditions are, for example, temperatures below 15 ºC, rain, snow, strong winds.

Horizontal and slightly inclined damp-proofing (with the exception of horizontal damp proofing in walls and damp-proofing with water-repellant mortar) shall be given a protective covering at once, e.g., a thick covering of concrete. Sharply inclined and vertical damp proofing shall also be given a protective covering immediately if the damp-proofing has to be secured or there is a risk of damage.

Damp-proofing with plastics sheeting shall be carried out in compliance with the Manufacturer's instructions.

### 5.14.3 Damp-proofing against Rising and Lateral Moisture

#### 5.14.3.1 Damp-proofing of Walls against Moisture

Damp-proofing with felt shall be carried out with two layers of 500 g/sq.m bituminized roofing felt. The felt layers shall not be bonded either to the bed or to one another. Each layer shall overlap by not less than 10 cm.

Damp-proofing with thermoplastic sheeting shall be carried out with one layer of plastic sheeting, unless stated to the contrary in the specifications. The lengths shall overlap 5 cm at the joints. They shall be joined by solution welding, unless stated to the contrary in the specifications.

#### 5.14.3.2 Damp-proofing of Floors and other horizontal or slightly inclined Structural Members against Rising Moisture

Damp-proofing with felt shall be carried out with two layers of 333 g/sq.m unbacked bituminized felt, unless stated to the contrary in the specifications. The lengths shall be laid in such a manner that the joints of each layer must overlap not less than 10 cm at seams and

joints. Each layer shall be bonded to its bed over the whole surface by means of an adhesive coating to both its underside and the bed. The topside of the second layer shall be given a top coating with the same adhesive substance.

Damp-proofing with building paper shall be carried out with one layer of building paper unless stated to the contrary in the specifications. Not less than 1.0 kg adhesive shall be applied per square meter.

Damp-proofing with thermoplastic plastic sheeting shall be carried out with one layer of plastics sheeting. On slightly inclined surfaces, the lengths shall be fixed with adhesives. The courses shall be laid with the joints staggered. They shall overlap at least 5 cm. The lengths shall be joined by solution welding. With solution welding the overlapping shall not be water moist nor soiled with bitumen, adhesive, or other substances; if necessary, it shall be shielded from contamination with strips of paper. The edges of length which are uppermost at the overlap shall not to be tapered or smoothed off. Unbacked 500 g/sq.m bituminized felt shall be bonded to the sheet as a protective layer. The bituminized felt shall be bonded to the sheet as a protective layer. The bituminized felt shall be bonded to its bed over the entire surface by means of an adhesive coating applied to its underside and to the bed. The upper face of the bituminized felt shall be given a top-coating with the same adhesive. Not less than 1.0 kg of adhesive shall be applied per square meter for bonding coats, not less than 1.5 kg per square meter for top coats.

Damp-proofing with mastics shall be carried out with mastic asphalt in two layers of a total thickness of 15 mm, unless otherwise stated in the specifications. In the case of horizontal or slightly inclined surfaces, an intermediate course shall be laid down as a cut-off layer on the surface to be. damp-proofed before application of the first course. The choice of material for the cut-off layer is left to the Contractor if a particular type of cut-off layer (e.g., soda kraft paper, oiled paper, glass wool) is not stipulated in the specifications. The lengths of the cut-off layer shall laid in such a manner that they overlap at the edges with thin cut-off layers and make a butt-joint with thick cut-off layers.

### 5.14.3.3 Damp-proofing against Lateral Moisture

Damp-proofing with bituminized coatings shall be carried out with an undercoat and top coats.

An undercoating substance which must be worked cold shall be used for the undercoat unless otherwise stated in the specifications. The undercoat shall be applied as a single coat. It shall be completely dry throughout before further damp proofing operations are carried out.

Three coatings with a bitumen solution which must be worked cold shall be applied as cold flow top coats unless otherwise stated in the Specifications. Two coats of bitumen which must be worked hot shall be applied as hot flow top coats unless otherwise stated in the specifications.

Damp-proofing with felt shall be carried out with an undercoat, a layer of unbacked 500 g/sq.m bituminized felt, adhesive coats and a top coat.

Damp-proofing with thermoplastic plastic sheeting shall be carried out with an undercoat, a layer of plastic sheeting, a layer of bituminized felt as a protective course and a top coat.

Damp-proofing with mastics shall be carried out with an undercoat and layers of mastics. Two layers of 16% mastic asphalt "total thickness 10 mm" shall be applied unless otherwise stated in the specifications.

#### 5.14.4 Damp-proofing against seepage water and surface water in the open and indoors

Damp-proofing with felt shall be carried out with an undercoat and two courses of unbacked felt. Unbacked 500 g/sq.m bituminized felt shall be employed where unbacked felt is called for unless otherwise stated in the specifications.

Damp-proofing with building paper shall be carried out with an undercoat and several courses of building paper. Two courses of building paper shall be laid unless otherwise stated in the specifications. Not less than 1.0 kg of adhesive per square meter shall be applied for the adhesive coatings and the top coating.

Damp-proofing with copper strips shall be carried out with an undercoat and a course of copper strip. The entire surface of the copper strip shall be bonded in bituminized adhesive without filler by the casting and rolling-in process. The strip shall be laid with joints staggered. It shall overlap not less than 10 cm at the seams, not less than 20 cm at the joints. A top coating of bitumen without filler shall be applied to the copper strip unless otherwise stated in the specifications.

For bonding in the copper strip by the casting and rolling in process, bituminized adhesive with filler shall be employed not less than 5 kg/sq.m on horizontal and slightly inclined surfaces, not less than 6 kg/sq.m on vertical and sharply included surface corresponding to a volumetric weight of 1500 kg/cu.m unless stated in the specifications. About 2 kg of bitumen without filler shall be used to the square meter for the top coating.

Damp-proofing with aluminium strips shall be carried out with an undercoat, a course of aluminium strip and a course of unbacked 500 g/sq.m bituminized felt. The aluminium strip shall be bonded over the entire surface in bituminized adhesive with filler by the casting and rolling-in process. It shall overlap not less than 10 cm at the seams and not less than 20 cm at the joints.

The course of unbacked 500 g/sq.m bituminized felt shall be bonded to the aluminium strip over the entire surface by means of an adhesive coating on its underside and on the surface of the aluminized strip.

A top coating shall be applied to the surface of the bituminized felt. Bituminized adhesive without filler shall be employed for adhesive purposes and for the top coating unless otherwise stated in the specifications.

Bituminized adhesive with filler shall be employed for bonding in the aluminium strip by the casting and rolling-in process not less than 5 kg/sq.m on horizontal and slightly inclined

surfaces, not less than 6 kg/sq.m on vertical and sharply inclined surfaces - corresponding to a volumetric weight of 1500 kg/cu.m unless otherwise stated in the specifications.

For each adhesive coat in the bonding of the unbacked bituminized felt, not less than 1.0 kg/sq.m of adhesive shall be used, for the top coating not less than 1.5 kg/sq.m

Damp-proofing with thermoplastic plastics sheeting shall be carried out in accordance with the sections above.

Damp-proofing with mastic shall be carried out in accordance with the sections above.

### 5.14.5 Connection of the Damp-proofing to Pipelines

The damp-proofing shall be connected watertight to pipelines and other objects which penetrate it. The connections shall be carried out with the aid of built-in steel flanges unless otherwise stated in the specifications. Connecting parts shall be rust-free and given an undercoat.

### 5.14.6 Damp-proofing of Structural Joints and Damp-proofing over Structural Joints

Damp-proofing of structural joints and damp-proofing over structural joints shall be carried out in such a manner that it shall be capable of sustaining the special stresses which arise.

### 5.14.7 Multi-Ply bonded Water-proofing System

Multi-layer bonded external sealing shall protect structural works against water under pressure using sealing membranes according to DIN 18 195 for all immersion depths.

#### 5.14.7.1 Preparation of the Work

The sealing contractor has to carry out a visual inspection of the preceding work and to check for visible defects. Strengths, statics and levels are accepted as specified without verification or responsibility.

Concrete structures must be rubbed down to a smooth finish, free of pockets and burrs, show no subsidence or shrinkage cracks and have an adequate surface strength. Comers and edges must be rounded off to a minimum radius of 4 cm.

The masonry supporting the sealing must be given a smooth, clean rendering of a suitable mortar.

#### 5.14.7.2 Material

Sealing membranes are plastic sealing membranes of ECB (ethylene copolymer bitumen) according to DIN 16 732, Pans I and 2 latest version.

Sealing membranes are fleece-laminated at the underside and subject to a regular quality control by the Manufacturer as well as by an independent body.

Standard dimensions for sealing membranes:

- Thicknesses : 2 and 3 mm

- Widths : 1.04 and 2.08 m
- Length : 20 m

### 5.14.7.3 Execution

For bonded sealings, the sealing membrane must be bonded over its entire surface area without leaving any cavities. Seams and joints should be overlapped by at least 5 cm and kept completely free of bitumen/adhesives. When using hot melt adhesives (bitumen adhesives) the bonding work must be stopped if temperatures fall below +5 $^oC$.

Welding seams are of the overlap tape, with heat being applied to the seam area to plasticize the material, followed by contact pressure to ensure a homogeneous weld. The welding areas must be kept free of all impurities.

The width of the welding seam depends on the welding seam employed, i.e., by the type of the welding seam and the welding equipment used.

Hot air welding is carried out by electrically working manual hot air welding devices or automatic welding equipment. The welding machines are fitted with appropriate nozzles and an adjustable heating element. With automatic welding equipment. The air velocity and rate of feed are also variable. The nozzle tip temperature should be at least 600$^o$C in order to achieve homogeneous welding fusion.

The site seams and joint connections on sealing membranes must be checked for permeability. Test procedures as detailed hereunder are applicable or must be carried out in combination.

On sealing membranes, fusion of the material to the lowers sheet is clearly visible at the bottom edge of the overlapping sheet. No additional seam protection is required.

At the welding seam edge, a scriber is passed along with an angle of 90 degrees. The scriber tip will penetrate when reaching a defect.

### 5.14.7.4 Bitumen Membranes

Bitumen membranes consist of layers coated or impregnated on both sides with bitumen. The types are classified according to the type of layer. If membrane types other than those specified are used, it will be necessary to check their suitability for the application in question.

Standard dimensions:

- Thickness : varying according to type of membrane
- Width : 1.00 m
- Length : 10 m

Bitumen membranes are to be bonded with hot bitumen over its entire surface, keeping cavities to a minimum. The membranes must overlap at the seams by 10 cm and at the joints and connections by 15 cm. On vertical surfaces, only membranes up to a length of 2.5 m should be used.

Bitumen adhesive compounds and surface coatings for hot application must be heated to the point where they achieve an appropriate viscosity (pourability). Surface coatings are normally to be smeared onto the surface.

#### 5.14.7.5 Connections and Terminations to the Structure

The connections and terminations of sealing membranes to structures shall be completed with the aid of connection strips concreted in or clamping rails or loose or fixed flanged connections according to water-proofing requirements. Unless otherwise specified, the latter shall be fabricated and held available on site.

Pipes, well shafts and components which penetrate the membrane surface must be fitted by customer with appropriate loose-fixed flange constructions to ensure secure connection.

All structural steelwork components must be given an appropriate anti-corrosion coating finish.

Expansion joint reinforcements shall be applied and constructed in an appropriate number of layers to withstand the structural movements given at the membrane level. Reinforcing strips shall be arranged so that they are separated mutually by a sealing layer or an extra layer of raw bitumen membrane 500 in each instance. Special constructions are required for joints where particularly severe structural movements are to be assumed.

Adhesive bond flanges are permitted only for sealing against seepage, they must be appropriate for the of sealing employed and should be of an appropriate metal, plastic or plastic-coated sheet metal. Minimum width 120 mm, in case of cast-iron gulleys 100 mm.

Within these introductory comments, protective layers are deemed to be covering materials applied to the membrane to prevent from mechanical, static, dynamic and thermal influences affecting the membrane and possibly causing its destruction.

The covering layers themselves must not be of a type which might cause damage to the sealing membrane; if necessary, protective layers must be isolated from the membrane by separating or protective layers distributed over a number of joints. Any joints in the structural work must be continued congruently.

Protective layers of masonry must be constructed in thicknesses of at least 11.5 cm. Vertical protective layers must be separated in longitudinal direction at 7 m intervals and isolated from horizontal or inclined surface by lined joints.

#### 5.14.7.6 Description and Sequences of Execution

Wall sealing against external water pressure according to DIN 18 195, Part 6 or latest version to be fabricated with CARBOFOL or equivalent sealing membranes (plastics sealing membranes acc. to DIN 1 6 732) for all immersion depths as to the following structure:

- Cold bitumen primer to be delivered and applied onto the dry and cleaned concrete wall surfaces free of burrs and concrete pockets for reasons of dust bonding and adhesiveness.

  Consumption of bitumen: approx. 0.3 kg/sq.m Before applying the first layer, the primer should be sufficiently dry.

- Raw felt paper 500 to be delivered and bonded all over onto the wall surfaces with hot bitumen 85/25 or B 25, using the pouring and rolling-in method and avoiding any cavities.

  Consumption of adhesive compound:

  - Bitumen unfilled 1.5 kg/sq.m
  - Bitumen filled 2.5 kg/sq.m
  - Joint and seam overlapping to be provided according to DN 18 195.

- Hot bitumen paint coat 85/25 or B 25 shall be delivered and regularly applied onto the wall surfaces, using the brushing-on method.

  Consumption of bitumen : min. 1.5 kg/sq.m.

- Carbofol or equivalent sealing membrane, 2 mm thick, fleece-laminated underside, to be delivered and rolled all over the surface into the melted bitumen, using the flaming method and avoiding any cavities.

According to Manufacturer's laying instructions, seams and joints are to be overlapped for at least 5 cm, kept free of bitumen and welded homogeneously with hot air.

- Raw felt paper 500 to be delivered and laid according to Position 2.2.

- Hot bitumen paint coat 82/25 or B 25 shall be delivered and regularly applied onto above position.

  Consumption of bitumen: min. 1.5 kg/sq.m

Base sealing against external water pressure shall be fabricated according to DIN 18 195, Part 5 or latest version with sealing membrane, Carbofol or equivalent (plastic sealing membranes acc. to DIN 16 732) for all immersion depths as to the following structures:

- Raw felt paper 500 shall be delivered and bonded all over the surface onto the ground surfaces by means of hot bitumen 82/25 or B 25, using the brushing-on or pouring and rolling in method and avoiding any cavities.

  Consumption of bitumen: min. 1.5 kg/sq.m

  Joint and seam overlapping shall be provided according to DIN 18 195 or latest version.

- Sealing membrane (Carbofol or equivalent), 2 mm thick, fleece-laminated underside, shall be delivered and bonded all over the surface onto the raw felt paper of the above position by means of hot bitumen 85/25 or B 25 and avoiding any cavities. In case of a hot paint coat being applied onto above position, the flaming method shall be used.

Consumption of bitumen: 1.5 kg/sq.m. According to Manufacturer's laying instructions, seams and joints are to be overlapped for at least 5 cm, kept free of bitumen and welded homogeneously with hot air.

- Raw tut paper 500 shall be delivered and bonded all over the surface onto the Carbofol sealing membrane of above position, avoiding any cavities.
- Hot bitumen paint coat 85/25 or B 25 shall be delivered and regularly applied onto above position. Consumption of bitumen: min. 1.5 kg/sq.m.

### 5.14.8 Cement Tiles in Gravel Bedding on Roofs and Terraces

The upper layer of the roofing system shall be built up as follows:

- the top of the roofing construction shall be covered with assorted gravel pebbles, round corn, which shall be weather-proof and free from dirt or any other impurities. Diameter shall be in the range of 7 to 16 mm. Thickness of layer 50 mm;
- - cement tiles shall be preferably of granolithic material and shall be of size 40x40x5 cm embedded dry onto above-mentioned gravel.

**Tests and Properties**

All materials to be supplied and installed shall be in accordance with the relevant standards.

Selection of samples for testing material will be made by the Employer.

**Auxiliary Works**

Unless otherwise specified, all and any kind of works, materials, services, safety measures, etc., as well as, and if so requested by the Employer, all tests and samples required for the completion of the work shall be included in the contract price.

### 5.14.9 Damp-proofing Against Pressurized Water

The scope of work covered by this sub-chapter shall be deemed to comprise: damp-proofing against pressurized water by means of bituminous damp-proofing by unbacked felts against water under hydrostatic pressure (e.g., groundwater, pocketed water, pressurized water in sloping soils, etc.).

Also included is all labour, equipment, and the supply of the materials and building components connected therewith, including unloading and storage on the Site, unless otherwise stated in the specifications.

#### 5.14.9.1 Execution of Work

Prior to the start of his operations under this sub-chapter, the Contractor shall verify that all conditions are suitable for the timely and effective car-wing out of his work. Where unsuitable conditions are found, they shall be reported in writing to the Employer and under the Employer's direction immediately corrected. In particular, the Contractor shall verify that such conditions as the following do not exist:

- unsuitable thickness or unsuitable construction of the protective layers,
- absence of joints in the protective layer or unsuitable arrangements of joints,
- unsuitable position or inappropriate design of the structural joints,
- incorrect position of the proposed damp-proofing,
- inadequate precautions against slipping of the structure on the damp-proofing and against slipping of the protective layers on the damp-proofing,
- inadequate retaining pressure on the damp-proofing,
- excessive pressure per unit area on the damp-proofing,
- gaps left for rammed joint required between brickwork and damp-proofing are too small,
- surfaces show undesirable unevenness,
- surfaces are too rough, too porous, too smooth,
- inadequate sealing (e.g., of lightweight concrete),
- surfaces too damp,
- surfaces too strongly absorbent,
- surfaces insufficiently firm,
- oily surfaces, paint residue,
- corners, edges or fillets not rounded or insufficiently rounded,
- concrete or brickwork surfaces not levelled or insufficiently levelled,
- pockets, holes and shuttering imprints (edges, fins, flutes),
- stress cracks and settlement cracks,
- inappropriate or unsuitable type of position of building components penetrating the damp-proofing,
- absence of elements to connect the damp-proofing to building components penetrating the damp-proofing,
- flanges which have not been checked for tightness of seal or which are unsuitable with regard to size or surface,
- unsuitable working space.

While the work is being carried out, the Contractor shall keep watch and note whether any conditions exist, or are likely to arise, which may adversely affect the damp-proofing (e.g., behavior of structural members adjacent to structural joints in manner not conforming to the specifications, harmful effects through oil or chemicals, inadequate dewatering, etc.), he shall notify the Employer of any unsatisfactory circumstances immediately in writing.

Damp-proofing works may be carried out in weather conditions which may detrimentally affect the damp-proofing only if the damaging effect can be definitely prevented by special precautions. Such weather conditions are, for example, temperatures below 15 $^{0}$C, rain, snow. sharp winds.

On completion of the damp-proofing, the Contractor shall carefully inspect it for defects; any defects found shall be immediately rectified. If the next layer (protective layer, concrete or brickwork) is not applied directly after the damp-proofing, the Contractor shall repeat his investigation of the damp-proofing immediately before application of the next layer and shall eliminate any defects. Bolts in joint flanges shall be re-tightened.

In order for the Employer to be given the opportunity of taking part in the examination, the Contractor shall notify him well enough in advance of the time appointed for it.

If the Contractor is responsible for applying the next layer, or if so stipulated in the specifications, the Contractor shall protect the damp-proofing against the sun and against harmful over-heating and any other type of damage until such time as the next layer (protective layer, concrete or brickwork) is applied.

**5.14.10 Damp-proofing with Unbacked Felts**

The bed shall have an undercoat applied to it. The undercoat shall be allowed to dry out thoroughly before the remaining damp-proofing works are carried out.

Bituminized felt or the 500 g/sq.m grade shall be used.

The layers shall be bonded together and final layer shall be provided with a topcoat. Intimate bonding of the layers one with another, particularly on vertical surfaces and at joints and seams, shall be promoted by ironing and the application of pressure. For bonding and top coating purposes, adhesives and top-coating materials shall be used. The adhesive coating shall contain not less than 1.5 kg/sq.m of adhesives per layer and the top-coating not less than 1.5 kg/sq.m of top-coating material; go obtain these results, the rate of application shall not be less than 2.0 kg/sq.m. If the specification calls for the use of any adhesive and a top-coating material having a higher bulk density than the bulk density of bitumen without filler, the minimum weight of adhesive and top-coating material to be applied per sq.m shall be higher in the same ratio as the bulk densities; for conversion purposes, the bulk density of bitumen without filler shall be taken as 1000 kg/cu.m.

If the specifications stipulate that damp-proofing with unbacked felts shall be reinforced by copper strips, the following provision shall be taken:

- The copper strips shall be bonded in between the first and second layers of felt counting from the waterside.

- The copper strips shall be bonded to the felt layer by the pour-and-roll method. The strips shall overlap at least 10 cm along the side and at least 30 cm at the end.
- For bonding the copper by the pour-and-roll method, an adhesive shall be used unless stated to the contrary in the specifications. The adhesive shall be applied in the following coverage: not less than 5 kg/sq.m when bonding to horizontal and slightly inclined surfaces, not less than 6 kg/sq.m when bonding to vertical and steeply inclined surfaces, assuming in each case adhesives having a bulk density of 1500 kg/cu.m. If adhesives with higher or lower bulk densities are used, the minimum weight of adhesive applied per sq.m shall be higher or lower in the same ratio as the bulk densities.
- Care shall be taken to ensure that no electrically conducted connection result between the copper strip and other metals.

**5.14.11Connection of the Damp-proofing to Penetrations**

The connections shall be made with the aid of fixed flanges (built-in steel flanges) and loose flanges.

The connecting elements (fixed flanges and loose flanges) shall be cleaned to remove rust and dirt. The points which are in contact with the damp-proofing shall have an undercoat applied to them immediately after cleaning.

Bonding shall not be carried out on top of fixed flanges, and loose flanges shall not be tightened until the undercoat has dried thoroughly and contains no more solvent. The undercoat on fixed flanges shall be free from moisture before bonding on top of it; if necessary, special steps shall be taken to dry it immediately beforehand.

The damp-proofing shall be reinforced in the region of fixed flanges. The reinforcement shall take the form of a further layer of unbacked felt extending at least 30 cm beyond the flange in all directions. In the region of the fixed flanges, the individual layers shall meet the butt joints; the joints in the individual layers shall be staggered relative to each other.

The damp-proofing shall be clamped between the fixed flanges and the loose flanges.

**5.14.12Damp-proofing over Structural Joints**

Damp-proofing over structural joints shall be reinforced unless stated to the contrary in the specifications.

Damp-proofing over structural joints intended to allow only for the contraction and creep or only the expansion of structural members shall be reinforced by putting in cupfluted copper strip 0.2 mm thick. The copper strip shall be bonded.

Damp-proofing over structural joints intended only to allow for differential vertical movements of adjoining structural members up to a settlement difference of 1.0 cm shall be carried out as above. If settlement differentials of more than lcm are to be allowed for, the damp-proofing shall be carried out in such a manner that the more stringent conditions involved are satisfied,

Damp-proofing over structural joints intended to allow for movements resulting from temperature changes, vibration, torsion, etc., shall be carried out so that in both type and

Extent, it satisfies the special conditions arising.

**Sealing Joints in Protective Layers**

Joints in the protective layers applied to damp-proofing of floors and ceilings shall be out without damaging the damp-proofing and completely filled with hot-flow bitumen sealing compound unless stated to the contrary in the specifications.

**Tests and Properties**

All materials to be supplied and installed shall be in accordance with the relevant standards. Selection of samples for testing material will be made by the Employer.

**Auxiliary Works**

Unless otherwise specified, all and any kind of works, materials, services, safety measures, etc., as well as, and if so requested by the Employer, all tests and samples required for the completion of the work shall be included in the contract price.

## 5.15 Roads and Surfacing

### 5.15.1 General

External & Internal Roads shall be designed for slow moving axial loads of fifteen tones. and shall be surfaced with rolled asphalt concrete wearing surface for External Roads and concrete wearing surface for Internal Roads complying with the requirements of relevant British Standards, or other approved standard. For the External Roads asphalt concrete wearing course shall consist of a concrete base and shall have a total thickness, of not less than 40mm or as approved by the Employer. The pavement thickness shall be determined from Road Note 31 published by Transport and Road Research Laboratory.

### 5.15.2 Materials

Materials used in the sub-base, base and pavement shall the requirements of the relevant British Standard or other approved standard.

Before any section of the roadworks is commenced, and during its construction, the

Employer may request the carrying out of tests and control tests to determine the degree ofcompaction in the sub-grade, base and pavement. No section of the work shall be covered until it has been approved by the Employer.

### 5.15.3 Preparation of formation

The upper of the 300mm of the subgrade shall, if required by the Employer, be improved to strength of greater than CBR 15% by blending it with a granular material or stabilizing agent.

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 four to seven tonne power-driven roller unless otherwise ordered or permitted by the Employer.

### 5.15.4 Drains

All drains, sewers, cable ducts and other necessary work below road formation level shall be completed, inspected and passed by the Employer's Representative before any road work is started.

### 5.15.5 Kerbs

Continuous lengths of insitu concrete kerbs or precast concrete kerbs set on a concrete bed are to be laid on each side of the roads to define the limits for vehicular access.

### 5.15.6 Paving slabs and trench covers

Concrete paving slabs shall comply with a relevant approved Standard. They shall be manufactured by hydraulic pressing.

All trench covers shall be a minimum of 50mm thick and shall be provided with by 50mm recesses for lifting purposes where required. They shall be reinforced with expanded metal to the approval of the Employer. The l; expanded metal shall be in the middle of the covers with 25mm cover to the edges. Non-standard shapes may be vibrated instead of being hydraulically pressed. In all other respects the 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.

### 5.15.7 Turfing

Non-paved areas indicated to be soiled and seeded shall consist of a depth of vegetable soil raked and sown with approved grass seed at the rate of 0.68kg to ten square metres. Sown seed shall be watered as necessary until growth is established.

### 5.15.8 Stone areas

Areas indicated to be surfaced with chippings shall be treated with an approved week killer, then made up with rolled to a consolidated even surface and final thickness of Approved granite chips, crushed natural stone or ballast shall be spread, leveled and lightly rolled to a finished even thickness of 50mm.

## 5.16 Roofing / Claddings

### 5.16.1 References

The materials, workmanship and tests shall confirm to the standards and Codes of Practice the standards or equivalent approved by the Employer.

| Title | Subject |
|---|---|
| BS 970 | Wrought steels for mechanical and allied Engineering purposes |
| BS 1202 | Nails |
| BS 1449 | Steel plate, sheet and strip |
| BS 1470 | Wrought aluminium and aluminium alloys for general Engineering purposes - plate, sheet and strip. |
| BS 1494 | Part 1: Fixing accessories for building purposes. Fixings for sheet, roof and wall coverings |
| BS 3416 | Specification for bitumen-based coatings for cold application, suitable for use in contact with potable water |
| BS 3837 | Expanded polystyrene boards. |
| BS 4868 | Profiled aluminium sheet for building. |
| BS 5427 | Use of profiled sheet for roof and wall cladding on buildings |
| BS 6577 | Mastic asphalt for building (natural rock asphalt aggregate) |
| BS 6925 | Mastic asphalt for building and civil Engineering (limestone aggregate) |
| CP 143 | Sheet roof and wall coverings |
| CP 144 | Part 4: Roof coverings. Mastic asphalt. |
| CP 297 | Precast concrete cladding (non load bearing). |

### 5.16.2 Submittal for approval

The Contractor shall submit to the Employer for approval:

- Detailed working drawings showing cladding types, sheeting layouts etc. within four weeks of start of steel fabrication.
- Drawings and specifications for site use should describe all materials in sufficient detail to enable them to be properly identified and installed.

- Such working drawings are to clearly show details of cladding construction with their relationship to other elements of the structure and super-structure works.

  Any area that requires special attention on site, such as those requiring additional fixings, should be clearly identified. These drawings shall make reference to specifications for handling, storage, working and installation. A complete layout of all fixings shall be submitted for approval.

- Detail drawings of the design showing all flashings, lapping, gutter details, openings etc. shall be submitted and approved before erection commences.
- Colour samples of cladding and roofing which shall be incorporated within the works.
- Calculations required in accordance with the specification. Relevant manufacturers technical literature shall accompany design calculations and drawings.
- A properly detailed maintenance manual shall be submitted on completion of the works: this must also contain full details of the installation and materials including a set of working drawings as built.

### 5.16.3 Cladding

**Lightweight Cladding**

Lightweight claddings shall be a weatherproof, decorative profile metal sheeting, complying with the requirements of BS 5427 or other approved standard and used in combination with an approved acoustic and thermal material to provide a composite lightweight cladding.

The roof of the existing Engine Hall is clad with a profile steel sheet double sandwich construction in ONDATHERM 101, 30mm thickness, with 10% ONDALUX translucent insulating panels manufactured by Sollac of France. Cladding proposal for use in the construction of the power station extension shall be similar in appearance to that used in the construction of the original power station.

The Employer's approval of the proposed cladding shall be obtained before any material is ordered.

Steel sheeting must be coated on both sides with Zinc or Aluminium / Zinc (Zalutite or equivalent) and in addition have a durable, decorative coating suitable for withstanding the industrial marine atmospheric conditions at the site.

The life to first maintenance of the paint/film shall be 10-20 years as per BS 5427 Table E3. The lift to first maintenance of the galvanizing or Aluminium / Zinc shall be 10-20 years as per BS 5427 Table D2.

The minimum thickness of bare metal for single skin cladding shall be 0.9 mm.

Materials that combine coatings of differing flexibility such as bitumen and polyesters will not be permitted in polluted atmospheres unless the problem of polyester embrittlement is adequately catered for.

The sheeting shall be single or double skinned and shall a thermal transmittance value not greater than 0.45W / sq.m. deg. C and an acoustic attenuation value not less than 40dB.

**Fixing**

The sheets shall be fixed to the steel framework in strict accordance with manufacturer's instructions using non corrosive self-tapping screws or hook-bolts complying with BS 1494

Part 1, and sealing washers. Heads of screws or bolts shall be colour capped to match the sheeting.

All screws fixings are to be cadmium plated suitable for external use. All rivets are to be Monel type 4.8mm diameter with a minimum grip range of 1.5mm/9.0mm. Visible screw fixings to the external skin of the building are to be completed with colour caps, similarly rivets on the wall cladding areas and associated flashing and trims.

Fixings should be designed in accordance with wind loadings applicable to the area in addition to the minimum standard contained and described in the specification.

An authenticated certificate must be supplied by the Contractor from an approved supplier confirming the correct grade quality of the quality of the main fixings together with performance data, e.g. pull-out values of the fixings as required in this performance specification.

No site drilling of steelwork shall be permitted without the approval of the Employer in writing.

**Sealing Strip**

Sealing strip shall be of asbestos fibre filled pressure sensitive butyl or homogeneous quality, polyisobutylene or similar approved material from an approved supplier. The sealer shall be non-asphaltic, non-shrinking, non-drying and non-toxic with superior adhesive properties to metals, plastics and painted surfaced up to 104°C. Except where otherwise described sealing strip shall be minimum of 16mm wide and of sufficient depth to provide a suitable weather tight seal. All sealants to be laid in continuous length.

**Manufacturers Recommendations**

All fixings and sealant strips are to be installed strictly in accordance with the manufacturer's recommendations.

**Insulation**

The Contractor shall use insulation between sheets or on the inside sheet of the cladding to obtain the required thermal and sound attenuation properties. Insulation shall be either foil backed fiberglass, rockwool or non-flammable material.

**Spare material**

The Contractor shall supply to the Client at completion at least ten square meters of roofing material in complete sheets for use in maintenance.

### 5.16.4 Flat roof Roof covering

Reinforced concrete flat roofs, if used, shall be insulated with a lightweight concrete screed of 50mm minimum thickness and weatherproofed with an approved specialist roofing system or by other means approved by the Employer.

The roof finishes shall only be applied by suitable trained operatives and for specialist systems an approved specialist Sub-Contractor shall be employed by the Contractor.

**Roof Finish**

The lightweight concrete screed shall have a dry density not exceeding 950 $kg/m^3$ and a minimum crushing strength at 28 days, measured on a 150mm cube, of $2N/mm^2$ (20 $kg/cm^2$). The lightweight concrete screed shall be laid to the falls shown on approved drawings and in bay snot exceeding $20m^2$ in area.

The roof shall be waterproofed using an approved built-up roofing system supplied and fixed by a specialist Sub-contractor.

Alternatively, subject to the Employer's approval, the roof shall be waterproofed using tropical asphalt laid in two layers to a total thickness of 20mm over an asbestos based sheathing felt. White spar chippings be laid to a thickness of 10mm over the tropical asphalt. Vents shall be provided as necessary.

**Concrete Roofing**

Reinforced concrete flat roofs, if used, shall be insulated with a lightweight concrete screed of 50mm minimum thickness and weatherproofed with an approved specialist roofing system or by other means approved by the Employer.

The roof finishes shall only be applied by suitably trained operatives and for specialist systems an approved specialist Sub-contractor shall be employed by the Contractor.

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## 5.17 Carpentry and joinery

### 5.17.1 Timber

Timber for carpenter's or joiner's work shall be hardwood or softwood of approved quality, the best of a species and suitable for the proposed purpose. All timber shall be subject to inspection by the Employer, both before and after finishing. The Contractor shall provide all necessary labour and facilities for the inspection of timber.

Moisture content shall be within the following limits:

- Internal work 10 to 12 percent.
- External work 12 to 15 percent.

The slope of the grain shall not exceed

- One in eight in hardwood
- One in ten in softwood

Discoloured sapwood, checks, splits, shakes and large or loose knots shall not be allowed.

### 5.17.2 Plywood

Moisture content shall be between 10 percent and 15 percent, all plies being tightly bonded and face veneers capable of being finished with a smooth surface. Plywood shall be first grade for polishing and second grade for painting.

### 5.17.3 Hardboard

Hardboard shall be tempered or plain 3mm and have a minimum density of per cubic meter and shall have one face suitable for sand-papering and receiving all normal decorative finishes.

### 5.17.4 Preservatives

All 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 with two coats of preservative before fixing. All fixing blocks pallets and other hidden timber shall be so treated prior to fixing.

### 5.17.5 Screws

Stainless steel cross-slot type screws, countersunk where necessary, shall be used throughout the work. Where shown in cups, these shall be of the fully recessed type.

### 5.17.6 Nails

Nails shall conform to an approved standard. All nails and spriggs for external use shall be sherardized.

### 5.17.7 Construction

The Contractor shall be responsible for the sound construction of components, using recognized forms of joints in appropriate positions where these are not specified. Lost head nails may be used in work for painting, punched and filled. Edge to edge joints shall be made with cross grained tongues or shall be approved glued and machined joints (e.g. zig zag type). Window and door frames shall be constructed without horns projecting at top or bottom corners, with tenon, comb or dowelled joints, waterproofed-glued and primed.

### 5.17.8 Finish

Joinery shall be finished in such a way that neither the texture of the surface of the wood nor the joints are apparent after painting.

### 5.17.9 Knotting and priming

Wherever possible, joinery which is for painting shall be knotted and primed before leaving the joiner's shop. Backs and hidden surfaces shall be primed.

### 5.17.10 Fixing

Where fixing to blockwork etc., except where lugs are shown on drawings, holes for screws shall be drilled with a rotary drill and filled with cold caulking compound. Fixings to concrete shall be, unless other-wise shown, by means of approved inserts cast in. Where these are omitted either by oversight or intention, fixing to concrete shall be as for blockwork.

### 5.17.11 Protection

Joinery shall be given waterproof covering during transit and at all times kept dry. Joinery shall be stacked under cover both in the joinery works and on the site. Joinery shall be carefully protected from damage before and after fixing, and shall be boxed in with approved temporary coverings where directed. Exposed arises shall be protected.

### 5.17.12 Defective work

Any joiner's work which shrinks, splits, fractures, warps, parts in the joints or shows any other defect shall be taken down and renewed to the Employer's satisfaction and any work disturbed as a consequence shall be made good at the Contractor's expense.

### 5.17.13 Doors

All doors shall be of approved manufacture and are to be guaranteed against defects for 12 months.

Wood doors described as flush type shall be plywood faced with a cellular resin bonded core, and edges shall be closed with hardwood lapping. Plywood faces shall be of approved material and of minimum thickness. The door finish shall be as directed.

### 5.17.14 Sizes and tolerances of doors

Samples showing construction shall be made available to the Employer. Doors shall be finished to a maximum thickness of 45mm unless indicated otherwise. The finished width and height shall be such as to allow for 'shooting' on site as is customary when fixing. The doors shall be straight and true on all faces and the Contractor will be required to replace at no extra cost any door which shows any sign of undulation or unevenness in the finished surface whether due to defect in the core or ply facing, including if necessary, the cost of hanging and transferring ironmongery.

### 5.17.15Openings For Glazing

Doors are to be prepared for glazing where approved by the Employer including the provision of one loose and one fixed set of hardwood glazing beads, pinned on fixed side, mitred at corners, including fully recessed brass cups and screws on loose side and, in case of polished doors, of the same timber as the face veneer and to match.

**For Ventilation**

Louvered openings are to be provided where approved by the Employer. In the case of polished doors, louvers and frames shall be hardwood of same timber as face veneer and to match, unless otherwise detailed.

### 5.17.16 Ironmongery and miscellaneous fittings

Ironmongery shall be subject to the approval of the Employer and shall be obtained from approved manufacturers whose names shall be submitted before orders are placed.

### 5.17.17 Door closers

Door closers may be overhead type or floor fitted, in locations as required by the Employer. They shall be of an approved type, provided with fine adjusting facilities. The size of the door closer shall be relative to the weight of the wing and shall be approved by the Employer.

### 5.17.18 Workmanship

The quality of workmanship shall be of approved standard. Ail carpenter's work shall be left "from the saw" unless otherwise described or directed. Carpentry shall be properly framed together. All surfaces of timber which may be exposed to view shall be wrought and finished with a clean, even, smooth surface.

### 5.17.19 Faults

Any carpenter'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 Employer.

### 5.17.20 Glazing

#### 5.17.20.1 Glass

All glass shall be of approved manufacture to BS 952 and shall be of the qualities required and free from bubbles, smoke wanes, air holes and other defects. Glass shall be delivered to the Site in cut sizes in packages bearing the manufacturer's name and/or trademark. The type, quality and thickness or weight of the glass shall be clearly marked on each package.

Sheet glass shall be —ordinary glazing or quality or —selected glazing quality as required and shall be of weights required.

Polished plate glass shall be —glazing quality for glazing 6mm nominal thickness and shall be clear or Georgian wired or as otherwise required.

Wired glass shall be polished plate or cast with Georgian wire mesh. The mesh shall be square with the frames and shall line up with adjoining panes.

The panes shall be face ground, be polished on both sides and fully transparent and reflecting. The minimum thickness of panes depends on the size demanded, the location of glazing and the wind pressure to be ascertained. Thicknesses shall be in accordance with maximum pane sizes given in BS 952 and shall be shown on the construction drawings.

**Glazing to timber: general**

All glazing shall be generally in accordance with BS 6262.

**Glazing to timber: internal doors**

The glass shall be bedded on strips of wash leather, and secured with removable beads.

**Glazing to aluminium windows and doors**

Glass shall be secured in aluminium windows and doors with an approved polysulphide compound or plastic trim. Neoprene or nylon stripping shall be used between window and frame to ensure a weatherproof seal.

**Glass louvres**

Glass louvers, if used, shall be matched at the ends and finished with rounded and polished edges.

**General**

On completion of the works, all broken or cracked glass shall be replaced and all glass cleaned inside and out, to the satisfaction of the Employer.

## 5.18 Painting and decorating

### 5.18.1 Paint

Paints for priming, undercoating and finishing shall be ready paints of the best quality so as to produce first class and durable finishes and shall comply with relevant standards approved by the Employer. All paints shall be obtained from an approved manufacturer who shall certify that the paint is suitable for the intended purpose.

All paint shall be ready mixed and supplied in sealed 5 litre drums or cans, unless otherwise approved by the Employer, bearing the name of the manufacturer and properly labelled as to quality. It shall not be adulterated by the addition of thinners, dryers, dispersers or any other

materials, unless on the maker's express instructions to permit satisfactory application. Painting materials used on cement or plastered surfaces, none of which are likely to have sufficient time to dry out fully before painting commences, shall be of a type specially prepared for this purpose and so designed as to resist the effect of lime or other alkaline substances which may be expected to be present in these surfaces.

All materials shall be used and applied strictly in accordance with the approved manufacturer’s instructions.

### 5.18.2 Linseed oil

Linseed oil shall be best quality refined raw or boiled linseed oil.

### 5.18.3 Turpentine

Turpentine shall be best quality. No substitutes shall be used unless approved by the Employer.

### 5.18.4 Knotting

Knotting shall be of the best quality, consisting of shellac dissolved in methylated spirits, and shall be free from resin and naphtha.

### 5.18.5 Stopping

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.

### 5.18.6 Workmanship

No painting shall be done on exterior work during wet or foggy weather or on any surfaces which are not thoroughly dry.

All reasonable precautions shall be taken to keep down dust in areas where painting is in progress, and an ample supply of clean dust sheets shall be provided to protect the work and adjacent surfaces and furniture or fittings whilst the work is in hand. Any damage shall be made good at the Contractor's expense.

All dust and dirt be removed before painting and finishing coats damaged by dust or other preventable cause shall be rubbed down and repainted.

All ironmongery and other items to surfaces which are to be painted shall be removed before preparation commences and refixed on completion of the painting process, when the paint is dry.

Each coat of paint shall be fully brushed out to achieve an even film over the whole of the work, paying attention to the covering of rivet heads, bolts, nuts, corners, recesses, hidden surfaces, etc. Spray painting shall not be permitted, except for internal faces of walls and ceilings.

Successive coats shall not be applied until the previous coat is properly dried out, but on no account shall more than 72 hours be allowed to elapse between coats.

Successive coats shall be rubbed down with fine glass paper and approved by the Employer as being dry, hard and satisfactory, before the next coat is applied.

Each coat of undercoat and the finishing coat shall be of sufficiently differing colour to enable the successive coats to be recognized and counted.

### 5.18.7 Woodwork

All surfaces of woodwork to be painted shall be prepared, primed and painted four coats, as follows:

All cracks, crevices and holes shall be scraped out, primed and made good with hard stopping, faced up and rubbed down to an even surface.

All large knots shall be cut out and made good with sound wood. All small knots shall receive two thin coats of knotting.

Finally, all work shall be well rubbed down with fine glass paper and all dust removed to present an even surface for painting and then painted as follows: -

- One coat of primer.
- Two coats of undercoat.
- One coat of high gloss finishing paint.

All timber required to be built into, bedded or fixed against brick-work, masonry or concrete shall be given two priming coats and one under-coat on the concealed surfaces.

Hardwood 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.

### 5.18.8 Steelwork and iron work

(EXCEPT STRUCTURAL STEELWORK)

Before painting, the following treatment shall be carried out: -

- Remove all loose scale and rust, by burning off process or by mechanical means.
- De-grease any fouled areas.
- Vigorously brush with a wire brush to remove loose dust particles

After the above treatment, all iron and steelwork, except galvanized metal, shall be painted with:

(i) Two coats of primer - one applied at manufacturer's works.

(ii) Two coats of undercoating.

(iii) One coat of high gloss finish of approved colour.

### 5.18.9 Concealed steelwork

The Contractor shall arrange that all steel rails, slings, beams, bracing and other members wholly or partly hidden, not being galvanized or otherwise rust-proofed and painted as specified, shall be prepared and painted with two coats of primer before the covering work commences in that area. Iron and steelwork which is to be built into or against work, masonry or concrete shall be painted with two coats of black mastic paint.

### 5.18.10 Painting over bitumastic paint or on coated pipes

The surfaces shall be thoroughly cleaned to remove grease, dirt or other deleterious matter, and then painted as follows:

- One coat of sealer.
- One coat of leafing aluminium.
- One coat of undercoat.
- One coat of high gloss finish.

### 5.18.11 Painting on copper

The surfaces shall be thoroughly cleaned with white spirit and then painted as follows:

- Two coats of undercoat.
- One coat of high gloss finish.

### 5.18.12 Painting on Galvanized steel or ironwork

The surface shall be thoroughly cleaned and degreased with degreasing solution to remove grease, dirt or other deleterious matter and then painted as follows:

- One coat calcium primer at works.
- One coat of oleo-resinous undercoating paint.
- One coat of oleo-resinous finishing paint.

### 5.18.13 Concrete, blockwork and plaster

Fair-faced blockwork, plastered walls and the soffits of concrete roofs shall be rubbed down smooth and all loose portions dust removed. Hollows or damaged portions are to be repaired and the whole work to be thoroughly dried out before paint is applied.

Finally paint with one coat of anti-suction primer and two finish coats of approved emulsion paint.

Alternatively, finally paint with porous flat oil paint in two coats.

#### 5.18.14 Other painting and decorating materials

Materials and workmanship not herein fully specified and which may be offered for use in the works shall be of first class quality. Materials and workmanship shall be as approved by the Employer, who may order any section of the work, with which he is dissatisfied, to be remedied at the Contractor's expense.

#### 5.18.15 Touching up and cleaning generally

At the completion of all works, the Contractor shall clean down the premises, wash pavings and steps, wash and leather down wall tiling, etc., clean all sanitary fittings, touch up paintwork, 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.

## 5.19 Plumbing

### 5.19.1 Pipes

Copper pipes shall generally be used throughout having compression joints or capillary joints of an approved type. They shall be secured to the structure with copper saddle clips at not more than one metre centres. Pipes to wash hand basins and W.C. cisterns shall be 15mm bore and supply pipes to header tanks 25mm bore.

### 5.19.2 PVC piping and fittings

Unplasticised PVC piping and fittings complying with BS 3505 will be permitted where adequately protected or where risk of impact is small.

### 5.19.3 Copper tubes and fittings

Copper tubing shall be light gauge in accordance with BS 2871 and the fittings shall be gunmetal in accordance with BS 864. The whole of the tubing and fittings shall be obtained from an approved manufacturer. Joints for fittings shall be compression or capillary type of an approved manufacture.

Branches shall be fixed to a constant fall and pipe bends shall be free from throating, flattening or rippling and the bore and thickness shall be maintained throughout. All bending shall be carried out with bending machines or springs. Cut and shut method of bending will not be permitted.

Butt welds will not be accepted and tubing shall be prepared for welding by swaggering out the copper tube to form a cup to receive the end of the tube, which shall be carefully prepared and jointed to ensure a close fit with the tube which enters.

### 5.19.4 Poly butylene

Poly butylene tubing and the fittings shall be accordance with relevant British stranded or equivalent. The whole of the tubing and fittings shall be obtained from an approved manufacturer. Joints for fittings shall be compression or capillary type of an approved manufacture.

Wherever possible purpose made bends shall be used rather than angle fittings.

Every bib and pillar tap shall be provided and fixed with union or cap and liner coupling.

The tubing shall be fixed with copper or brass pipe clips with wall flanges or brass pipe brackets, etc., at not more than 1 metre centers. Where tubes are required to be suspended from soffit of roofs they shall be fixed with approved purpose made hangers, one end bolted around the pipe and the other end split and cut and pinned to the soffit of the concrete roof. At completion of the works the Contractor shall clean the copper tubes and fittings where exposed to view.

### 5.19.5 Sheet lead

Sheet lead, if used for flashings, shall be milled lead conforming with BS 1178 and shall be laid in the best manner without solder. Unless otherwise required, sheet lead shall be at least 21 $Kg/m^2$.

### 5.19.6 Stop cocks

All stop cocks shall be approved material and reputed Brands having appropriate pressure classification, unless otherwise directed.

Each fitting or group of fittings shall have a stop cock inserted in the service adjacent to the fitting.

### 5.19.7 Ball valves

Ball valves shall be approved material and reputed Brands having appropriate pressure classification, unless otherwise directed.

### 5.19.8 Overflows

The overflows from storage tanks shall be larger diameter than supply pipes, shall be taken from the top and carried to a prominent position so as to cause a nuisance when functioning.

### 5.19.9 PVC downpipes

PVC downpipes and fittings shall comply with BS 4576: Part 1.

### 5.19.10 Testing

The whole of the plumbing shall be tested to the satisfaction of the Employer, who shall be notified beforehand and will supervise the testing. The work shall be handed over in sound and perfect condition.

### 5.19.11 Rainwater outlets in flat roofs

Rainwater outlets shall be approved high density polythene including domical grating. The outlets shall be cast in posting and the screed and roof covering dressed in to ensure a watertight connection.

### 5.19.12 Workmanship

The layout of the plumbing shall be to approved standards and of the highest workmanship, with all bends to easy sweeps and bores and thicknesses maintained throughout.

## 5.20 Plasterwork and other wall and ceiling finishes

### 5.20.1 Gypsum

The gypsum used for plaster shall be pure calcium sulphate of approved quality and shall be delivered to the site in bags. The gypsum used for setting coats of plaster over cement-sand backing coats shall be of the retarded hemi-hydrate variety. All under-burnt or over-burnt gypsum will be rejected and the Contractor shall provide facilities for each batch of material to be checked and tested on the site to the satisfaction of the Employer. The gypsum shall be kept in proper sheds on site exactly as described for cement.

### 5.20.2 Metal lathing for plastering

The lathing shall be made from mild steel and shall be of the ribbed expanded type weighing not less than 2kg per square metre. The material shall be protected by one coat of paint. Nails for fixing the lathing shall be flat headed galvanized nails. Wire shall be soft galvanized wire. All these materials shall comply with standards approved by the Employer.

### 5.20.3 Metal angle and casing beads

The beads shall be of the expanded metal dust proofed type.

### 5.20.4 Storage of materials

Cement and premixed plaster shall be stored off the ground in a dry weatherproof store, away from damp surfaces. Similar precautions shall be taken with metal lathing.

Sand shall be stored under clean conditions and no contamination by soil or other harmful substances shall be allowed.

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.

### 5.20.5 Preparation of backgrounds

Backgrounds for plasterwork 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 blockwork which are to be plastered or rendered shall be raked out to a depth of 13mm.

All unprotected ferrous metals shall be given one of approved primer before plastering is commenced.

### 5.20.6 Plaster work

Undercoats shall consist of Portland Cement, hydrated lime and sand, gauged in the proportions 1:1:6. The undercoat shall be keyed to take the finishing coat and allowed to dry out completely before the latter is applied.

Finishing coats shall be applied strictly in accordance with the recommendations of the manufacturer of the particular brand to be used. The total thickness of the two coats shall not be less than 15mm thick.

### 5.20.7 External rendering

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 machine, to give a "Tyrolean" finish of uniform thickness and texture. An approved plaster may be used in both coats. All external rendering shall be protected from rain and direct sunlight for a period of 7 days. Rendering shall comply with BS 5262.

### 5.20.8 Workmanship generally

All proprietary brands of plaster or plastering 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 Lo the manufacturer's instructions regarding the time allowed to elapse between mixing and using.

The plastering and rendering shall be carried out by men 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.

### 5.20.9 Joints in plastered surfaces

Joints shall be introduced in plastered surfaces over all joints between differing backgrounds and over all movement in blockwork backings.

### 5.20.10 Glazed ceramic and porcelain tiling

Glazed ceramic wall tiles shall be of nominal size 300mm x 200mm x 6mm and all floor tiling shall be Porcelain and size 600mm X 300mm X 12mm design to be selected and fittings shall be good quality and obtained from a supplier approved by the Employer. The ceramic tile and grouting materials shall be obtained from the Sri Lankan Manufacture approved by the Employer.

The Contractor shall ensure that the rendering is accurately formed and has a true, plumb surface which is free all high spots and depressions.

The floated coat shall consist of a 13mm thick rendering of 1:6mm by volume of Portland cement and sand; it shall be finished with woodfloat. 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 set out to the Employer's satisfaction. The height of tile courses

shall be set out properly by means of a tiling roof all tiles and joints shall be accurately aligned, both vertically and horizontally. Joints between the tiles shall be 2mm 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 rendered 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 leveled on to the wall with a plasterer's trowel having 6mm x 6mm notches at 25mm 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 white grouting cement; the finish shall be flush and free from all voids and irregularities.

All wall faces shall be finished plumb and all floor tiling shall be leveled flush throughout free from unevenness and irregularities of plane; all angles shall be straight and true. The finished work 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. Any damage which doe: occur shall be made good by the Contractor at his own expense. The of the work shall be left in a state satisfactory to the Employer.

#### 5.20.11 Acid resisting tiles

Acid Resisting tiles shall conform to BS EN ISO 3679. The tiles shall be 150 x 150mm 22mm ribbed (non-slip) ceramic quarry tile.

The separating layer shall consist of either bituminous felt to BS 747, building paper to 1521 or 500 gauge polythene film.

The separating layer shall be laid flat in a continuous layer over the screed base, with lapped joints between adjacent sheets and shall not be stuck down.

The bedding mortar and grouting joints shall be formed from materials that will resist the environment as satisfactory as the tiles.

Movement joints shall be provided in accordance recommendations of BS 5385. Each movement joint shall be at wide and of a depth equal to the combined thickness of tiles and bedding mortar.

## 5.21 Fencing and gates

### 5.21.1 Chain link fencing for transformer bay

Chain link fences shall be constructed of PVC coated steel wire in accordance with BS 1722: Part 10 or similar National Standard approved by the Employer. Chain link shall be of such manufacture that when any one segment is cut, remaining segments within the pattern retain their rigidity. Overall height of the fencing shall be 2 ½ metres above ground level, excluding barbed wire. A further depth shall be buried in the ground, if this is done on the existing fence, but where ground conditions prevent this 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.

All mesh shall be of PVC coated steel wire of diameter with of 3.55mm diameter with a length of side not exceeding 50mm. Line wires shall be of PVC coated steel wire of the same gauge to adequately support the mesh rigidly. Line wires shall be provided at top and bottom of the mesh fencing and at two evenly-spaced intermediate levels. The top wire shall be doubled, making five-line wires in all. The line wires shall pass through the concrete supporting posts. Mesh and line wires shall comply with BS 4102.

### 5.21.2 Posts and Struts

Supporting posts and struts shall be of reinforced concrete to the same approved standards as above. The post shall be set in concrete in the ground and shall have cranked tops set at 45° to the posts, through which shall pass three standards of galvanised barbed wire to BS 4102. Droppers shall be fitted at the centre of each bay of to prevent the barbed wires being bunched together.

### 5.21.3 Gates for fencing areas

Gates and gateposts shall be generally constructed and installed in accordance with BS 1722: Part 10.

Gates shall be constructed of galvanized chain link mesh on a galvanized RHS or tubular steel frame, with three strands of barbed wire across the top on cranked galvanized extension arms.

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. All these fittings shall be galvanized. The vertical drop bolts are to drop into galvanized steel tubes cast into the road, to secure the gates when in both closed and open positions.

Gate posts be made of concrete or galvanized RHS section and set in concrete in the ground. Gate hinges (pivots) shall be heavily galvanized. Details of the gate posts shall be submitted for the Employer's approval before fabrication.

### 5.21.4 Accuracy

The fencing and gates shall be erected truly vertical and to the lines and levels shown on drawings approved by the Employer.

# 6 Power Station Fire Detection and Protection System

## 6.1 Scope of Specification

This specification covers all firefighting installations, supplement by a fire detection and fire alarm system, complete in every respect and suitable for satisfactory operation to offer protection for all installations of this Gas turbine power plant, wherever needed.

## 6.2 Scope of Supply

The scope of supply comprises design, manufacturing, testing, delivery, erection and commissioning as well as providing all required documentation for the equipment as specified.

The fire pumps shall be sized to cover the water demand for fighting of the proposed Gas turbine power plant. One electric motor Driven fire pump and one Diesel engine driven stand-by fire pump shall be provided. Both pumps shall be vertical shaft turbine-type. The diesel pump with a right angle gear shall take suction from the screening and pumping station and supply firefighting water through a ring main system to outdoor hydrants, indoor hose stations, foam systems, sprinkler systems and water spray fixed systems.

Under normal stand-by conditions, the firefighting system shall be pressurized by one (1) electric motor driven jockey pump.

The jockey pump shall make up leakages and meet the demand of one (1) indoor hydrant without the need to the start the fire pumps for such a small consumption.

All water based extinguishing systems shall be connected and drained to the plant drainage system.

All pumps, pipes and any other parts of extinguishing systems and components for the firefighting water system shall be made of sea water resistant material.

The system shall be complete and functional in every respect, mentioned or not in this specification.

The scope of equipment shall mainly consist of the following:

- Fire pump installations
- Underground fire service main
- Hydrants and hose cabinets
- Standpipes and hose systems

- Sprinkler systems
- Water Spray fixed systems
- Foam water spray systems
- Fire Alarm and Control Panel
- Ultraviolet flame detectors
- Spot type Fixed and rate of rise temperature detectors
- Spot type smoke detectors
- Air aspiration smoke detection systems
- Linear heat detection systems
- Mobile and portable fire extinguishers
- Installation material such as supports, hangers, sleeves, clamps, gaskets, sealing, bulk heads, isolating valves, fire stops, electrical cables etc. for the complete protection system
- Spare parts and special tools (Shall be included the cost in Schedule 3, Mandatory Spare Parts of Volume 5)
- Provisions to expand the system to the existing power plant

The fire Fighting installations and detection systems to be installed are indicated in the following table.

| **Building/Area Equipment To be Protected** | **Fire Fighting System** | **Detection System** |
|---|---|---|
| Gas Turbine/Generator unit | $CO_2$ Extinguishers or aerosol suppression Manual/Automatic Operation | Ultra violet flame detectors, Fixed and Rate of rise Temperature detectors and Gas detectors |
| Fuel pump house | Automatic foam – water spray system and combined foam/water indoor hydrants | Fixed and Rate of rise Temperature detectors |
| Switchgear Compartments/Buildings | $CO_2$ Extinguishers, Manual/Automatic Operation | Air Aspiration System for cubicles/ cabinets and optical smoke detectors for building |
| GT local Controller cubicle/Switchgear | Inert Gas Extinguishers, Manual/Automatic Operation | Air Aspiration System for cubicles/ cabinets and optical smoke detectors for building |
| Battery room | Portable $CO_2$ extinguishers | Gas detectors |

| Building/Area Equipment To be Protected | Fire Fighting System | Detection System |
|---|---|---|
| All Oil – Filled Transformers | Automatic water spray fixed system | Fixed and Rate of rise Temperature detectors and/or buchholz – relay (automatic trip of transformer) |
| Emergency and Black Start Diesel Generator areas | Building fully sprinklered Outdoor/indoor with or without enclosure | Fixed and Rate of rise Temperature detectors and/or optical smoke detectors |
| Cable floors, shaft and tunnel | Automatic Water Spray Fixed systems<br>Alternative : Fire protective coating of cables | Linear Heat Detection and optical Smoke detectors |
| CCR and Control Engineering Room | Portable $CO_2$ and Dry Powder extinguishers | Optical Smoke Detectors |
| All other Plant Area | Outdoor hydrants | Manual fire alarm stations |

## 6.3 Construction Requirements

### 6.3.1 General

Generally, the design, installation and tests shall be accomplished in accordance with the NFPA Codes and Standard with DIN, VDE and VDS Forms and Standards herein specified.

The equipment/material to be supplied for fire fighting, detection and alarm installation shall be approved by Employer and the Fire Brigade of Sri Lanka.

Each major component of protective fire fighting equipment shall be marked in local language and English accordance with NFPA recommendations. Each and every valve in every system shall be identified with metal tag, bearing a white enamelled number on a red field, secured to the valve wheel or body. All details of this requirement shall be subjected to Employer's approval.

The fire fighting installation must in any case be ready for operation before commissioning the Gas Turbine Units.

The design of buildings civil constructions and all fire protections shall also confirm to local regulations, latest edition and amendments and are subject to acceptance by the local authority having jurisdiction.

### 6.3.2 Fire Zones

Fire Zones shall be sub-divided into various fire zones, separated by fire resistant Walls/ceilings/ doors and dykes etc. in accordance with relevant standards.

### 6.3.3 Fire pump Installations

The firefighting pumps shall be designed, installed and tested accordance with NFPA 20, latest edition.

The firefighting pumps suction shall be from water intake and screening plant building.

The firefighting pumps shall supply the firefighting water through an underground fire service main to outdoor hydrants, indoor hose stations, sprinkler systems, water spray fixed system and foam systems.

The pump installations shall be located in a separated fire pump room. Which shall be of fire resistant construction, accessible from the outside;

The delivery pressure of the fire pumps shall by such that the operating pressure at the most remote outdoor hydrant or indoor hose station shall not be below five (5) bars while largest water based extinguishing system under operation.

The fire pump shall be of the vertical shaft turbine type. The diesel engine driven fire pump shall be provided with a right-angle gear.

Each pump shall have its own controller and the pump units shall be complete with all accessories as per NFPA requirements.

The materials of pumps, pipes, valves etc. shall be suitable for the use of sea water.

The Diesel oil storage tank for the diesel engine shall have capacity for eight (8) hours continuous operations at full load. The storage tank shall be located inside the fire pump room. A filling connection with locally mounted semi rotary hand pump shall be provided. Fill and vent lines shall be extended to outdoors.

The pumps shall start automatically upon pressure drop in the discharge main at different and adjustable set points.

Remote start of the fire pumps from the central control room shall also be possible. For each pump, the following remote indication shall be displayed in the central control room;

- Pump in stand by condition
- Pump in operation
- Pump failed discharge

For the fire pumps, adequate minimum flow devices are required to allow reduced consumption for only one (1) or two (2) outdoor hydrants.

All valves, gauges, testiness, flow meters, etc. as well as fire hose connections outside the firefighting pump room shall be provided as per NFPA 20 latest edition.

## 6.4 Outside Protection

The outside protection shall be designed, installed and tested in accordance with NFPA No 24 latest editions.

### 6.4.1 Underground fire service main

An underground fire service main shall be designed in form of supply rings around and throughout the PowerStation to serve outdoor hydrants, standpipes with indoor hydrants and water based extinguishing systems.

The underground main shall be constantly pressurized by the firefighting pump installations.

Two (2) delivery points shall be provided for the water supply from the fire pump station in to underground mains. The various supply rings shall be sectionalized with post indicator gate valves.

Generally, all post indicators and outdoor hydrants shall be protected with crash barriers against mechanical damages.

The underground mains shall be made of ductile cast iron, spigot and socket-jointed, pipes according to ISO 2531, with trust-resisting joints (TYTON or equivalent), inside cement line and outside epoxy coated with additional PE protection sleeve.

As an alternative, the underground mains can be made of glass fibre reinforced pipes and fittings (GRP) according to AWWA/ANSI standard if it is verified that reference systems are working reliable and satisfactory since a period of minimum 10 years.

The underground mains shall be designed as follows;

| | |
|---|---|
| • Working pressure | 8 – 10 bars |
| • Design pressure | 16bars |
| • Minimum diameter of underground main | DN200 |
| • Minimum diameter of branches to standpipes | DN100 |
| • Extinguishing systems | |

### 6.4.2 Outdoor Hydrants

Outdoor hydrant shall be of the wet barrel type with two (2) outlets DN 65 (2 ½") with quick acting ball valves and instantaneous coupling with cap and chain for fire house connections. The hydrant shall be designed as follows;

| | |
|---|---|
| - Working pressure | 8-10 bars |
| - Design pressure | 16 bar |
| - Diameter of connection to underground main | DN150 |

The instantaneous coupling must be compatible with coupling system used by public fire brigade.

Between each hydrant barrel and the underground main, a hydrant connection valve DN150 shall be provided as illustrated in NFPA 24.

Outdoor Hydrant shall be provided in all areas of the buildings and equipment which are to be protected and the distance between hydrant shall not exceed 75 m.

### 6.4.3 Hose cabinet for Outdoor hydrants

Next to each of outdoor hydrant, a weather resistant properly ventilated and red painted hose cabinet with a key behind of a breaking glass together with the cabinet including master key for all installed cabinets shall be provided, containing the following equipment;

- Two (2) fire hoses DN 65 (2 ½) 20m length with instantaneous couplings and hose straps.
- Two (2) fire hose nozzles (flow adjustment)
- Four (4) fire hoses DN 50 (2"), 20m length with instantaneous couplings and hose straps
- Two (2) jet spray branch pipes DN 50 (2") with instantaneous coupling.
- One (1) dividing breech (DN 65/50,65,50) with quick acting ball valves
- One (1) fire axe
- One (1) crowbar
- Brackets for all the equipment
- Extra hydrant wrench

The instantaneous coupling must be compatible with the couplings of the outdoor hydrants.

## 6.5 Standpipe and Hose Systems

The standpipe and hose systems shall be designed, installed and test for class III service in accordance with NFPA no 14 latest edition.

The standpipe systems shall be of the wet pipe type and water pressure maintained at all times.

The pipes shall be of seamless steel and hot – dipped zinc coated (galvanized).

### 6.5.1 Indoor Hydrants

Indoor hydrants for instant intervention shall be provided for all building as listed under the scope of supply in such a number that portions of each floor can be reached by nose stream.

Each indoor hydrant shall be enclosed in a metallic, wall mounted cabinet. Each cabinet shall be painted red and contain the following;

- One (1) suitable landing valve with reducer, instantaneous coupling and fire hose readily attached.
- One (1) swiveling hose reel with a 30m length, DN 25 (1") non collapsible fire hose with jet/spray branch pipe with tail piece readily attached.

### 6.5.2 Foam/Water indoor hydrants

Foam/ water indoor hydrant shall be provided for all building as listed under the scope of supply in such a number that all portions of each area can be reached by a hose stream.

The foam/water indoor hydrants shall be complete metallic cabinets with two foam concentrate storage tanks. The storage tanks shall be of plastic material, each with a capacity of min. 60 kg foam concentrate. The foam concentrate must be suitable to withstand the maximum ambient temperatures for minimum two (2) years.

The cabinets shall be printed red and contain the following:

- One (1) suitable landing valve with reducer
- Two (2) containers each of min 60kg multi – purpose foam concentrate
- Two (2) inline proportions
- Interception valves
- Two (2) swiveling hose reels with fire hoses, each hose of 30 m length, 52mm diameter with instantaneous couplings
- Two (2) jet/spray branch pipes, 52mm (2") diameter with instantaneous coupling
- Two (2) foam making Brach pipes with instantaneous couplings
- Brackets and wenches for all equipment The cabinets may be skid or wall

  mounted.

### 6.6 Sprinkler Systems

The sprinkler systems shall be designed, installed and tested in accordance with NFPA 13, latest edition.

Only automatic sprinkler systems of the wet pipe type shall be provided. Pipes or tubes shall be of seamless steel.

The piping systems shall be provided with flushing and inspectors test connection allowing a flow equivalent to one sprinkler head discharge.

All valves on connections to water supplies shall be approved indicating valves with a reliable position indication.

Approved pressure gauges shall be installed on sprinkler risers, above and below each check valve. A mechanical alarm (water-motor gong) shall be provided for each sprinkler system.

Alarm check valves shall be provided with reliable flow indicators, preferably vane type water flow indicators shall be used.

Water flow alarms shall be announced at Main Fire Alarm Control panel.

All sprinkler valve stations shall be pre-assembled and skid mounted.

### 6.7 Water Spray Fixed Systems

The water spray fixed systems shall be designed, installed and tested in accordance with NFPA No 15, latest edition.

Complete systems shall be released automatically via the fire detection and fire alarm system. Manual release must also be possible using the test valve installed at deluge valve and using a push button to electrically actuate the deluge valve.

Fire detection, actuation of extinguishing system, manual actuation of the system, detector faults and cable faults shall be announced at Fire Alarm Control panel.

All-pipe work normally empty and downstream the deluge valves shall be made of seamless steel and hot-dipped zinc coated (galvanized). The threaded ends of galvanized pipes, after installation, shall be properly protected against corrosion.

Open spray nozzles shall be protected with plastic caps to prevent plugging and corrosion.

The systems shall be designed to discharge effective water spray from all nozzles within 30 seconds following operation of the detection system.

All deluge valve stations shall be pre-assembled and skid mounted.

Adequate drainage for the area to be protected shall be arranged for safe disposal of escaping flammable liquids and to prevent the spread of fire.

### 6.8 Foam-Water Spray Systems

The foam-water spray shall be designed, installed and tested in accordance with NFPA 16, latest edition.

Complete systems shall be provided with all required components.

The systems shall be released automatically via the fire detection and fire alarm system.

Manual release must also be possible.

Fire detection, actuation of extinguishing system, manual actuation of the system, detector faults and cable faults shall be announced at Fire Alarm Control panel.

The foam produced shall extinguish fires of the type produced by the handled fuels and oils.

Foam concentrate shall be stored in suitable tank with level indication.

The foam concentrate must be suitable to withstand the maximum ambient temperatures for minimum of two (2) years.

Foam concentrate supply to the proportions shall be preferably by the pressure-proportioning tank method with or without diaphragm.

All foam concentrate pipe work shall be made of stainless steel.

All pipe work normally empty and downstream of the deluge valves shall be made of seamless steel and hot-dipped zinc coated (galvanized). The treaded ends of galvanized pipes, after installation, shall be properly protected against corrosion.

Open spray nozzles shall be protected with plastic caps to prevent plugging and corrosion.

Provisions shall be made for flushing the systems with clean water after use.

All deluge valve stations shall be pre-assembled and skid mounted.

Adequate drainage for the area to be protected shall be arranged for safe disposal of escaping flammable liquids and to prevent the spread of fire.

### 6.9 Gas Turbine Unit Fire Protection System

An automatic Carbon dioxide or aerosol fire protection system shall be provided in all machinery enclosures of the gas turbine-generator unit.

The equipment shall consist essentially of fire detectors distributed strategically within the enclosures which, on sensing a dangerous condition at any location, will initiate audible and visual alarms, trip all running plant including ventilation and air conditioning equipment, and release Carbon dioxide into the affected enclosure. Actuation of the fire protection system shall also trip the Turbine-Generator unit and immediately cause the fuel supplies to the unit to be shut off at a point external to the enclosures.

Facilities for alternative manual actuation of the fire protection system shall also be provided such that, when the manual mode has been selected the protection sequence will not proceed beyond the alarm stage without manual action by an operator. The fire protection system shall be segregated into separate zones so that individual zones can be selected to the manual mode whilst, at the same time, retaining the automatic mode for the remaining enclosures.

Fire detection for each gas turbine enclosures shall be by means of ultra violet flame detectors with a back-up system utilizing combined Fixed temperature/ rate-of-rise of temperature detectors. The detectors shall be selected to be suitable for Diesel and RLNG fired Gas Turbine units.

Further to above, a Gas leakage detection system, to detect any gas leakage inside the gas turbine enclosure and possible risk areas, shall be provided for future RLNG operation.

All of these detectors shall be integrated with Gas Turbine control systems using suitable means to carry out necessary protection functions.

Activation of any of these detectors shall be notified to the operator automatically through alarms on Main fire alarm and control panel (MFACP) and audible & visible alarms. Audible and visual fire alarms shall be provided in all machinery enclosures, the local Control Cabinets and Central Control Room. Additional audible alarms shall also be provided external to the turbine-generator enclosures.

Detector and wiring faults shall be detected through suitable means and notified to the operator about the same through alarms.

A suitable interlocking system shall be provided for $CO_2$ fire protection system for the safety of the people.

Particular areas of high fire risk such as confined spaces where lubricating oil could possibly come into contact with high temperature surfaces, shall receive special consideration. Such areas shall be treated as separate fire protection zones with detection and Carbon dioxide injection facilities operating independently of the system provided for the machinery enclosure concerned.

The fire protection equipment shall be completed in all respects including pipework, valves, fire detectors, nozzles, control equipment, fully charged Carbon dioxide cylinders and cylinder racks.

### 6.10 Inert Gas Suppression System

For switchgear rooms and local control cubicles, automatic inert gas suppression system for fire protection shall be provided. The fire detection for these areas shall be done through Air aspiration smoke detection system and upon detection necessary automatic action shall be taken by the local air aspiration smoke detection module itself and/ or the Main Fire Alarm Control panel to automatically activate the inert gas suppression system.

There shall be possibility to select automatic or manual actuation mode or to completely switch off the gas suppression system whenever necessary.

Design of the Inert gas suppression system shall be as per the relevant NFPA standards to completely suppress the fire within the area covered by the system.

The gas suppression system shall be completed in all respects including pipework, valves, nozzles, control equipment and proper inert gas storage.

### 6.11 Fire Detection and Fire Alarm System

Fire Detection and Alarm System shall be designed, installed, tested and commissioned with all necessary equipment, accessories and cabling in accordance with NFPA or VDE 0833, DIN 14675 and VDS Form 2095 standards, or equivalent. 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 audibly and visibly displayed on Main Fire Alarm Control panel and audible & visible alarms shall be initiated in the appropriate Fire Zone where the detection actuated.
- The system shall differ whether the alarm was initiated by an automatic detection device or by a manual fire alarm station
- Each and every detector connected to the signaling line circuits shall be addressable
- The system shall uniquely identify each and every detector upon activation, failure or isolation
- Individual fire detection, detector failures and warning alarms of Air aspiration systems of GT control cabinets and switch gear rooms shall be announced locally and remotely in Main Fire Alarm Control panel as well.
- Audible alarms may be silenced by pushing a silence button on the Main Fire Alarm Control panel. Any subsequent actuation of a detection device shall again sound the audible alarm.
- Fixed firefighting systems, designed for automatic operation, shall be released upon detection of fire.

- Operation of fixed firefighting systems, whether automatically or manually released, shall be indicated on the Main Fire Alarm Control panel.
- Fire doors, fire dampers or any other equipment or device shall be released or shutdown as required.
- Short circuit, wire break or any other system troubles shall be indicated on the Main Fire Alarm Control panel.
- Proper protection shall be provided in the Main Fire Alarm Control panel for overvoltage
- The electronic circuits used in the system shall be of failsafe design and be provided with proper coating to have resistance to humidity and corrosion which prevents the operation from being impaired by dust and dirt.
- 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 in the Central Engineering Room or CCR.

### 6.11.1 Analog Addressable Fire Detection and Alarm System

#### 6.11.1.1 Scope of Work

The scope of work shall include designing, supplying, installing, testing and commissioning of Analogue Addressable Fire Detection cum Alarm System with central monitoring system. This shall conform to relevant latest NFPA standards for fire alarm systems.

The system shall have UL/FM certification.

#### 6.11.1.2 General

The detection and alarming facilities relevant to fire system shall be carried out by number of different types of detectors installed to protect the relevant areas of the power plant together with the installed Main Fire Alarm Control panel (FACP) at CCR. The FACP shall be able to supervise individual detectors for proper performance as well as to give pinpoint location of fire alarm.

All wiring to interconnect detectors with FACP shall be done through a signaling line circuit using 2 core twisted shielded Fire Retardant low smoke PVC insulated armored copper cable. All addressable detectors and addressable input/output modules shall be connected together to form one or several SLC loops as per FACP manufacturer's recommendation. The loop cards shall have built-in circuit isolator to accommodate Class A wiring. The loop cards shall be of modular construction.

The detectors shall be analog addressable type. If the detector in not of analog addressable type, a dedicated analog addressable monitor module shall be provided to interface with FACP. The detector shall be easily removable for the purpose of easy maintenance. The address programming shall be facilitated through the base of the detector/ monitor module or from the FACP.

All detectors and bases shall be of the same manufacturer of the FACP as much as possible.

#### 6.11.1.3 Fire Alarm Control Panel (FACP)

The Fire Alarm Control Panel shall be microprocessor based fully Analogue Addressable.

The type and make of the Fire Alarm Control panel shall have demonstrated satisfactory performance in similar applications for at least 05 years and shall be internationally proven in power plants (i.e. Notifier NFS2-3030 or equivalent).

##### 6.11.1.3.1 Hardware

For FACP, the CPU shall be 100% hot redundant, that in the event of a fault in one CPU, all detectors and functions must remain fully functional with hot standby CPU.

FACP shall be modular in structure for ease of installation, maintenance and future expansion. The FACP shall have a Liquid Crystal Display of Alphanumeric type. Annunciation facility shall also be inbuilt into the FACP.

##### 6.11.1.3.2 Detector connection

The Fire Alarm Control panel shall be connected to the various detectors/devices by means of 2 wire loops.

All addressable units shall be connected to the FACP through the Loop cards and shall be addressed through unique addresses.

The panel shall have the facility to accommodate at least a minimum amount of 300 addressable detectors & input monitor modules and 100 addressable output modules which are spread all over the power station premises.

The system shall be designed such that it shall be possible to add at least 30% of the Detectors for future expansion without extra cost on the panel.

##### 6.11.1.3.3 Features

Shall be equipped with an Analogue Control Unit with centralized monitoring for control of all Analogue Addressable Detectors, Manual Call Stations and Switching Systems (for actuating Fire suppression system) connected

The FACP shall also be able to carry out continuous self- monitoring when in normal condition.

The FACP shall be able to obtain analogue value for detectors in the Circuit where ever applicable.

The FACP shall be able to analyze all analogue inputs from all addressable units through its own software and shall be able to identify fire, possible fire or fault conditions.

The FACP shall have the facility to set sensitivity for each smoke detector.

The FACP shall carry out priority selection of alarm in case of alarm activities in two or more remotely located units occur simultaneously. In such cases, the manual call stations shall have the highest priority.

#### 6.11.1.3.4 Actions taken

In case of Fire in an area handled by Fire suppression system, the FACP shall be able to actuate fire suppression system.

Commands for actuators shall be sent through output relay contacts or addressable output modules as applicable.

#### 6.11.1.3.5 Time Delay for Alarms

When an alarm condition is sensed at the FACP from a smoke or heat detector, a delay time/alarm verification period shall be started.

If the sensor is still in alarm after the delay time expires, an alarm condition is reported.

The delay time shall be adjustable.

#### 6.11.1.3.6 Walk Test Facility

The FACP shall have the facility to perform walk test.

Test buttons and software features shall be provided to test the electronic circuits and detector health.

In the walk test mode, the performance of each device can be checked by initiating the device.

In case of testing of the system from the FACP the Display shall be able to give readouts of analogue value of all detectors being tested.

Audible devices shall be initiated, if configured at a preprogrammed time.

If a zone is inadvertently left in walk test mode, it shall automatically reset to normal after the idle time is exceeded.

During the walk test, the zones other than the programmed zones shall be under continuous supervision (normal mode).

In case of any alarm initiated by detector/devices, the walk test shall get terminated automatically.

#### 6.11.1.3.7 Fault Identification and Isolation

It shall be possible from operator controls of FCAP to deactivate a single/ multiple devices or a zone in the system.

The FACP shall also give adequate warning signal whenever there is dust accumulation in detectors.

Short / Open circuit fault of SLCs and detectors shall also be indicated at the FACP.

In such cases, the fault isolators shall isolate the faulty segment automatically.

The missing Detectors/Devices shall also be indicated at the FACP with identification of the location.

#### 6.11.1.3.8 Logging function

Events shall be recorded and stored for future reference.

Events shall include all incidents of fire detection, detector faults, circuit isolations, warning conditions, change of configurations, walk test activation and etc. in chronological order.

Shall have the capability to store at least the latest 15,000 events.

Programming functions shall include alarm/trouble type assignment, point descriptor assignment, alarm message assignment, etc.

Programming shall be carried out from the FACP keyboard or utilizing the authorized laptop/desktop computer software.

#### 6.11.1.3.9 Software

The Contractor shall be responsible for preparation and installation of System Software into the FACP.

The Software shall be user friendly. The system shall be secured against Software errors.The system shall have the ability to be upgraded so as to incorporate more features at a later date.

#### 6.11.1.3.10 Safety Measures

Alarm signals arriving at the FACP shall not be lost following a primary AC power failure.

The FACP shall have its own Battery Backup of a minimum of 24 hours in normal run and then half an hour in alarm condition.

Failures of batteries shall be notified to the operator through alarms.

The System shall be of fail-safe and adequate safe guards shall be ensured that in the event of a failure of a part of the System it shall not handicap the complete System.

#### 6.11.1.3.11 Interfacing with Public Address system

The FACP shall have provision for interfacing with the existing Public Address System. FACP shall be able to call four telephone numbers per channel.

The voice communication for commands and instruction shall be given to existing PA system console.

#### 6.11.1.3.12 Enclosure

The FACP shall be totally enclosed dust and vermin proof type, made of minimum 13-gauge dust inhibited sheet with even baked finish.

### 6.11.1.4 Automatic Addressable Fire Detectors

Automatic fire detectors shall be of the fixed temperature & rate of rise heat detectors, linear heat detectors, spot type optical smoke detectors, air aspiration smoke detectors and ultraviolet flame detectors, subject to Employer's approval.

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. The area coverage per smoke detector shall strictly follow relevant standards.

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.

All detectors shall have real intelligence itself. This means even without the control panel, the detector can make decision and diagnose itself.

All detectors shall also have an integral short circuit isolator, which in the event of a single cable fault will isolate the "culprit" piece of cable and retain all devices on the loop operationally. Automatic testing facility of the isolated section to check the presence of fault continuously, shall also be provided.

Each detector shall possess an integral LED giving a red flashing indication for fire detection.

The detectors shall be hermitically sealed to prevent their operation from being impaired by dust, dirt and humidity. The standard base shall be supplied with sealing plate to prevent entry of dirt/dust/moisture into the wire terminal of the detector contact points.

The sensitivity of all detectors shall be adjustable from software.

Removal of a detector from its associated base shall not affect the continuity of the detection loop.

The detectors shall be such that they can be inserted into or removed from the base by a simple push twist mechanism to facilitate exchange/ for cleaning and maintenance.

After resetting the alarm, the detector shall resume operations without readjustment of any kind.

The sensitivity of the detector shall not vary with change in ambient temperature, humidity, pressure or voltage variation and the detector shall not trigger false alarm due to the above conditions.

The detector shall be free from maintenance and functionally tested at periodic intervals. All detectors shall be identical in construction, design and characteristic to facilitate easy replacement and interchangeable by suitable programming.

#### 6.11.1.4.1 Addressable Manual Call Points (MCP)

Addressable Manual call point shall be used to trigger a fire alarm manually, and shall be suitable for connection to the system's loop.

For indoor MCP shall be surface mounted with protection category of IP 24. For outside the building areas, the manual fire alarm stations shall be wall or post mounted, designed according to protection class IP54.

Shall contain an integrated short circuit isolator which shall ensure that a fault is localized and that the loop continues to function fully in the event of a wire break or a short circuit.

The Manual call station shall be with suitable protection to avoid mal-operation and misuse.

Contacts shall remain closed until MCP is manually reset.

The device shall be red in colour and suitable for surface or flush mounting. The manual call points should be visible to everybody. Their location should be marked and highlighted if necessary for it to be visible.

#### 6.11.1.4.2 Sounders

The sounder shall be addressable electronic type and shall give discontinuous/ intermittent audible alarm whenever any detector or call box operates.

Electronic sounders shall have a sound level of at least 85 dB(A) measured at 1 meter from the device.

The sounder shall be programmed to get activated in event of an alarm from a single detector/device or a group of detectors/ devices.

#### 6.11.1.4.3 Fixed and Rate of rise Heat Detector

The heat detectors shall be capable of detecting rapid rise in temperature and fixed absolute temperatures in a way that the detectors shall be capable of detecting fast flaming fires and slow smoldering fires equally well.

The fixed temperature limit and the limit for rate of rise in temperature for the detectors to be installed shall be selected as per the manufacturer's standard considering the specific requirement of the location.

Transferring the temperature value as an analogue value to the controls is necessarily not required. However, the detector shall be addressable for unique identification.

The heat detectors shall meet the requirements of EN 54.

#### 6.11.1.4.4 Linear Heat Detector

The linear heat detectors and the operating temperature set points shall be selected as per the manufacturer's standard considering the specific requirement of the location.

However, the selected detector shall provide easy installation and maintenance, generating minimal false alarms, provide hazard coverage at every point on the cable for maximum protection, be compatible with the addressable Fire alarm control panel.

Resettable Linear heat detectors are necessarily not required.

The linear heat detectors shall meet the requirements of EN 54.

#### 6.11.1.4.5 Smoke Detector

Individual smoke detectors used other than the air aspiration type smoke detectors shall be of optical type.

For enclosures of local controller cubicles, switchgear rooms, cable floors and stores buildings, optical type smoke detectors shall be installed. Installations shall be carried out as per relevant NFPA standards.

The detectors shall be addressable having an accuracy better than 0.5% obs/ft.

Built in tamper resistant feature shall be provided.

False detections due to dust, heat and other conditions shall of minimum and the units shall meet the requirements of EN 54.

#### 6.11.1.4.6 Ultraviolet Flame Detector

The ultraviolet flame detectors for gas turbine compartments shall be selected as per the manufacturer's standard considering the specific requirement of the location.

The detectors shall meet the requirements of EN 54.

### 6.11.2 Air Aspiration Smoke Detection System

#### 6.11.2.1 Scope of Work

This scope of work shall cover the requirements of design, supply of materials, installation, testing, and commissioning of Air Aspiration Smoke Detection System for the areas specified in this document. The system shall include all equipment and appliances necessary to install the system, complete with suitable highly sensitive technology providing sensitivity of the order of minimum 0.02 – 16% obs/m or better with aspirators connected to a bundle of micro bore sampling tubes.

Air aspiration smoke detector system shall be provided to give early warning of smoke in Gas turbine controller cubicles, switchgear cubicle, MCCs and all other necessary areas in local controller cubicle of gas turbine units and switchgear room.

#### 6.11.2.2 Codes and Standards

The entire design, materials and equipment, installation, testing and commissioning shall be carried out to comply with NFPA Standards.

#### 6.11.2.3 Approvals

All the equipment shall be tested, approved / listed by at least FM or UL.

#### 6.11.2.4 Detector/ Air Sampling Unit

The air sampling type very early smoke detection system shall detect the invisible by products of materials, before getting degraded during the pre-combustion stages of an incipient fire and shall actively and continuously sample the air and shall operate, independent of air movements.

The system shall incorporate addressable micro bore sampling tubes and pinpoint locations. Each controller cubicle, switchgear cubicle, cabinet and etc. shall be monitored through individual micro bore sampling tubes.

The System shall have a sensitivity of the order of minimum 0.02 – 16% obs/m or better using suitable smoke detector, aspirator, filters and other means.

It shall have a display featuring LEDs and alarm Reset facilities and system isolation functions. The system shall be configured by a programmer that is either integral to the system, portable or PC based.

The system shall allow programming of:

- Multiple Smoke Threshold Alarm levels.
- Time Delays.
- Faults in micro bore tubes, detectors, power supplies, aspirator, filter block and communication network as well as an indication of the urgency of the fault.
- Configurable relay outputs for remote indication of alarm and fault Conditions which can be integrated in to Fire Alarm and Control panel.
- Data Communication link with Fire Alarm Control panel to access data relevant to all the sampling points of the detector.

It shall consist of an air sampling micro bore tube system to transport air to the detection system.

The sampled air shall pass through electronic particle separators/ filters or necessary means as required to segregates large particles that are not associated with elements of combustion. The particle separator would require no cleaning or maintenance. If not, self-cleaning facility shall be provided. The filters shall be replaceable and disposable.

System shall utilize advanced algorithms to exactly identify elements of combustion.

System shall report any fault on the unit locally.

System shall have the capability of being remotely monitored through Fire Alarm Control panel.

It Shall provide very early smoke detection and provide multiple output levels corresponding to Alert, Action and Fire. These levels shall be completely programmable.

Shall monitor for filter contamination.

Shall incorporate a flow sensor to provide staged airflow faults, blocked micro bore tubes or pinpoint locations.

Transport time from the least favorable sampling point shall not exceed 120 Seconds.

The detector shall have learning tools for acclimatize itself to the surrounding conditions in which it is installed and shall thus be able to auto adjust its sensitivity to adapt to its environment.

The detector should have built-in event logging. It shall store smoke levels, alarm conditions, operator actions and faults. The date and time of each even shall be recorded. Each detector shall be capable of storing up to 10,000 events.

#### 6.11.2.5 Software

The software package shall centrally monitor and configure very early warning smoke detection and fire protection systems in multiple locations.

The software package shall be compatible with smoke detection and fire protection systems that are approved by global approvals bodies and meet all local codes.

The software shall consist of monitoring and configuration components.

The configuration component shall allow users to configure detectors remotely using a PC connected over a suitable data network.

The software shall operate on Windows 7 latest version, having user friendly user interface.

The monitoring component shall allow users to monitor individual detectors, multiple detectors connected over a suitable data network.

The software shall support multiple no of local and remote password based access control.

The system shall be suitable for providing output in English languages.

The work station shall interpret status change data, transmitted from ports and provide graphic annunciation, control history, logging and reports.

### 6.11.3 Visible Alarms

Red flash lights shall be installed inside the building and outside at main entrances. The lights shall have a frequency of 60 or 90 flashes per minute with an ample light energy.

### 6.11.4 Manual Release Push Buttons

Push buttons for manual release of fixed extinguishing systems shall be designed provided, however, colored in yellow or blue.

### 6.12 Cabling

Signaling and release lines shall be marked as “fire alarm cable” and be laid in conduits. Minimum wire size shall be 0.8 mm or as per manufacturer standard. Further requirements for cabling and wiring as special shall be considered.

### 6.13 Fire Extinguishers

The extinguishers shall have designed, installed and tested in accordance with NFPA No.10, latest edition.

#### 6.13.1 Mobile fire extinguishers

For each turbine/ generator unit, one (1) fire extinguisher of dry powder type and one (1) with $CO_2$, each with a capacity of approximately 50kg net shall be provided and located in the machine hall.

Further mobile extinguishers for other buildings, areas or equipment to be protected shall be provided as required. The fire extinguishers shall be mounted on hand carts and furnished with a 6m hose each.

#### 6.13.2 Portable fire extinguishers

Portable 12kg dry powder extinguishers shall be installed in all buildings.

Switchgear, electronic, control and computer rooms shall be additionally equipped with portable 5kg $CO_2$ extinguishers.

The fire extinguishers shall be wall-mounted and arranged at easily visible and accessible places following the normal exit paths.

Numbers and locations of extinguishers shall be satisfactory to local authorities and are subjected to approval.

The maximum travelling distance to an extinguisher shall not exceed 25m.

The portable fire extinguishers shall have fitted with pressure indicators.

The fire extinguishers must be provided as early as possible, however, at least on commencement of the commissioning preparations.

After completion, random functional tests as of 5% of the supplied portable extinguishers shall be performed in connection with the training programs including refilling of the used extinguishers.

All mobile and portable fire extinguishers must be compatible with the refilling units.

### 6.13.3 Fire Extinguishing Refilling Units

Complete fire extinguishers with all required accessories shall be provided for refilling, service and maintenance of all kinds of fire extinguishers provided for the power plant.

## 6.14 Fire Blankets

Fire blankets and other rescue equipment shall be provided as required

# 7 Water Treatment Plant

The water treatment plant supplied under this contract shall supply the requirement of the clarified water, filtered water, demineralized water for the base load continuous operation of the plant with required redundancy of equipment for reliable continuous operation. The raw water shall be sourced from the existing Kelani river water channel in Kelanitissa Power Station. During the drought period of the year salinity level of the water increases drastically due to sea water ingress. So, the plant should be designed taking into consideration of such variation in river water quality.

The supply shall include all equipment, auxiliaries and piping required for safe and reliable operation.

The specification describes mainly the task of the individual equipment, also allowing provision for necessary and possible future developments and a certain latitude for the specific standards of the manufacturer. Selected equipment shall be, in all respects, well within the range of manufacturer's proven experience and shall not involve the use or application of any prototype design or components. It is emphasized that the broad specifications for equipment and instruments included herein shall be subjected to verification during detailed engineering.

The Contractor's supply shall include but not be limited to the engineering design, manufacturing, material testing, delivery, installation, commissioning, warranty and trial operation of the equipment.

The Contractor shall choose pre-fabricated standard equipment which shall be approved by the Employer. The final flow design capacities shall be adapted to the Gas Turbine type chosen and NOx control and inlet chilling (optional) water requirement.

The Contractor shall familiarize himself about the required connections to the exiting installations.

The bidder shall supply the following documents with the bid for the proposed river water treatment plant and demineralization plant.

- Process flow diagrams
- P & I diagram
- Proposed layout

### 7.1 Contractor's Eligibility criteria for the supplier

The Supplier shall have more than ten (10) year experience and expertise in execution of river water treatment, demineralization reverse osmosis desalination projects, capacity to suit power plants.

The supplier should have completed more than at least five (05) water treatment projects similar or higher capacities during last five (05) years outside the supplier's country.

Experience and Resources Supplier shall have capability to execute the river water treatment, demineralization reverse osmosis desalination projects work on the basis of experience and resources as identified as follows.

I. The Supplier should have a well-established Quality Management System in position and it should have an appropriate International Organization for Standardization (ISO) certification(s).

II. The Supplier should have qualified and trained personnel. The key professional staff of the bidder's organization should have very good knowledge of design codes and standards like ASME, ASTM, TEMA, ISO, BIS etc.

### 7.2 River Water Treatment Plant

#### 7.2.1 Scope of Specification

This specification covers the general technical requirement of the following systems.

- Raw water clarifier and filter plant
- Chemical preparation and feed system

With all necessary equipment for satisfactory operation.

The system and its components supplied shall meet this specification and shall also conform with the specification for "General technical requirement" under chapter 1.

Water treatment system shall include but not necessarily limited to following processes.

1. Pretreatment
2. Biocide Treatment
3. Clarification
4. Coagulation
5. Multi Stage Filtration
6. Water softening and Extra filtration
7. Post treatment

The demineralized water of the proposed water treatment plant shall meet the specification laid down by the Gas Turbine manufacturer and also shall satisfy the conditions to inject into the turbine without making any adverse effect to the life of the Gas Turbine.

#### 7.2.2 Layout

The river water treatment plant and its associated equipment consists of;

- Clarifier shall be installed outdoors
- Filtration plant and associated equipment e.g: pumps, blowers and filtered water basin shall be installed in the water treatment building
- Chemical preparation and feed equipment shall be installed in the chemical dosing building in protected concrete tubs.
- A separate chemical store. The minimum capacity of the store shall be enough to store chemical required for 3 months base load operation of the Gas Turbine Plant.
- The control and switching panel shall be placed together with the demineralization control panel located in a separate room of the water treatment building.
- The area identified for the river water plant and demineralizing plant shall be located at a suitable place agreeable to Employer within the site demarcation.
- The bidder shall submit proposed process flow with the bid.
- A layout diagram for the proposed water treatment plant shall be provide along with the bid and same should be reviewed along with the Employer at the detail design stage.

The layout arrangement shall provide adequate access for safe, simple and easy operation.

Special care shall be taken care for the easy and safe handling of the chemicals and for the chemical protection of all mechanical, electrical and civil components.

### 7.2.3 Operation features

The scope of supply describes of the river water treatment plant and its associated equipment required to process raw water from the Kelani River. Typical water analysis data obtained from the daily operation of Kelanitissa Combined Cycle Power Plant is shown below.

The above data provided are indicative only. However, the contractor shall be responsible for obtaining all water samples and analysis necessary for final design purposes and shall submit copies of all such information to the Employer.

Contractor shall verify all flows which represent clarified and filtered water for the final design at the plant.

The minimum clarifier capacity shall be 150% of the normal plant requirement when all Gas Turbines run at its peak load.

The chemicals will be delivered in bags or drums and shall be emptied directly into the preparation or storage tanks. The river water treatment plant shall be operated fully automatically.

**Kelani River Water Quality Analysis Data 2017**

| Parameter | Jan. | Feb. | March | April | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Conductivity (µS/cm)** | 35550 | 20400 | 23000 | 7630 | 13450 | 994 | 3210 | 1665 | 195 | 169 | 1021 | 1424 |
| **Total Hardness (ppm)** | 3820 | 3200 | 4500 | 1500 | 1400 | 160 | 260 | 240 | 35 | 50 | 80 | 130 |
| **Turbidity (NTU)** | 11 | 15 | 24 | 18 | 13 | 7 | 22 | 16 | 27 | 58 | 64 | 49 |
| **Total Dissolved Solids (mg/l)** | 2546 | 2133 | 3000 | 1000 | 933 | 106 | 173 | 160 | 23 | 33 | 53 | 86 |
| **Suspended Solids (mg/l)** | 18 | 21 | 38 | 17 | 34 | 11 | 11 | 35 | 29 | 20 | 11 | 20 |

Ammonia content (ppm)- No detectable amount

Iron content (ppm) – 0.2

Temperature-28-35 °C

Vanadium analysis cannot be done.

The following operating steps shall be controlled fully automatically;

- Inlet raw water flow control
- Dosing of all chemicals according to the inlet raw water flow and water quality
- Desludging of the clarifier
- Necessary interlocks and shutdown
- Backwash of filters

However manual provisions shall be made for the above automatic operations.

### 7.2.4 Scope of Supply

The scope of supply comprises all equipment, resins and chemicals, filter media, pipes with supports, valves, instrumentation and controls necessary to ensure proper safe and easy operation and maintenance of the river water treatment plant under all conditions.

Platforms, stairs and ladders, necessary lifting beams etc. required for operation and maintenance of the equipment shall be included in the scope of supply. All interconnecting pipe work as well as the piping to all users in the power plant shall be provided. This includes pipe supports, pipe racks and steel works for piping in trenches or protection sheets for street crossing etc. Provisions shall be made for the future extension of the plant.

All the filter media and filter elements should be provided with the bid.

#### 7.2.4.1Scope of equipment supplied

The river water treatment plant shall include the following listed equipment which shall be provided for major system components and no way exclude other necessary components and equipment not mentioned.

All the equipment except clarifier installed in the system shall have 2 x 100% redundancy to operate the plant without any shutdown of plant during the maintenance or breakdown of any equipment.

- Raw water pumps (2 x 100%) made of suitable material to suit the river water, complete with electric motors, necessary valves, pressure gauges, piping and fixing materials.
- Clarifier made of stainless steel, grade 316 complete with over flow weir system, desludging device, sampling device.
- Clarified water pumps (2 x 100%) made of suitable material to suit the river water, complete with electric motors, necessary valves, pressure gauges, piping and fixing materials.
- All necessary pumps (2 x 100%) such as circulating water pumps, filtered water pumps, backwash water pumps, dosing pumps etc. made of suitable material to suit the river water, complete with electric motors, necessary valves, pressure gauges, piping and fixing materials.

- Complete sludge treatment plant to meet the requirement specified by Central Environment Authority (CEA) of Sri Lanka.
- All required chemical preparation, storage and dosing equipment consisting of two preparation tanks for each chemical with a capacity to store at least 2 days requirement and one dosing tank for each chemical with a capacity to store one day requirement to operate under worst raw water quality.

  Complete with all electrical motors, agitators and all accessories such as bag and drum handling facilities peeling funnels operating valves, dilution chambers, sampling equipment, associated piping and instrumentation and control.
- All the filter media and filter elements should be provided.
- Set of complete local and remote instruments for measuring the flow rates, turbidity, pressure and levels at each stage of the treatment process.
- Fully automatic control system based on PLC to control and monitor the water treatment plant and demineralizing plant via HMI having storage capability of RAID 10. The system shall be capable of data storage and retrieval of past data for at least one month with alarm annunciation.
- Electrical switch panel complete with all necessary motor protection switches, relays, fuses etc.
- Set of electrical and control cables.

All additional necessary equipment for proper safe operation of the plant shall be included such as,

- All electrical connections up to the low voltage terminal boards of panels, cubicles, motors and etc.
- All interconnecting piping systems for the distribution of the raw water and treated water
- All minor pipes necessary for installation & operation as drainage pipes, vents and etc.
- All safety equipment as emergency showers, eye washers, plastic suits, protective gloves and shoes, safety goggles, suitable first aid sets, inclusive of eye wash bottles, medicaments and antidote chemicals etc.
- All protection equipment against corrosion wherever necessary
- All necessary base frames, base plates, anchor bolts and supports etc.
- All steel parts imbedded in foundation
- All platforms, ladders, etc for easy operation and
- All standard equipment and accessories which are normally required for the supply schedule but not mentioned here

### 7.2.4.2Scope of Service

The contractor shall be fully responsible for the design, detail engineering, manufacture, transportation, erection and trial operation of the whole water treatment plant.

**Work shop tests**

All components of the water treatment plant shall be tested at the manufacturer's works accordance with the relevant standards and codes and as specified in “General Technical Requirements”

**Site Tests**

When installed at site, at first, a pressure test of the whole plant shall be carried out. Secondary a functional test with a commissioning operation over 30 days for reliability and acceptance shall be carried out.

These tests shall have no influence on the initial operation and reliability test of the complete power plant.

### 7.2.5 Raw water intake

Raw water pumps (2 x 100%) of suitable capacity for the plant requirement shall be installed at the water channel of the existing old steam plant of the Kelanitissa Power Station. The Contractor shall do the required civil, mechanical modification at the raw water intake of the plant in consultation with the Employer without disturbing the existing raw water and fire water pumps. Pump material shall be suitable for the worst water condition for operation.

### 7.2.6 Construction Requirement

The equipment and the material shall conform to high standards of engineering, design, workman ship and construction and shall be capable of operating efficiently, satisfactorily and without excessive wear or maintenance under the service conditions stated in this specification.

Each system shall be designed, manufactured, inspected and tested in accordance with the latest issue of the applicable codes and standards with the construction requirements stated in general technical requirements.

### 7.2.7 Pumps

In general, horizontal, centrifugal pumps shall be provided.

The dosing pumps shall be of the diaphragm type.

The material of the pumps shall be resistant against all conditions during operation. All centrifugal pumps shall be capable of continuous operation. The flow rate of the dosing pumps shall be controlled automatically according to river water flow.

### 7.2.8 Valves/Piping

In general diaphragm type shut-off valves shall be used in the system. Butterfly valves will be accepted for nominal diameter greater than DN 150. The material of the valves shall normally be cast iron. The material of the valves at chemical dosing system shall be rigid PVC or any other suitable material.

The valves shall have sufficient range and capability to provide rated flow systems. All raw water, treated water pipes shall be of stainless steel. The pipe connections shall be welded and/or flanged in accordance with the applicable standard.

The piping material up to fixed point for all chemicals up to the injection points at clarifier shall be flexible reinforced plastic hoses of suitable material installed in protective galvanized pipes.

### 7.2.9 Tanks

All chemical storage, preparation and dosing tanks shall horizontal/vertical type made from carbon steel inside rubber lined with a minimum rubber thickness of 4 mm. the tank shall include flanges and dished ends and saddles for mounting on concrete pads.

All tank necessary connections and instrumentation in addition to spare connections shall be provided. A ladder shall be furnished to provide convenient and safe access to the tank manhole and top mounted nozzle connections. It shall be attached to the tank by welding or other means.

The tank has a dished bottom flat bolted on cover with a hinged cover lid. Each

tank shall be equipped with an agitator made from suitable material. Chemical

concentrations are to be specified by the contractor as per the design.

All necessary connections and instrumentation as required for the tank shall be provided by the contractor.

### 7.2.10 Multi stage Filters

The out put from the clarifier may subjected to suitable type of multistage filtration to suit the process design. The multi stage filters shall have redundancy of 2 x 100 % for higher reliability of the operation of the plant.

Filters shall be fabricated from welded carbon steel, for a design pressure of 6 bar or clarified water pumps shut-off head, which ever is greater.

Each filter shall be complete with necessary manholes, sight glasses, flange pipe connections and structural steel supporting legs.

Epoxy resin coating system shall be applied for filter inside and for the internals. A backwash collector system shall be designed to remove effectively the maximum expected quantity of backwash water.

The operation and backwashing of the filter shall be done automatically. Provisions for manual operation and backwashing shall also be made. Only one filtered shall be washed at a time. The operating time of each filter between two back washing cycles shall be 24 hours minimum.

Each filter shall be complete with a sampling device and pressure gauge on the inlet and outlet connections.

### 7.2.11 Clarifier

Lamella type one complete unit with all necessary internals, valves, pipes, fittings and set of automatic controls for sludge blowdown shall be provided. The material of the clarifier shall be of stainless-steel Grade 316.

The arrangement shall be outdoor complete above ground.

The designed rate of the clarifier shall be 150% of the continuous consumption of the plant at base load operation of all Gas Turbines.

The sludge concentrator shall be provided and located in the area where the heaviest sludge can be collected and removed with the minimum loss of water. The unit shall be furnished complete with a walk way on the unit, all necessary support, sampling devices, sludge collecting systems and inlet controls. All necessary measuring and monitoring instruments shall be provided.

Sampling valves at suitable locations to know the clarifier performance and sludge built up shall be provided.

### 7.2.12 Control and monitoring equipment

The Control and monitoring equipment shall fulfil the general technical requirements specified under the chapter 4.0. Type and make of equipment supplied under the water treatment plant shall be internationally proven. Type and make as well as scope of equipment are subjected to approval of the Employer.

The contractor shall ensure a fail-safe operation of the plant in the event of power/control air failure.

The design of all plant shall provide safe operation for easy filling, cleaning, maintenance and repairing of plant. All the plant and their automatic control shall be designed and implemented in such a way that a breakdown of power or compressed air will not cause critical situation and plant shall be put in fail safe condition. In case if control system is designed with central control processing unit (CPU), the safe position of the plant shall be ensured and all indications on mimic panel shall be made alive through hard wire relay technique during the CPU fail mode condition.

The control and monitoring of equipment shall be selected and designed in such a way, that the following functions shall be properly performed from the control board manually.

- Start/stop operation of all pumps, ventilators, air blowers, etc
- Regulate flow to clarifier
- Control of chemical composition
- Control of clarifier, sludge blowdown, flushing of lines, etc
- Control of flow to cooling towers

Local, direct on site key-switched control panels shall be provided for the clarifier bridge, bag slitting machine, pumps and agitators for the chemical preparation equipment.

Particular attention shall be paid to clarifier controls, to ensure that the sludge blanket is not lost due to excessive flow agitation. Also, since initial startup of the clarifier can require an excessive length of time, it is preferred to operate the clarifier on a continuous basis.

#### 7.2.12.1 Measuring Equipment

A sufficient number of local and panel mounted instruments for the purpose of reliable plant operation, detailed alarm indication and recording as well as through and analytical fault finding are to be provided.

Tentative and indicative list of instruments and equipment listed below shall be provided, but not necessarily limited to the same.

#### 7.2.12.2 Online Process Instruments

1. Pressure Indicator
2. Pressure Indicator & Transmitter
3. DP Indicator and Transmitter
4. Pressure switch
5. Flow indicator and transmitter
6. Level Gauges
7. Level indicator and Transmitter
8. Level switch
9. Temperature indicator

#### 7.2.12.3 Online analytical Instruments

1. pH indicator and transmitter
2. Conductivity indicator transmitter
3. ORP indicator transmitter

4. Turbidity indicator transmitter

#### 7.2.12.4 Off line Analyzers

1. Portable water quality analyser
2. Lavy-ond clorine comparator with 1 lit Ortho-toludine
3. SDI test Kit Assembly

#### 7.2.12.5Alarm annunciation

All alarm units shall be of the HMI based alarming unit at the water treatment plant control room in accordance with, general requirements for I & C equipment specified under chapter 4.0. Critical alarms shall be also be displayed at the plant DCS HMI located in Central Control Room.

#### 7.2.12.6 Control panel

The contractor shall furnish a free-standing control board to contain all system instrumentation and controls (excluding local instruments). The board shall contain at least following, programable logic controllers (PLCs), power supplies, all relays, timers, contractors, signal lamps, disconnectors and control switches, alarm devices and contacts, fuses and terminals.

Control board shall be of;

The control board shall be located within the water treatment building control room. No indicators or recorders or indication lamps shall be positioned with their base less than 750mm from the bottom of the board 3mm steel all-round and be in accordance with general requirement. The panel shall be dust tight according to IEC.

The contractor shall furnish all internal electrical wiring according to the general requirement for I & C equipment specified under chapter 4.0.

## 7.3 Demineralization Water Plant

### 7.3.1 Scope of Specification

This specification covers the general technical requirement of the following systems.

- Demineralization water plant
- Regeneration station with chemical storage tanks and
- Regeneration waste neutralization station

With all necessary equipment for satisfactory operation of the power plant.

Contractor's supply shall include but not be limited to the engineering design, manufacturing, material testing, delivery, installation, commissioning and trial operation of the equipment.

The system and its components supplied shall meet this specification and shall also conform with the specification for “General technical requirement” under chapter 4.

Demineralization water treatment system shall include but not necessarily limited to following processes.

1. Final polishing
2. Demineralization

The demineralized water of the proposed water treatment plant shall meet the specification laid down by the Gas Turbine manufacturer and also shall satisfy the conditions to inject into the turbine without making any adverse effect to the life of the Gas Turbine.

### 7.3.2 Layout

The demineralization water plant and its associated equipment shall be installed in the water treatment building.

Control and switch panels of the demineralization water plant shall be installed together with river water treatment plant control panels in a separate room of the water treatment building which is a part of the scope supply under this contract.

RO plant, final polishing equipment and associated equipment shall be installed in the same water treatment building.

The bidder shall submit proposed process flow with the bid.

The layout arrangement shall provide adequate access for safe, simple and easy operation.

Special care shall be taken care for the easy and safe handling of the chemicals and for the chemical protection of all mechanical, electrical and civil components.

### 7.3.3 Operation features

The scope of supply describes of the demineralization water plant and its associated equipment required to process treated water from the Kelani River.

The above data provided are indicative only. However the contractor shall be responsible for obtaining all water samples and analysis necessary for final design purposes and shall submit copies of all such information to the Employer.

Contractor shall verify all flows which represent clarified and filtered water for the final design at the plant.

The minimum clarifier capacity shall be 150% of the normal plant requirement when all Gas Turbines run at its peak load.

The chemicals will be delivered in bags or drums and shall be emptied directly into the preparation or storage tanks. The river water treatment plant shall be operated fully automatically.

The following operating steps shall be controlled fully automatically;

- Inlet raw water flow control
- Dosing of all chemicals according to the inlet raw water flow and water quality
- Desludging of the clarifier
- Necessary interlocks and shutdown
- Backwash of filters

However manual provisions shall be made for the above automatic operations.

### 7.3.4 Scope of Supply

The scope of supply comprises all equipment, pipes with supports, valves, instrumentation and controls necessary to ensure proper safe and easy operation and maintenance of the river water treatment plant under all conditions.

Platforms, stairs and ladders, necessary lifting beams etc. required for operation and maintenance of the equipment shall be included in the scope of supply. All interconnecting pipe work as well as the piping to all users in the power plant shall be provided. This includes pipe supports, pipe racks and steel works for piping in trenches or protection sheets for street crossing etc. Provisions shall be made for the future extension of the plant.

During the dry season, river water salinity exceeds 40000 μS/cm due to ingress of sea water. Hardness exceeds 4000 ppm during this period. Accordingly, the plant shall be designed to suit the worst river water conditions.

All the filter media, filter elements, RO elements should be provided with the bid.

#### 7.3.4.1 Scope of equipment supplied

The demineralization Water Plant-shall include the following listed equipment which shall be provided for major system components and no way exclude other necessary components and equipment not mentioned.

a. All the equipment installed in the system shall have 2 x 100% redundancy to operate the plant without any shutdown of plant during the maintenance or breakdown of any equipment.

b. All the pumps (2 x 100%) made of suitable material to suit worst conditions of the river water, complete with electric motors, necessary valves, pressure gauges, piping and fixing materials.

c. RO section shall have 2 x 100% redundancy.

d. The demineralized water plant shall have at least two identical exchanger trains, each train capable of providing the required demineralized water consumption of the plant.

e. Operation and regeneration of the plant shall be done automatically form control room. However, provision shall be made for manual operation.

f. The star-up/shut down and the recirculation of the plant (if required) will be controlled automatically by the level of the demineralized water storage tank.

g. Necessary automatic interlocks for the safe shutdown of the plant shall be provided.

h. Regeneration waste from the plant shall be collected in a neutralization tank of sufficient capacity to handle the total waste effluent of plant. The mixing of the waste with neutralization shall be done by mixing ejectors, and the neutralization plant.

i. All regeneration waste collected in the tank shall be neutralized in the neutral pH range as allowed by regulation of the government of Sri Lanka before being discharged.

j. Minimum demineralized water production rate shall be 150% of the plant total requirement from each exchanger train.

k. The exchanger train shall have at least 24-hour operation capacity per each regeneration cycle.

l. Demineralized water shall meet the requirement for water purity for injection in Gas Turbines to control the NOx.

m. All required chemical preparation, storage and dosing equipment consisting of two preparation tanks for each chemical with a capacity to store at least 2 days requirement and one dosing tank for each chemical with a capacity to store one day requirement to operate under worst raw water quality.

n. Complete with all electrical motors, agitators and all accessories such as bag and drum handling facilities peeling funnels operating valves, dilution chambers, sampling equipment, associated piping and instrumentation and control.

o. All the filter media and filter elements should be provided.

p. Set of complete local and remote instruments for measuring the flow rates, conductivity, silica level, pressure, tank level and any other required chemical parameters at each stage of the treatment process.

q. Iron exchangers made from carbon steel/rubber lined complete with supporting legs, lifting eye bolts, manholes, sight glasses, nozzle bottom with nozzles, water inlet distributor, associated piping for carbon steel/rubber lined, set of valves from cast iron/rubber lined, sampling equipment and necessary instrumentation.

r. The iron exchangers shall have 2 x 100% redundancy.

s. Exchange resin filling chargers

t. Resin strainers (traps) shall be installed down stream of each exchanger, complete with insert and differential pressure measuring device with contact switches.

u. Two no. of acid storage tanks made from carbon steel rubber lined, total storage capacity for 03 months of Base Load operation, complete with supporting saddles, lifting eyebolts, manhole, vent trap, associated piping from carbo steel/rubber lined, set of valves from cast iron/rubber lined and necessary instrumentation. Tanks shall be double shell type with leak control device. Installation and design of storage including unloading facilities shall meet the latest soil protection standards (German WHG or equivalent).

v. Two no. of caustic soda tanks made from carbon steel/rubber lined, total storage capacity for 03 months of Base Load operation, complete with supporting saddles, lifting eyebolts, manhole, vent trap, associated piping from carbo steel/rubber lined, set of valves from cast iron/rubber lined and necessary instrumentation. Tanks shall be double shell type with leak control device. Installation and design of storage including unloading facilities shall meet the latest soil protection standards (German WHG or equivalent).

w. All Dosing pumps (2 x 100%) for regeneration and neutralization made from cast iron/rubber lined, complete valve, pulsation damper, pressure gauge, necessary operating valve, piping and fixing material.

x. Chemical unloading pumps (2 x 100%) made from suitable material complete with electric motor, necessary valves, pressure gauges, piping and fixing material.

y. Neutralization tank made of suitable material with enough capacity for 24-hour operation.

z. All neutralization pumps (2 x 100%) made from cast iron/rubber lined, complete valve, pulsation damper, pressure gauge, necessary operating valve, piping and fixing material.

aa. All regeneration pumps (2 x 100%) made from stainless steel, complete valve, pressure gauge, necessary operating valve, piping and fixing material.

bb. Demineralized water tank made from stainless steel, minimum capacity of 900m$^3$, complete with supporting beams, lifting eyebolts, manholes, associated piping from stainless steel, set of valves from stainless steel and necessary instruments.

cc. Mixed bed air blowers (2 x 100%) made form cast iron/rubber lined, complete with motors, suction air filters, suction and discharge silencers, complete with valves, pressure gauge, necessary operating valve, piping and fixing material.

dd. Regeneration station for acid and caustic soda dilution control, complete with all necessary flow indicators for caustic soda and dilution water, necessary operating valves, piping and fixing material.

ee. Set of complete interconnecting piping for the specified components including all necessary valves, pipe supports, hangers, fixing material, etc.

ff. Set of complete local and remote instruments for measuring the flow rates, conductivity, silica, pressure and levels of the different measuring points required for safe and easy operation of the plant.

gg. Electrical switch panel complete with all necessary motor protection switches, relays, fuses etc.

hh. Set of electrical and control cables.

All additional necessary equipment for proper safe operation of the plant shall be included such as,

a. All electrical connections up to the low voltage terminal boards of panels, cubicles, motors and etc.
b. All interconnecting piping systems for the distribution of the raw water and treated water
c. All minor pipes necessary for installation and operation as drainage pipes, vents and etc.
d. All safety equipment as emergency showers, eye washers, plastic suits, protective gloves and shoes, safety goggles, suitable first aid sets, inclusive of eye wash bottles, medicaments and antidote chemicals etc.
e. All protection equipment against corrosion wherever necessary
f. All necessary base frames, base plates, anchor bolts and supports etc.
g. All steel parts imbedded in foundation
h. All platforms, ladders, etc for easy operation and
i. All standard equipment and accessories which are normally required for the supply schedule but not mentioned here

#### 7.3.4.2 Scope of Service

The contractor shall be fully responsible for the design, detail engineering, manufacture, transportation, erection and trial operation of the whole water treatment plant.

**Work shop tests**

All components of the water treatment plant shall be tested at the manufacturer's works accordance with the relevant standards and codes and as specified in “General Technical Requirements”

**Site Tests**

When installed at site, at first, a pressure test of the whole plant shall be carried out. Secondary a functional test with a commissioning operation over 30 days for reliability and acceptance shall be carried out.

These tests shall have no influence on the initial operation and reliability test of the complete power plant.

### 7.3.5 Construction Requirement

The equipment and the material shall conform to high standards of engineering, design, workman ship and construction and shall be capable of operating efficiently, satisfactorily and without excessive wear or maintenance under the service conditions stated in this specification.

Each system shall be designed, manufactured, inspected and tested in accordance with the latest issue of the applicable codes and standards with the construction requirements stated in general technical requirements.

### 7.3.5.1 Pumps

In general, horizontal, centrifugal pumps shall be provided.

The dosing pumps shall be of the diaphragm type.

The material of the pumps shall be resistant against all conditions during operation. All centrifugal pumps shall be capable of continuous operation.

### 7.3.5.2 Valves/Piping

In general diaphragm type shut-off valves shall be used in the system. The material of the valve shall be cast iron with inside rubber lining. Stainless steel material shall be used for the spindle, cones and seats of all valves. Care shall be taken for the selection of the diaphragm material.

All remotely controlled valves and pneumatic valves shall be provided with seal gas filled inductive limit switches in all cases where their open or close positions must be signaled to the control room and/or where these conditions must be fed to interlock circuits for ensuring safe operation of the plant. The valve shall have sufficient range and capability to provide rated flows.

All water pipes with in the water treatment plant shall be of stainless steel. All flanges for chemical lines shall be protected with plastic/elastic or acid/caustic proof material shells.

All pipes and flanges of acid and caustic lines shall be according to international safety standards.

For the rubber line pipes, only standard pipe fittings shall be used. Each fitting shall have its own flanges to be connected with a straight pipe.

Minimum diameter of tubes shall not be less than 20 mm, except for impulse measuring lines.

### 7.3.5.3 Tanks

All tanks shall be vacuum resistant against a pressure of not higher than 0.9 bar.

**Chemical storage tanks**

The chemical storage tanks for the storage of acid and caustic soda solution shall be of horizontal cylindrical type made from carbo steel, inside rubber lined with a minimum rubber thickness of 4 mm.

The tank shall include flanges and dished ends and saddles for mounting on concrete pads.

All nozzles shall be of carbon steel with flange ends and shall be mounted on top of the tanks.

All tank necessary connections and instrumentation in addition to spare connections shall be provided.

A ladder shall be furnished to provide convenient and safe access to the tank manhole and top mounted nozzle connections. It shall be attached to the tank by welding or other means.

Chemical concentrations are to be specified by the contractor as per the design.

All necessary connections and instrumentation as required for the tank shall be provided by the contractor.

The chemical storage capacity shall be sufficient for 3 months operation of the water treatment plant.

**Neutralization Tank**

All effluent going to waste from the water treatment plant shall meet the regulation of Sri Lanka. Therefore, when using acid or caustic soda for regeneration of the ion exchangers, these effluents shall pass a neutralization tank before being discharged.

The material of the neutralization tank shall be carbon steel inside rubber lined.

The installation of the tank shall be above zero level.

The neutralization tank shall be fitted with a complete mixing system with water jets fed through the pressurized circulating water line of the neutralization pumps. The Contractor shall furnish all equipment required for proper operation of neutralization system including the chemical injection system.

The capacity of the neutralization tank shall be designed so that the effluent from the demineralization water plant can be taken up and neutralized.

Two level switches mounted in the neutralization tank shall be used for automatic control of the main pump (selected by means of a selector switch). The main pump shall start up when reaching the high level switch and shall stop when the neutralization pit level has reached the low level switch.

The neutralization tank shall be emptied in one hour with one neutralization pump in operation.

The pH-value in the pressure line of the neutralization pumps shall be continuously measured and recorded on control panel.

### 7.3.5.4 Filters

**<u>Carbon Filters</u>**

Chlorine shall be used as a treatment in the river water treatment plant. Therefore, Contractor shall provide activated carbon filters in front of the demineralization train to protect the exchanger resins against free chlorine and organic matters.

The filters shall be constructed of welded carbon steel with a minimum design pressure of 8.0 bar or filtered water pump shut off head, whichever is greater. Each carbon filter shall be complete with manholes, sight glass, flanged pipe connection and structural steel supporting legs.

Rubber lining shall be applied to the internals to prevent contact between the activated carbon and carbon steel tank. Minimum thickness of rubber lining shall be 4 mm. The lining shall be spark tested with 5000 volts for each mm thickness along with 5000 volts as basic value.

Each filter shall be designed for a maximum filtration rate of 20 $m^3/h$.

The filter bed depth shall be a minimum of one meter of activated carbon, and a 100% free board shall be provided above the top of the filter bed.

Annual loss of filter material shall not exceed 3%. Activated carbon shall be shipped in durable bags. No loose or bulk delivery of activated carbon will be accepted. The filter internals shall be arranged so that no sub fill will be required to support the filter media.

Design of the internal piping shall provide uniform collection and distribution of flow throughout the entire bed volume, avoiding excessive velocity or channeling in any part.

The drain system shall provide uniform collection of effluent at rated capacity and shall be designed to distribute backwash water uniformly through the bed. The backwash collector system shall be designed to remove the maximum expected quantity of backwash water effectively.

All internal distributor and collector systems shall be designed to meet the specified design conditions and shall be installed prior to shipment.

Each filter shall be complete with a sample valve on the inlet and outlet connection, and a dial type pressure gauge with manual isolating valve on the inlet and outlet connection.

Each activated carbon filter shall be provided with manual vent valve and piping and one manual drain valve and piping to the nearest sump.

### 7.3.5.5 Ion Exchangers

The ion exchangers units shall be vertical axis pressure vessels and shall be constructed of welded carbon steel. with a design pressure of 8.0 bar filtered water/decarbonated water pumps shut off heads, whichever is greater.

The ion exchangers vessels shall be 4.0 mm thick rubber lined inside. The lining shall be spark tested with 5000 Volts for each mm thickness along with 5000 volts as basic valve.

The inside chemical distribution and drain system shall be acid and caustic resistant.

Each ion exchanger vessel shall be provided with the necessary flange connection and manholes. The manholes shall have an access of 600 mm.

All vessels shall be provided with observations windows. Windows shall have a clear opening Of at least 7.5 cm wide by 30 cm vertical height.

Single resin exchange units such as cation and anion units shall have one observation window (fluidized bed system) or two observation windows when resin backwash is provided inside of operating unit.

The mixed bed exchangers shall have generally three observation windows.

The exchanger tanks shall be supplied all internal piping prior to shipment. All internal piping systems of the hub or header-lateral type shall be installed in the exchange units using flanged gasket connections, attached to the vessel nozzles. All piping shall be rigidly supported and braced to withstand motion of water and resin beds. The vessel internals shall be arranged so that no sub fill will be required to support the media.

Design of the internal piping shall provide uniform collection or distribution of flow throughout the entire exchange bed volume avoiding excessive velocity of channeling in any part. The under-drain system shall provide uniform collection of effluent at rated capacity and shall be designed to distribute backwash water uniformly through the bed. The backwash collector system shall be designed to remove effectively the maximum expected quantity of backwash water when backwashing with water having the maximum expected temperature without loss of serviceable material.

The number of nozzles in each exchanger shall be at least $80/m^2$.

Ali ion exchanger shells shall have all internals shop mounted in true alignments, properly secured and/or braced to prevent misalignment, loosening or damage during shipment.

Contractor shall not claim e greater capability of the resin offered than does the resin manufacturer. All resin shall be new, unused material received in manufacturer's original unbroken containers. A resin proprietary to the Contractor shall only be allowed if a compatible substitute is identified.

Additional auxiliaries shall comprise inlet and outlet pressure gauges, automatic control devices conductivity controllers, sampling valves on inlet and outlet connection, etc.

### 7.3.5.6 Regeneration System

All resins shall be regenerated in the exchanger vessels. The regeneration system shall perform all regenerating functions. The kind of regeneration shall be counter flow.

Contractor shall specify his counter-current regeneration technique and his means for stabilizing the resin bed during regeneration.

The regeneration system shall consist of caustic soda and sulphuric acid storage tanks, chemical dosing pumps and the necessary distribution system.

All piping including regenerating chemical feed and regenerating feed-water and drainage, shall be furnished. All controls required for regeneration shall be provided.

Both the sulphuric acid and caustic soda solutions are to be diluted by mixing inline. The equipment furnished shall permit accurate control of both rate and volume of regenerating solutions.

#### 7.3.5.7 Air Blowers

The mixed bed air blowers shall be of the rotary piston type.

The blowers shall be furnished with the electric motor drives and all necessary equipment.

The noise level shall be less than 85 dB(A) at 1.0 m distance of the noise source.

## 7.4 Control and monitoring equipment

The Control and monitoring equipment shall fulfil the general technical requirements specified under the chapter 4.0. Type and make of equipment supplied under the water treatment plant shall be internationally proven. Type and make as well as scope of equipment are subjected to approval of the Employer.

The contractor shall ensure a failsafe operation of the plant in the event of power/control air failure.

The design of all plant shall provide safe operation for easy filling, cleaning, maintenance and repairing of plant. All the plant and their automatic control shall be designed and implemented in such a way that a breakdown of power or compressed air will not cause critical situation and plant shall be put in fail safe condition. In case if control system is designed with central control processing unit (CPU), the safe position of the plant shall be ensured and all indications on mimic panel shall be made alive through hard wire relay technique during the CPU fail mode condition.

The control and monitoring of equipment shall be selected and designed in such a way, that the following functions shall be properly performed from the control board manually.

- **a.** Start/stop operation of all pumps, ventilators, air blowers, etc
- **b.** Regulate flow to clarifier
- **c.** Control of chemical composition
- **d.** Control of clarifier, sludge blowdown, flushing of lines, etc

**e.** Start/stop of demineralization trains

**f.** Control of flow to cooling towers, if applicable

Local, direct on site key-switched control panels shall be provided for the clarifier bridge, bag slitting machine, pumps and agitators for the chemical preparation equipment.

Particular attention shall be paid to clarifier controls, to ensure that the sludge blanket is not lost due to excessive flow agitation. Also, since initial startup of the clarifier can require an excessive length of time, it is preferred to operate the clarifier on a continuous basis.

The initiation oi regeneration shall be on the basis of water volume treated and the quality (conductivity and Silica) of the effluent.

If, during its service run, a demineralizer train delivers unacceptable water, the flow shall be automatically stopped. If the poor quality persists for a preset time period an alarm shall be actuated. An indication shall be initiated at the control board to operate when a demineralizer is shut off by conductivity/Silica or water volume treated, as well as when other changes of the plant occur.

### 7.4.1 Measuring Equipment

A sufficient number of local and panel mounted instruments for the purpose of reliable plant operation, detailed alarm indication and recording as well as through and analytical fault finding are to be provided.

Required instrumentations and controls are to be provided matching safety requirements and functional requirements. In this assignment, list of instruments, controls, alarms, annunciation equipment, etc. have been listed for indicative purpose. However the same is not exhaustive.

Necessary residual I&C system design are to be carried out by the RO plant contractor and to be installed for the reliable and easy operation of the plant.

Tentative and indicative list of instruments and equipment listed below shall be provided, but not necessarily limited to the same.

**Online Process Instruments**

1. Pressure Indicator
2. Pressure Indicator & Transmitter
3. DP Indicator and Transmitter
4. Pressure switch
5. Flow indicator and transmitter
6. Level Gauges
7. Level indicator and Transmitter
8. Level switch
9. Temperature indicator
10. Treated water and demineralized water production totalizers

**Online analytical Instruments**

1. pH indicator and transmitter
2. Conductivity indicator transmitter
3. ORP indicator transmitter
4. Turbidity indicator transmitter
11. Silica level analyser and transmitter

**Off line Analyzers**

1. Portable water quality analyser
2. Lavy-ond clorine comparator with 1 lit Ortho-toludine
12. SDI test Kit Assembly

### 7.4.2 Alarm annunciation

All alarm units shall be of the HMI based alarming unit at the water treatment plant control room in accordance with, general requirements for I & C equipment specified under chapter 4.0. Critical alarms shall be also be displayed at the plant DCS HMI located in Central Control Room.

### 7.4.3 Control panel

The contractor shall furnish a free-standing control board to contain all system instrumentation and controls (excluding local instruments). The board shall contain at least following, programable logic controllers (PLCs), power supplies, all relays, timers, contractors, signal lamps, disconnectors and control switches, alarm devices and contacts, fuses and terminals. PLC shall comply with the general requirements specified under chapter 4.0.

The control board shall be located within the water treatment building control room. No indicators or recorders or indication lamps shall be positioned with their base less than 750mm from the bottom of the board 3mm steel all-round and be in accordance with general requirement. The panel shall be dust tight according to IEC.

The contractor shall furnish all internal electrical wiring according to the general requirement for instrumentation & control equipment specified under chapter 4.0.

### 7.4.4 Spares to be supplied

1. The following spares shall be supplied under this contract and same shall be included in schedules of Schedule 2, Mandatory spares in volume 5.

- Set of spare parts listed as follows
  - One from each electrical circuit breaker, RCB, MCB, MCCB, Isolator, Relay for each type installed
  - At least five number of fuses for each type installed
  - One set of pump spares for each type for 5 years operation

- One motor for each type
- One spare valve for each type if number of valves installed are less than 10
- Two spare valves for each type if number of valves installed are more than 10
- One spare item from each type of pressure indicators, level indicators, flow indicators, temperature gauges, level switches, pressure switches, flow switches, transmitters of each type
- PLC spares: One processor card for each type, one input and output cards for each type, one power supply card for each type, one communication card for each type, one programmed storage card, complete programming software tool installed in a new sperate Laptop computer
- One HMI PC complete with interface cards

2. All the chemicals required for 6 months operation of the water treatment plant for Gas Turbine Plant to run at base load operation at 100% plant factor. This shall be included in schedules of Consumables in volume 5.

RESULTANT WIND DATA IN COLOMBO

| Year | January | | February | | March | | April | | May | | June | | July | | August | | September | | October | | November | | December | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. | Dir. | Spe. |
| **2013** | 027 | 7.0 | 184 | 5.5 | 179 | 4.7 | 193 | 4.5 | 225 | 7.0 | 233 | 6.7 | 230 | 6.2 | 230 | 6.6 | 227 | 5.7 | 222 | 4.8 | 178 | 4.3 | 025 | 6.7 |
| **2014** | 016 | 6.5 | 358 | 5.2 | 243 | 4.9 | 188 | 3.7 | 214 | 5.8 | 231 | 7.3 | 230 | 7.4 | 220 | 5.7 | 216 | 5.5 | 218 | 3.9 | 056 | 4.0 | 028 | 5.5 |
| **2015** | 016 | 6.3 | 019 | 6.0 | 160 | 4.5 | 167 | 3.9 | 209 | 5.9 | 220 | 5.3 | 229 | 6.6 | 224 | 6.7 | 213 | 3.8 | 178 | 4.4 | 127 | 4.1 | 084 | 4.2 |
| **2016** | 018 | 6.4 | 017 | 4.8 | 201 | 4.8 | 186 | 4.6 | 204 | 5.9 | 222 | 6.7 | 229 | 6.6 | 228 | 8.3 | 229 | 7.1 | 223 | 5.5 | 043 | 4.7 | 027 | 5.9 |
| **2017** | 016 | 6.9 | 029 | 5.7 | 164 | 5.1 | 213 | 5.3 | 215 | 6.1 | 224 | 6.3 | 226 | 6.5 | 227 | 6.9 | 218 | 6.1 | 214 | 3.7 | 358 | 3.8 | 036 | 5.7 |

Dir. = Direction From North Spe. = Speed in Km/h

Annual Average Mean Sea Level Pressure & Recorded Annual Maximum Wind Speed at Colombo (2013 to 2017)

| Year | Average Mean Sea Level Pressure (hpa) | Recorded Maximum Wind Speed (km/h) |
|---|---|---|
| **2013** | 1009.1 | 40.0 |
| **2014** | 1009.5 | 26.4 |
| **2015** | 1010.0 | 18.6 |
| **2016** | 1010.0 | 21.4 |
| **2017** | 1009.9 | 20.8 |

Monthly Average Sunshine Data – Colombo

| Months | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| **January** | 6.8 | 7.5 | 9.1 | 8.2 | 8.3 |
| **February** | 7.4 | 9.4 | 8.4 | 8.3 | 8.1 |
| **March** | 8.1 | 9.2 | 9.2 | 9.4 | 8.9 |
| **April** | 8.5 | 8.0 | 8.2 | 9.4 | 8.7 |
| **May** | 4.9 | 6.4 | 6.7 | 4.7 | 5.7 |
| **June** | 4.6 | 6.4 | 6.2 | 6.4 | 6.2 |
| **July** | 5.5 | 7.3 | 7.2 | 7.0 | 7.0 |
| **August** | 7.0 | 5.9 | 7.5 | 7.9 | 6.5 |
| **September** | 6.2 | 6.6 | 5.2 | 7.3 | 5.5 |
| **October** | 6.9 | 6.4 | 6.7 | 7.5 | 5.1 |
| **November** | 6.9 | 5.1 | 5.9 | 5.2 | 5.5 |
| **December** | 6.0 | 5.1 | 6.0 | 7.7 | 7.7 |

Unit in Sunshine hours

**Note :** The Sunshine of the day is considered as the amount of Sunshine measured during the 24 hour period ending at 08.30 am on the days of following months.

**Recorded Highest Daily Average Night Relative Humidity (%) at Colombo for last 5 Years (2013-2017)**

| YEAR | MONTH | DAY | VALUE |
|---|---|---|---|
| 2013 | 5 | 3 | 98 |
| 2013 | 5 | 6 | |

**Recorded Lowest Daily Average Day Relative Humidity (%) at Colombo for last 5 Years (2013-2017)**

| YEAR | MONTH | DAY | VALUE |
|---|---|---|---|
| 2013 | 1 | 28 | 46 |
| 2017 | 1 | 8 | |

**Highest Recorded Hourly Rainfall Data – Colombo 2013 – 2017**

| Year | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Month | Nov | Dec | Dec | May | Apr |
| Date | 30 | 09 | 15 | 27 | 12 |
| Time Period | 1600-1700 | 1800-1900 | 0300-0400 | 0500-0600 | 1800-1900 |
| Rainfall in mm | 54.3 | 69.0 | 113.3 | 61.6 | 53.0 |

**Recorded Daily Maximum Rainfall at Colombo Port for last 5 Years (2013-2017)**

| Year | Month | Day | Value |
|---|---|---|---|
| 2016 | 5 | 15 | 162.0 |

Unit in millimeters

**Recorded Annual Maximum Rainfall at Colombo Port for last 5 Years (2013-2017)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 29.4 | 92.6 | 194.4 | 309.6 | 263.1 | 243.3 | 20.9 | 170.5 | 460.0 | 280.0 | 466.3 | 273.6 | 2803.7 |

Unit in millimeters

**Annual Mean Temperature at Colombo – 2017**

| YEAR | VALUE |
|---|---|
| 2017 | 28.2 |

Values in Celsius

**Recorded Daily Highest Maximum Temperature at Colombo for last 5 Years (2013-2017)**

| YEAR | Month | Day | VALUE |
|---|---|---|---|
| 2016 | 2 | 3 | 35.5 |

Values in Celsius

**Recorded Daily Lowest Minimum Temperature at Colombo for last 5 Years (2013-2017)**

| YEAR | Month | Day | VALUE |
|---|---|---|---|
| 2016 | 12 | 24 | 19.9 |

Values in Celsius

## Fuel Specifications

**(i) SPECIFICATIONS /DATA SHEET OF DIESEL (Gas Oil)**

| Property/Test | Method(ASTM-D) | Specifications |
|---|---|---|
| Appearance | | Clear & free from water and impurities |
| Density @15 $^0$C kg/$m^3$ | 1298/4052 | 820 - 860 |
| Colour ASTM | 1500 | Max. 2.0 |
| Distillation | 86 | |
| IBP $^0$C | | Report |
| T10 $^0$C | | Report |
| T50 $^0$C | | Report |
| T90 $^0$C | | Max 370 |
| Recovery @ 315$^0$C | | Min 50 |
| Recovery @ 350$^0$C | | Min 80 |
| Cetane Index or | 976 | Min 45 (Note1) |
| Cetane Number | 613 | Min 49 |
| CFPP $^0$ C | | Max 10 |
| Sulphur Content mg/kg | 4294 | Max. 3000 |
| Flash Point $^0$C | 93 | Min 60 |
| Viscosity Kin @37.8 $^0$C cst | 445 | 1.5 -5.0 |
| Water Content mg/kg | 95 | Max 500 |
| Cu Strip corrosion 3 hrs @ 50 $^0$C | 130 | Max 1 |
| Ash % m/m | 482 | Max 0.02 |
| Carbon residue %m/m | 524/4530 | Max 0.3 |
| Total Acid No. mg KOH/g | 974/664 | Max 0.2 |
| Caloric value gross kCal/kg | 240 | Min 10500 |

**Approval and the terms and Conditions imposed by Central Environmental Authority (CEA) for the 3 x 35 MW Gas Turbine Project at Kelanitissa**

## 2. SPECIFIC CONDITIONS

### 2.1. Air Pollution Control

2.1.1. Emissions from the stacks should adhere to the National Environmental (Stationary Source Emission Control) Regulations gazetted in Gazette Extra Ordinary No. 2126/36 dated 05.06.2019.

2.1.2. In order to maintain the ambient air quality in the surrounding area within the National Ambient Air Quality Standard, the physical height of the stack of the power plant shall not be less than 38 m as indicated in the Air Dispersion Modeling Study report annexed to the report of Proposed Gas Turbine Power Plant at Kerawalapitiya dated July 2019.

2.1.3. The PP should submit to the CEA the specification of the selected power plant prior to installation to ensure the conformity with the CEA standards.

2.1.4. The PP should install a suitable Air Pollution Control (APC) system in order to achieve the above emission levels consistently.

2.1.5. Sampling port/s for emissions from the stacks and working platform shall be made available with each stack.

2.1.6. A real time continuous emission monitoring systems shall be installed in each and every stack and shall be maintained in good working order with regular calibration records to monitor concentration of $SO_2$, NOx, $O_2/CO_2$, TSP, opacity, temperature and flow rate of the flue gas for regular management of the combustion process and flue gas control system. Air emission monitoring reports should be submitted to the CEA on a regular basis for review.

2.1.7. The PP shall submit a summary report clearly indicating the compliance of the performance of the proposed plant against the applicable standards stipulated in Ambient Air Quality Standards and Stationary Sources Emission Standards. The report should be submitted on stack emission and ambient air quality levels at the selected locations.

2.1.8. A monitoring protocol including ambient air quality at strategic locations and emission from stacks should be submitted to the CEA prior to installation of the proposed plant.

2.1.9. The PP should submit to the CEA the CEYPETCO specification of the fuel to be used.

2.1.10. A third party monitoring report on air emissions and ambient air quality should be submitted to the CEA once in 6 months.

## 2.2. Noise and Vibration Control

2.2.1. The noise level during construction period shall not exceed 75 dB (A) during 06.00 hrs. to 21.00 hrs. and 50 dB (A) during 21.00 hrs. to 06.00 hrs. at the boundary of the site.

2.2.2. The noise level during operation of the power plant should be maintained at or below 63 dB (A) from 06.00 hrs. to 18.00 hrs. and 50 dB (A) from 18.00 hrs. to 06.00 hrs. at the boundary of the power plant. In case any unpredicted constructional impacts are en-counted the PP shall develop a proper mechanism to address such impacts.

2.2.3 All buildings which would contain operation of machinery that are likely to generate excessive high noise/vibration shall be designed/installed in such a way to reduce noise/vibration levels so as to comply with the standards of the CEA.

2.2.5 Construction and operation of the power plant shall be planned and carried out not to cause any structural damage to the nearby buildings, physical structures etc. and vibration levels shall be maintained in complying with the limits set out in the proposed vibration standards of the CEA (Annex II).

## 2.3 Surface / Ground Water Pollution Control

2.3.1 Oil and grease should be stored in closed containers and secondary containments for stored oil should be provided. Oil/grease traps should be installed at suitable locations to prevent oil/grease entering into soil/water bodies with the run-off water.

2.3.2 Storm water within the project site during the construction period should be directed through the silt trap in order to prevent silt entering the Kelani river.

2.3.3 In case, significant amount of wastewater is generated during operation a wastewater treatment plant should be established. All wastewater generated during the operation process of the plant should be diverted to the treatment plant.

2.3.4 The treated effluent arising from the wastewater treatment plant shall conform to the tolerance limits for the Discharge of Industrial Wastewater into Inland Surface Waters as prescribed in the Gazette Notification (Extra Ordinary) No. 1534/18 dated 01st February 2008.

2.3.5 The PP should refrain from the practice of stockpiling of construction material and excavated peat near the canal to prevent such material entering in to water body through erosion by rains or any other means.

2.3.6 Special care should be taken not to spill any oil to the ground when removing the parts of the gas turbines. Any oil inside the gas turbine machines shall be emptied to barrels with care to avoid spilling before dismantling as indicated in the report of proposed Gas Turbine Power Plant at Kelanitissa dated July 2019.

2.3.7 Suitable mitigatory measures should be taken to prevent any leakage/spillage of fuel.

**2.3 Solid and Hazardous Waste Disposal**

2.4.1 Solid waste shall not be burnt in the open within or outside the proposed site.

2.4.2 Spoil material (soil, rock & debris etc.) generated during the demolishing of existing power plant shall be used whatever possible for site leveling, back-filling etc. Arrangement for disposal, if required, shall be made in consultation with the Kolonnawa Urban Council.

2.4.3 Hazardous substances on site shall be identified, recorded and properly stored and shall also be monitored by a designated officer to ensure that the possibility of accidental release is minimized.

2.4.4 Used lubricants or waste oil or any combustible material contaminated with oil or used for absorb spilled oil should not be burnt and it should be stored securely and should be dispatched to the authorized disposal facility. The proposed method of disposal should be informed to the CEA.

**2.5 Transport of material and equipment**

2.5.1 The routes for transport, including requirements for unusually heavy loads shall be subject to agreement with the appropriate traffic authorities.

2.5.2 Transport, loading and unloading of materials shall be carried out in such a way as not to cause nuisance to the people.

2.5.3 Construction material should be adequately covered during transportation to avoid wind induced dust and spillage.

2.5.4 The vehicles and the machinery used in the project should be maintained regularly, in order to avoid smoke emissions.

**2.6 Visual Aspects**

2.6.1 Aircraft warning lights should be installed at the top of the stack.

2.6.2 Red and white stripes on the stacks shall be painted to have high visibility to aircrafts.

## 2.7 Safety

2.7.1 The PP and the contractors shall be bound by accepted procedures for the safety of workers and shall adhere to relevant provisions of the Factories (Amendment) Law No. 12 of 1976 as amended from time to time.

2.7.2 The workers shall be provided with appropriate personnel protection equipment and the PP shall ensure that the workers wear such personnel protection equipment while working within the plant.

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# The Gazette of the Democratic Socialist Republic of Sri Lanka
EXTRAORDINARY

අංක 2126/36 - 2019 ජුනි මස 05 වැනි බදාදා - 2019.06.05
No. 2126/36 - WEDNESDAY JUNE 05, 2019

(Published by Authority)



## PART I : SECTION (I) — GENERAL

## Government Notifications

L.D.B. 4/81(VIII)

**NATIONAL ENVIRONMENTAL ACT No. 47 OF 1980**

REGULATIONS made by the President under Section 32 of the National Environmental Act, No. 47 of 1980, read with Sections 23J, 23K and 23L of that Act and Section 51 of the Nineteenth Amendment to the Constitution of the Democratic Socialist Republic of Sri Lanka.

MAITHRIPALA SIRISENA,
President.

Colombo,
05th June, 2019.

**REGULATIONS**

1. These Regulations may be cited as the National Environmental (Stationary Sources Emission Control) Regulations, No. 01 of 2019.

2. Any person who manages or is in control off any stationary source specified in Schedule I hereto which emanates stack emissions, shall construct such stationary source in conformity with the standards specified in Schedule II hereto.

3. All emissions from stationary sources which are not specified in Schedule I, shall comply with the standards specified in Part I and II of Schedule III hereto.

4. All fugitive emissions emanating from any industrial process shall be measured and controlled according to the methods and standards specified in Schedules IV, V, VI and VII hereto.

5. The methods approved by the Central Environmental Authority (hereinafter referred to as the "Authority") shall be used in the measurement of emissions.

6. The concentration of any stationary source emission measured shall be converted into dry condition. The following equation shall be used for such conversion :-

$$\text{DRY GAS CONCENTRATION} = \frac{\text{MEASURED CONCENTRATION}}{[100 - (\text{MOISTURE PERCENTAGE})]} \times 100$$

7. The stationary source emission concentration converted into dry condition under Regulation 6, shall be converted into standard condition. The following equation shall be used for such conversion :-

$$C_n (mg / Nm^3) = C_s (mg / m^3) \times \frac{(P_n \cdot T_s)}{(P_s \cdot T_n)}$$

where $C_n$ = Emission concentration at standard conditions
$C_s$ = Converted dry emission concentration
$P_n$ = Standard pressure 760 mmHg
$P_s$ = Stack pressure in mmHg
$T_n$ = Standard temperature 273 Kelvin
$T_s$ = Stack temperature in Kelvin

8. The stationary source emission concentration converted into standard condition under Regulation 7 shall be converted for relevant reference oxygen level specified in Schedule VIII hereto. The following equation shall be used for such conversion :-

$$E_r (mg / Nm^3) = E_m (mg / Nm^3) \left[ \frac{20.9 - O_2\,\%_{ref}}{20.9 - O_2\,\%_{m}} \right]$$

where $E_r$ = Emission concentration at fuel specific reference oxygen percentage
$E_m$ = Standardized emission concentration
$O_2\,\%_{ref}$ = Reference Oxygen percentrage of fuel type specified in Schedule VIII
$O_2\,\%_{m}$ = Measured volume percentage of oxygen level on dry basis.

9. Where the fuel type is not specified in Schedule VIII, the reference oxygen level shall be six percent (6%) : Provided that, where there is a mixed-fuel usage, the major fuel type based on energy input shall be considered. Reference oxygen level shall be ten percent (10%) for incinerators.

10. In the case of multi-fuel usage, for each fuel, the standards specified in Schedule II hereto shall be applied.

11. Minimum stack height of any combustion point source shall be determined by the following equation.

$$C(m) = H(m) + 0.6U(m)$$

where H = The height in meters of the tallest building within 5U radius of the point source.

C = Minimum stack height in meters.

U = Uncorrected stack height in meters.

U shall be determined by following equation.

$$U(m) = 1.36Q^{0.6}$$

where Q = Gross heat imput in Mega Watt (MW)

(i) This rule shall be applied for the combustion source with gross heat input greater than 0.620MW.

(ii) In any case, stack height shall not be less than 20 meters except for the combustion sources with gross heat input less than 0.620 MW.

12. In relation to thermal power plants and to any other combustion source, air pollution caused by Sulfur Dioxide ($SO_2$) emission shall be controlled by fuel quality, stack height or Sulfur Dioxide emission control devices to maintain the existing embient air quality standards. Minimum stack height shall be determinded by accepted air quality modelling software. In the absence of such modelling software, with the approval of the Authority, following equation shall be applied to determine the minimum stack height in meters.

Minimum stack height $H(m) = 14Q^{0.25}$

Where Q is Sulfur Dioxide ($SO_2$) emission rate kg/hour.

13. Emissions from Crematoriums shall be controlled by emission reduction devices incorporated into the stack of the crematorium.

14. Dioxin and Furan emissions form incinerators shall be controlled by maintaining temperature between $1000^0$ C to $1250^0$ C and 2-3 seconds retention time in secondary chamber.

15. No person shall emit or discharge any pollutant to atmosphere exceeding the pollutant based emision limits specified in Schedule III hereto.

16. Any person who fails to comply with the above regulations, shall be liable to an offence under the National Environmental Act, No. 47 of 1980.

17. In these regulations :-

"Authority" means the Central Environmental Authority established under the National Environmental Act, No. 47 of 1980 ;

"PM" means Particulate Matter ;

"ppm" means parts per million ;

"$Nm^3$" means cubic meter of air at standard conditions of $0^0$ C temperature and 760 mmHg Pressure ;

"Nitrogen Oxides ($NO_x$)" means total concentration of Nitric Oxide (NO) and Nitrogen Dioxide ($NO_2$) gas emissions from a stack.

(Regulation 2)

SCHEDULE I

1. Thermal Power Plants
2. Standby Generators
3. Boilers
4. Thermic Fluid Heaters
5. Incinerators
6. Cupolas, Blast Furnaces, Coke Ovens, Basic Oxygen Furnaces, Electric (induction & arc) furnaces
7. Cement Kilns

(Regulation 2)

SCHEDULE II

**Instrument/Equipment Based Standards**

PART I

THERMAL POWER PLANTS

| *Fuel* | *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|---|
| **Oil** | C<1 MW | Particulate Matter (PM), Sulfur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality and stack height as set out in Regulations 11 and 12 |
| | | Smoke | 20% Opacity |
| | 1≤C<3 MW | Sulfur Dioxide ($SO_2$) | Shall be controlled by fuel quality and stack height as set out in Regulation 12 |
| | | Nitrogen Oxides ($NO_x$) | 650mg/$Nm^3$ for steam turbine |
| | | | 550mg/$Nm^3$ for gas turbine/combined cycle turbine |
| | | | 850mg/$Nm^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 200mg/$Nm^3$ |
| | | Smoke | 20% Opacity |
| | 3≤C<25 MW | Sulfur Dioxide ($SO_2$) | Shall be controlled by fuel quality and stack height as set out in Regulation 12 |
| | | Nitrogen Oxides ($NO_x$) | 600mg/$Nm^3$ for steam turbine |
| | | | 500mg/$Nm^3$ for gas turbine/combined cycle turbine |
| | | | 850mg/$Nm^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 150mg/$Nm^3$ |
| | | Smoke | 20% Opacity |
| | 25≤C<100 MW | Sulfur Dioxide ($SO_2$) | Shall be controlled by fuel quality and stack height as set out in Regulations 12 |
| | | Nitrogen Oxides ($NO_x$) | 550mg/$Nm^3$ for steam turbine |
| | | | 450mg/$Nm^3$ for gas turbine/combined cycle turbine |
| | | | 700mg/$Nm^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 150mg/$Nm^3$ |
| | | Smoke | 20% Opacity |
| | C≥ 100 MW | Sulfur Dioxide ($SO_2$) | 1. 850mg/$Nm^3$ for new power plants with maximum 28kg $SO_2$ per day per MW subject to maximum 14 metric tons of $SO_2$/day for first 500MW plus 10kg $SO_2$ per day per MW for each additional MW.<br>2. Shall be controlled by fuel quality for existing power plants |

SCHEDULE II (*Contd.*)

**Instrument/Equipment Based Standards**

Part I

THERMAL POWER PLANTS

| *Fuel* | *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|---|
| **Oil** | | Nitrogen Oxides ($NO_x$) | 500mg/Nm$^3$ for steam turbine |
| | | | 450mg/Nm$^3$ for gas turbine/combined cycle turbine |
| | | | 650mg/Nm$^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 150mg/Nm$^3$ |
| | | Smoke | 20% Opacity |
| **Biomass** | C<0.5 MW | Particulate Matter (PM)<br>Nitrogen Oxides ($NO_x$) | Shall be controlled by stack height as set out in Regulation 11 |
| | | Smoke | 25% Opacity |
| | 0.5≤C<3MW | Nitrogen Oxides ($NO_x$) | 500mg/Nm$^3$ |
| | | Particulate Matter (PM) | 250mg/Nm$^3$ |
| | | Smoke | 25% Opacity |
| | C≥3MW | Nitrogen Oxides ($NO_x$) | 450mg/Nm$^3$ |
| | | Particulate Matter (PM) | 200mg/Nm$^3$ |
| | | Smoke | 20% Opacity |
| **Coal** | C<50MW | Sulfur Dioxide ($SO_2$) | 1600mg/Nm$^3$ |
| | | Nitrogen Oxides ($NO_x$) | 750mg/Nm$^3$ |
| | | Particulate Matter (PM) | 200mg/Nm$^3$ |
| | | Smoke | 20% Opacity |
| | C≥50MW | Sulfur Dioxide ($SO_2$) | 1. 850mg/Nm$^3$ for new power plants with maximum 50kg $SO_2$ per day per MW subject to maximum 30 metric tons of $SO_2$/day for first 500MW plus 25kg $SO_2$ per day per MW for each additional MW.<br>2. Shall be controlled by fuel quality for existing power plants |
| | | Nitrogen Oxides ($NO_x$) | 650mg/Nm$^3$ |
| | | Particulate Matter (PM) | 150mg/Nm$^3$ |
| | | Smoke | 15% Opacity |
| **Natural Gas** | C<50MW | Sulfur Dioxide ($SO_2$) | 75mg/Nm$^3$ |
| | | Nitrogen Oxides ($NO_x$) | 350mg/Nm$^3$ for steam turbine |
| | | | 250mg/Nm$^3$ for gas turbine/combined cycle turbine |
| | | | 400mg/Nm$^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 100mg/Nm$^3$ |
| | C≥50MW | Sulfur Dioxide ($SO_2$) | 75mg/Nm$^3$ |
| | | Nitrogen Oxides ($NO_x$) | 300mg/Nm$^3$ for steam turbine |
| | | | 200mg/Nm$^3$ for gas turbine/combined cycle turbine |
| | | | 350mg/Nm$^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 75mg/Nm$^3$ |

SCHEDULE II (*Contd.*)

**Instrument/Equipment Based Standards**

PART I

THERMAL POWER PLANTS

| *Fuel* | *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|---|
| **Naphtha** | Any | Sulfur Dioxide ($SO_2$) | 75mg/$Nm^3$ |
| | | Nitrogen Oxides ($NO_x$) | 350mg/$Nm^3$ for steam turbine |
| | | | 250mg/$Nm^3$ for gas turbine/combined cycle turbine |
| | | | 400mg/$Nm^3$ for internal combustion engines |
| | | Particulate Matter (PM) | 75mg/$Nm^3$ |
| **Munici-pal Solid Waste** | Any | Sulfur Dioxide ($SO_2$) | 70mg/$Nm^3$ |
| | | Nitrogen Oxides ($NO_x$) | 400mg/$Nm^3$ |
| | | Particulate Matter (PM) | 150mg/$Nm^3$ |
| | | Smoke | 20% Opacity |
| | | Carbon Monoxide (CO) | 50mg/$Nm^3$ |
| | | Hydrogen Chloride (HCI) | 20mg/$Nm^3$ |
| | | Mercury (Hg) | 0.001mg/$Nm^3$ |
| | | Lead (Pb) | 0.01mg/$Nm^3$ |

PART II

STANDBY GENERATORS

| *Fuel* | *Rated Output Capacity* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|---|
| **Gasoline, kerosene diesel or heavy oil** | Any | Particulate Matter (PM), Sulfur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$) | Shall be controlled by stack height and fuel quality as set out in Regulations 11 and 12 |
| | | Smoke | 10% Opacity |

PART III

BOILERS

| *Fuel* | *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|---|
| **Oil** | C<2 metric tons of steam/hour | Particulate Matter (PM), Sulfur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality and stack height as set out in Regulations 11 and 12 |
| | | Smoke | 20% Opacity |
| | C≥2 metric tons of steam/hour | Sulfur Dioxide ($SO_2$) Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality and stack height as set out in Regulations 11 and 12 |
| | | Smoke | 15% Opacity |
| | | Particulate Matter (PM) | 100mg/Nm$^3$ |
| **Bio mass** | C<2 metric tons of steam/hour | Particulate Matter (PM) Nitrogen Oxides ($NO_x$) | Shall be controlled by stack height as set out in Regulations 11 |
| | | Smoke | 20% Opacity |
| | C≥2 metric tons of steam/hour | Nitrogen Oxides ($NO_x$) | Shall be controlled by stack height as set out in Regulations 11 |
| | | Smoke | 15% Opacity |
| | | Particulate Matter (PM) | 200mg/Nm$^3$ |
| **Coal** | C<2 metric tons of steam/hour | Particulate Matter (PM), Sulfur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality stack height as set out in Regulations 11 and 12 |
| | | Smoke | 20% Opacity |
| | C≥2 metric tons of steam/hour | Nitrogen Oxides ($NO_x$) | 500mg/Nm$^3$ |
| | | Sulfur Dioxide ($SO_2$) | 850mg/Nm$^3$ |
| | | Smoke | 20% Opacity |
| | | Particulate Matter (PM) | 150mg/Nm$^3$ |

PART IV

THERMIC FLUID HEATERS

| *Fuel* | *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|---|
| **Oil** | C<5000 MJ/hour | Particulate Matter (PM), Sulfur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality and stack height as set out in Regulations 11 and 12 |
| | | Smoke | 20% Opacity |
| | C≥5000 MJ/hour | Sulfur Dioxide ($SO_2$) Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality and stack height as set out in Regulations 11 and 12 |
| | | Smoke | 15% Opacity |
| | | Particulate Matter (PM) | 100mg/$Nm^3$ |
| **Bio mass** | C<5000 MJ/hour | Particulate Matter (PM), Nitrogen Oxides ($NO_x$) | Shall be controlled by stack height as set out in Regulations 11 |
| | | Smoke | 20% Opacity |
| | C≥5000 MJ/hour | Nitrogen Oxides ($NO_x$) | Shall be controlled by stack height as set out in Regulations 11 |
| | | Smoke | 15% Opacity |
| | | Particulate Matter (PM) | 200mg/$Nm^3$ |
| **Coal** | C<5000 MJ/hour | Particulate Matter (PM), Sulfur Dioxide ($SO_2$), Nitrogen Oxides ($NO_x$) | Shall be controlled by fuel quality and stack height as set out in Regulations 11 and 12 |
| | | Smoke | 20% Opacity |
| | C≥5000 MJ/hour | Nitrogen Oxides ($NO_x$) | 500mg/$Nm^3$ |
| | | Sulfur Dioxide ($SO_2$) | 800mg/$Nm^3$ |
| | | Smoke | 20% Opacity |
| | | Particulate Matter (PM) | 150mg/$Nm^3$ |

## PART V

### INCINERATORS

| *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|
| C< 1 Metric Ton/Hour | Sulfur Dioxide ($SO_2$) | 70mg/Nm$^3$ |
| | Nitrogen Oxides ($NO_x$) | 400mg/Nm$^3$ |
| | Particulate Matter (PM) | 150mg/Nm$^3$ |
| | Smoke | 20% Opacity |
| | Carbon Monoxide (CO) | 50mg/Nm$^3$ |
| | Hydrogen Chloride (HCl) | 20mg/Nm$^3$ |
| | Mercury (Hg) | 0.01mg/Nm$^3$ |
| | Lead (Pb) | 0.05mg/Nm$^3$ |
| | Dioxin and Furans | Shall be controlled by temperature and retention time as set out in Regulation 14 |
| C≥ 1 Metric Ton/Hour | Sulfur Dioxide ($SO_2$) | 70mg/Nm$^3$ |
| | Nitrogen Oxides ($NO_x$) | 300mg/Nm$^3$ |
| | Particulate Matter (PM) | 100mg/Nm$^3$ |
| | Smoke | 10% Opacity |
| | Carbon Monoxide (CO) | 50mg/Nm$^3$ |
| | Hydrogen Chloride (HCl) | 15mg/Nm$^3$ |
| | Mercury (Hg) | 0.001mg/Nm$^3$ |
| | Lead (Pb) | 0.01mg/Nm$^3$ |
| | Dioxin and Furans | Shall be controlled by temperature and retention time as set out in Regulation 14 |
| Any Infected waste Incinerators | Sulfur Dioxide ($SO_2$) | 70mg/Nm$^3$ |
| | Nitrogen Oxides ($NO_x$) | 300mg/Nm$^3$ |
| | Particulate Matter (PM) | 100mg/Nm$^3$ |
| | Smoke | 10% Opacity |
| | Carbon Monoxide (CO) | 50mg/Nm$^3$ |
| | Hydrogen Chloride (HCl) | 15mg/Nm$^3$ |
| | Mercury (Hg) | 0.001mg/Nm$^3$ |
| | Lead (Pb) | 0.01mg/Nm$^3$ |
| | Dioxin / Furans | Shall be controlled by temperature and retention time as set out in Regulation 14 |

## PART VI

### CUPOLAS, BLAST FURNACES, COKE OVENS, BASIC OXYGEN FURNACES, ELECTRIC INDUCTION & ELECTRIC ARC FURNACES

| *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* |
|---|---|---|
| Any | Particulate Matter (PM) | 150mg/$Nm^3$ |
| | Sulfur Dioxide ($SO_2$) | 800mg/$Nm^3$ |
| | Nitrogen Oxides ($NO_x$) | 500mg/$Nm^3$ |
| | Smoke | 20% Opacity |

## PART VII

### CEMENT KILNS

| *Rated Output Capacity (C)* | *Type of Pollutant* | *Emission Limit* | |
|---|---|---|---|
| | | *Existing ** | *New *** |
| Any | Particulate Matter (PM) | 400mg/$Nm^3$ | 200mg/$Nm^3$ |
| | Sulfur Dioxide ($SO_2$) | 540mg/$Nm^3$ | 270mg/$Nm^3$ |
| | Nitrogen Oxides ($NO_x$) | 1250mg/$Nm^3$ | 1000mg/$Nm^3$ |
| | Smoke | 20% Opacity | 20% Opacity |

*** Cement kilns in existence prior to the date of operation of these regulations.**

**** Cement kilns which will commence operation after the date of operation of these regulations.**

(Regulations 3 and Regulation 15)

SCHEDULE III

**Pollutant Based Standards**

PART I

<table>
<tr><th>Pollutant</th><th>Process/Source</th><th>Emission Limit Combustion</th><th>Emission Limit Non - Combustion</th></tr>
<tr><td>Particulate Matters (PM)</td><td>Any</td><td>150mg/Nm$^3$</td><td>100mg/Nm$^3$</td></tr>
<tr><td>Smoke</td><td>Any</td><td>25% Opacity</td><td>25% Opacity</td></tr>
<tr><td>Carbon Monoxide (CO)</td><td>Any</td><td>900mg/Nm$^3$</td><td>1100mg/Nm$^3$</td></tr>
<tr><td rowspan="2">Sulfur Dioxide ($SO_2$)</td><td>Sulfuric acid manufacturing plants</td><td colspan="2">2kg/Metric ton of Sulfuric acid production</td></tr>
<tr><td>Any Other</td><td>1000mg/Nm$^3$</td><td>800mg/Nm$^3$</td></tr>
<tr><td rowspan="2">Nitrogen Oxides ($NO_x$)</td><td>Nitric acid manufacturing plants</td><td colspan="2">1.5kg/Metric ton of Nitric acid production</td></tr>
<tr><td>Any Other</td><td>500mg/Nm$^3$</td><td>–</td></tr>
<tr><td>Total Volatile Organic Compounds (TVOC)</td><td>Any</td><td>20ppm</td><td>10ppm</td></tr>
</table>

Part II

| *Pollutant* | *Process/Source* | *Emission Limits/Combustion or Non - Combustion* |
|---|---|---|
| Chlorine ($Cl_2$) | Any | Chlorine 35mg/$Nm^3$ |
| Hydrogen Chloride (HCL) | Hydrochloric acid manufacturing plants | 0.8 kg per Metric ton of Hydrochloric acid production |
| | Any other | Hydrogen Chloride 50mg/$Nm^3$ |
| Fluorine ($F_2$) | Any | Fluorine 20mg/$Nm^3$ |
| Fluoride ($F^-$) (Hydrogen or Silicon) | Phosphate Industry | 0.18 kg/Metric ton of raw material feed |
| | Any Other | Hydrogen Fluoride 2mg/$Nm^3$ |
| Hydrogen Sulfide ($H_2S$) | Any | 1mg/$Nm^3$ |
| Cadmium or its compounds | Any | 1mg/$Nm^3$ as Cd |
| Lead or its compounds | Lead Smelling | 0.2mg/$Nm^3$ as Pb |
| | Any Other | 0.2mg/$Nm^3$ as Pb |
| Antimony or its compounds | Any | 0.5mg/$Nm^3$ as Sb |
| Arsenic or its compounds | Any | 0.1mg/$Nm^3$ as As |
| Copper or its compounds | Copper smelling | 1mg/$Nm^3$ as Cu |
| | Any Other | 1mg/$Nm^3$ as Cu |
| Zinc or its compounds | Any | 1mg/$Nm^3$ as Zn |
| Mercury or its compounds | Any | 0.01mg/$Nm^3$ as Hg |
| **Dioxin/Furan** | **Any** | **2mg/$Nm^3$** |
| Ammonia | Any | 10mg/$Nm^3$ |

**(Regulation 4)**

SCHEDULE IV

**Fugitive Dust Emission Standards**

The difference between two simultaneous 3 hour Total Suspended Particulate Matter (TSPM) measurements (gravimetric) carried out on up-wind and down-wind basis from any process area or emission area shall not be greater than 450µg/$m^3$.

a. Measurement location shall be within 10 meters from any process equipment or emission area towards up-wind and down - wind directions.

b. The wind direction shall be the most predominant wind direction during the time period of measurement.

c. Any method approved by the Authority shall be used for the TSPM measurement.

**(Regulation 4)**

SCHEDULE V

**Fugitive Non-Methane Volatile Organic Compounds (NMVOC) Emission Standards**

The difference between two simultaneous Non-Methane Volatile Organic Compound measurements carried out on up-wind and down - wind basis from any process area which emits volatile organic compounds shall not be greater than 5ppm.

a. The measurement location shall be within 5 meters from any process equipment or emission area towards up - wind and down - wind directions.

b. The wind direction shall be the most predominant wind direction the time period of measurement.

c. Any method approved by the Authority shall be used for the determination of Non-Methane Volatile Organic Compounds.

**(Regulation 4)**

SCHEDULE VI

**Fugitive Acid Mist and Ammonia Emission Standards**

Fugitive acid mists or fugitive ammonia mist emissions from any process area shall not be greater than 20mg/$m^3$. The measurement location shall be within 5 meters down-wind from the process area. Sampling time period shall be 3 hours at the sampling flow rate 1 liter/min. Any method approved by the Authority shall be used for the determination of fugitive acid mist and ammonia mist emission level.

**(Regulation 4)**

SCHEDULE VII

**Asbestos Fiber Emission Standards**

Ambient asbestos fiber concentrations in process area shall not be greater than 1 fibre/$m^3$. The measurement location shall be within 20 meters down - wind from the process area. Any method approved by the Authority shall be used for the determination of asbestos fiber concentration.

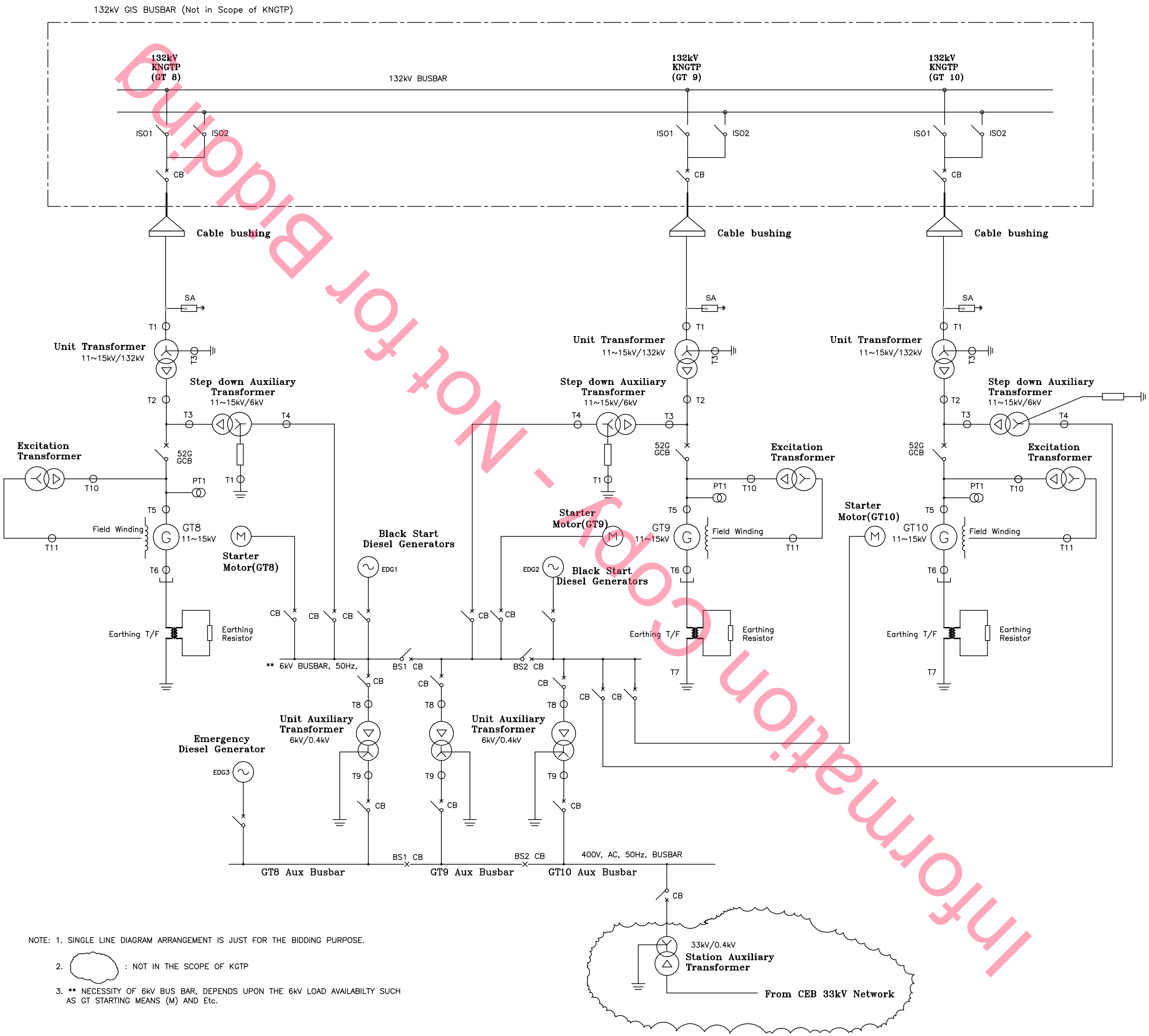
**(Regulation 8)**

SCHEDULE VIII

**Reference Oxygen Levels**

| *Fuel Type* | *Reference Oxygen Level* |
|---|---|
| Liquid and gaseous fuels | 03% |
| Solid fuels | 06% |

06- 44





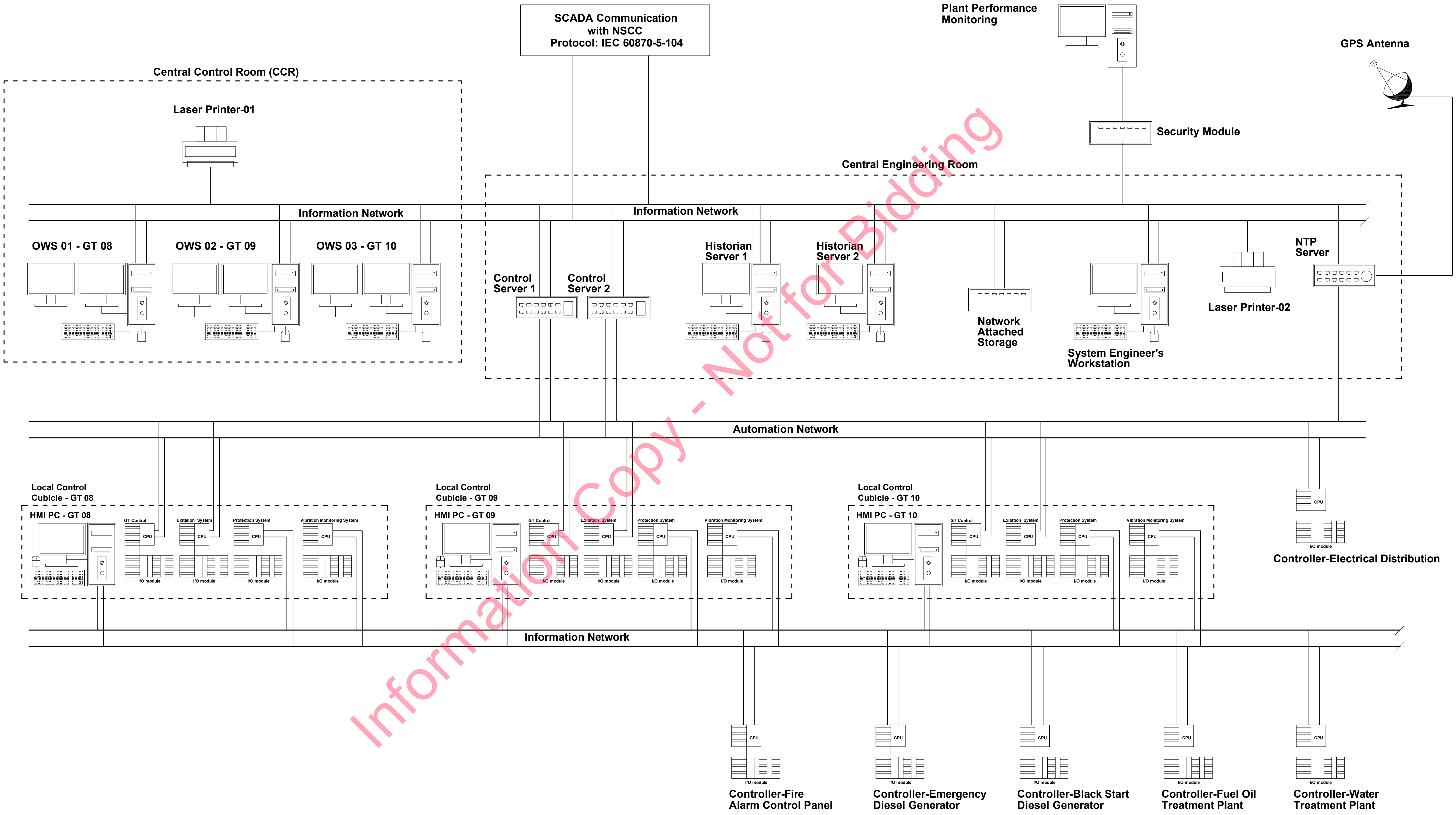

NOTE: 1. SINGLE LINE DIAGRAM ARRANGEMENT IS JUST FOR THE BIDDING PURPOSE.

2. : NOT IN THE SCOPE OF KGTP

3. ** NECESSITY OF 6kV BUS BAR, DEPENDS UPON THE 6kV LOAD AVAILABILTY SUCH AS GT STARTING MEANS (M) AND Etc.

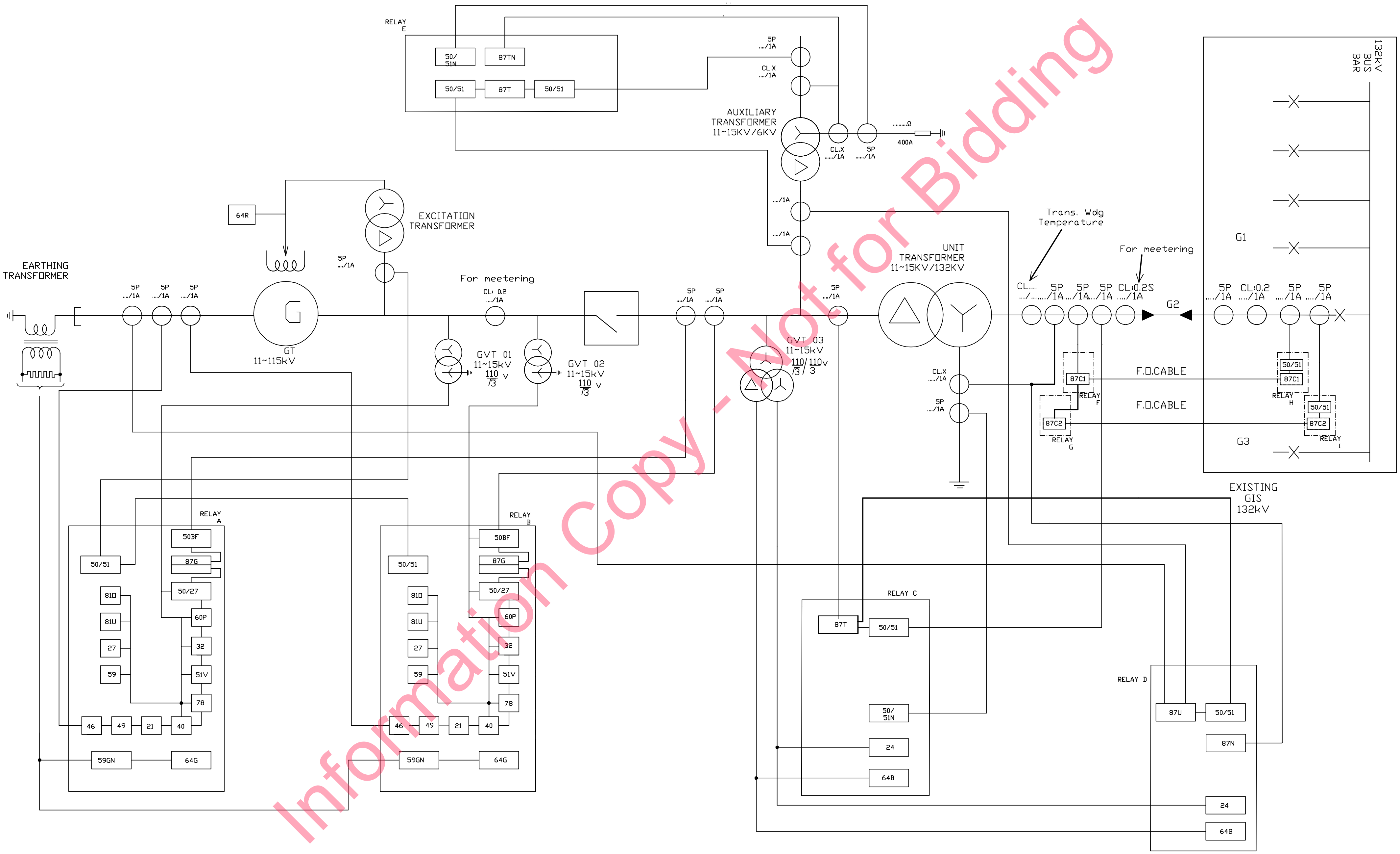
Single Line Diagram for KGTP

# Appendix - E3

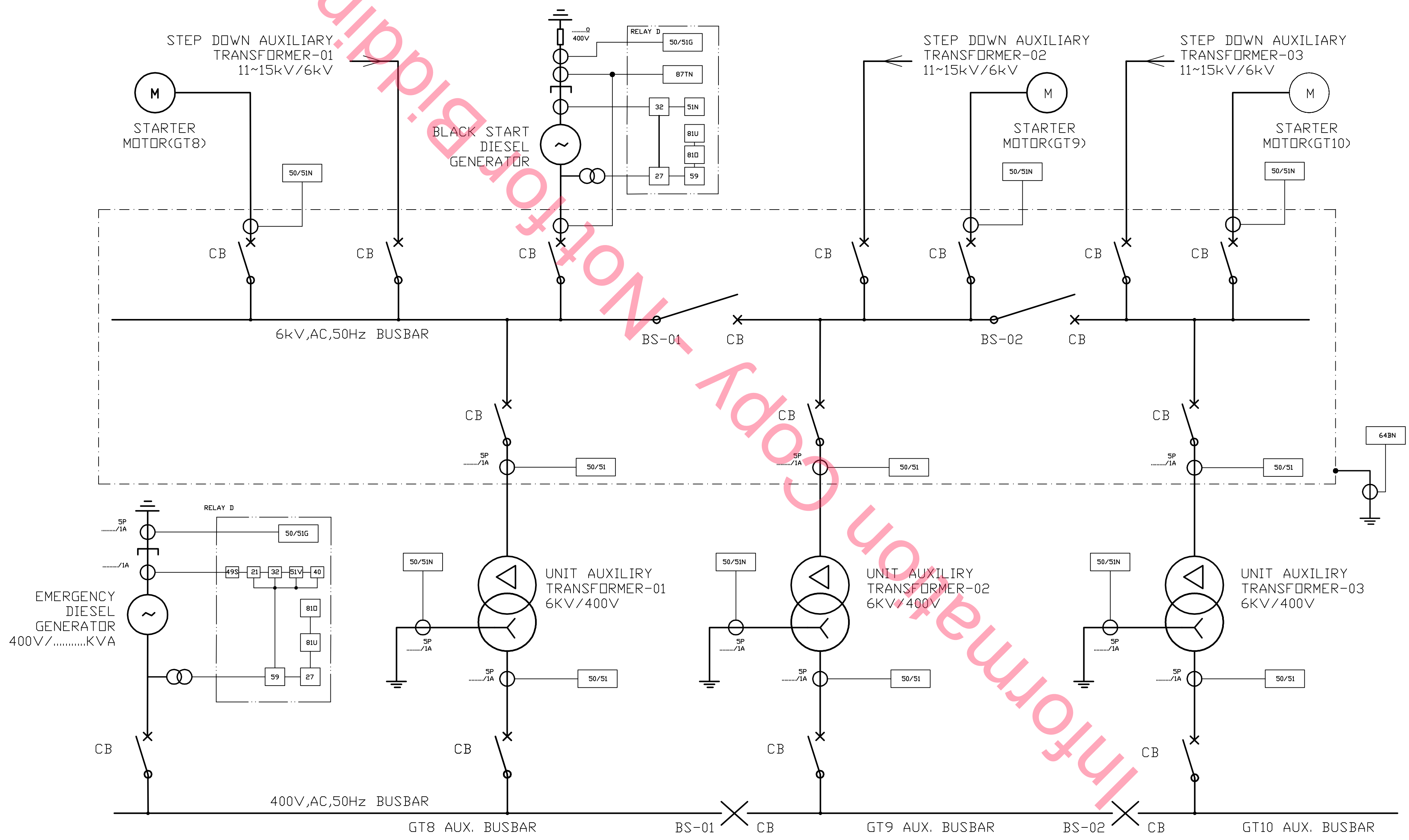





**Basic System Architechture for Distributed Control System (DCS)**

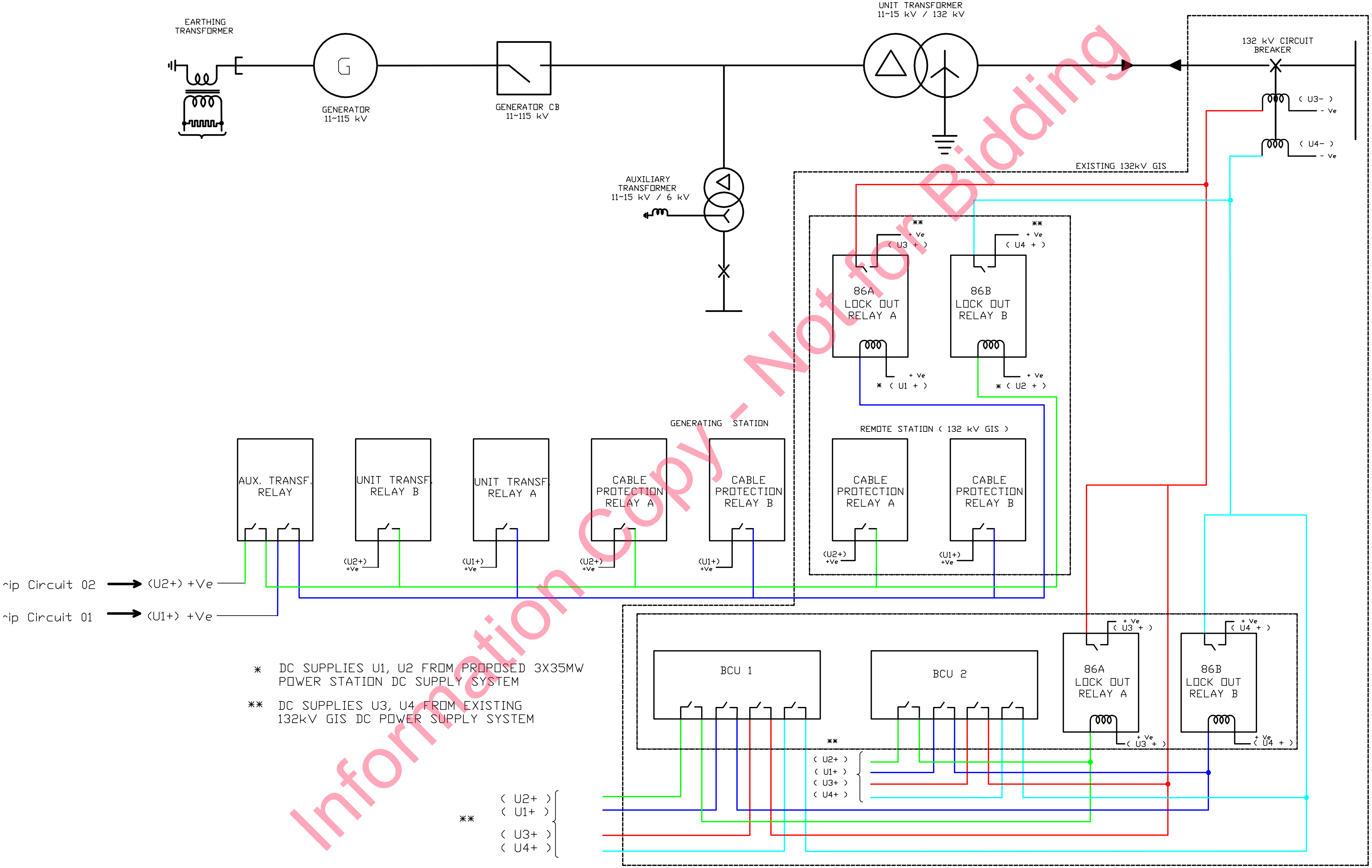



Appendix E4: Protection scope for Generator, Unit T/F and Step down Aux. T/F





Appendix E5: Protection scope for Emergency Diesel Generator




Appendix E6: Trip Scheme for 132kV Circuit Breakers of Kelanitissa Gas Turbines original

Appendix - F

Geotechnical Engineering Division

*Quality is Our Trademark*

# GEOTECHNICAL INVESTIGATION REPORT

ELS SI 3837



**PROJECT**

GREATER COLOMBO TRANSMISSION AND DISTRIBUTION LOSS REDUCTION PROJECT

Soil Investigation for he proposed Construction at Kelanitissa 33KV GIS Substation

**CLIENT**

Hyosung Corporation

20 December 2016

**ENGINEERING & LABORATORY SERVICES [PVT.] LTD.**
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| | | | | | |
|---|---|---|---|---|---|
| | | | Document No: | | ELS/3837 |
| 1 | 20/12/2016 | Soil Investigation Report at Kelanitissa | R.D.Perara | Prof. B.L.Tennekoon | For R.M.Wasantha Ratnayake |
| **Rev** | **Date** | **Description** | **Prepared By** | **Foundation Recommendation given By** | **Approved By** |


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## *Content*

# SOIL INVESTIGATION FOR PROPOSED CONSTRUCTIONS AT KELANITISSA 33KV GIS SUBSTATION

## 1.0 Introduction

A comprehensive geotechnical assessment has been conducted by **M/s. Engineering and Laboratory Services (Pvt) Ltd** for **Hyosung Corporation**, to determine the geotechnical conditions present within the investigated land. This report includes the work carried out by Engineering and Laboratory Services (Pvt) Ltd to determine the sub soil and ground water conditions at the site along with the foundation recommendation for the proposed construction at kelanitissa 33kv GIS substation, Colombo.

## 2.0 Site Description

The proposed investigated premise is located at the Kelanitissa power station, New Kelani Bridge Road, Colombo. The investigated land is relatively flat and there were no visible elevation difference between the boreholes. Access road to the premise is from South.

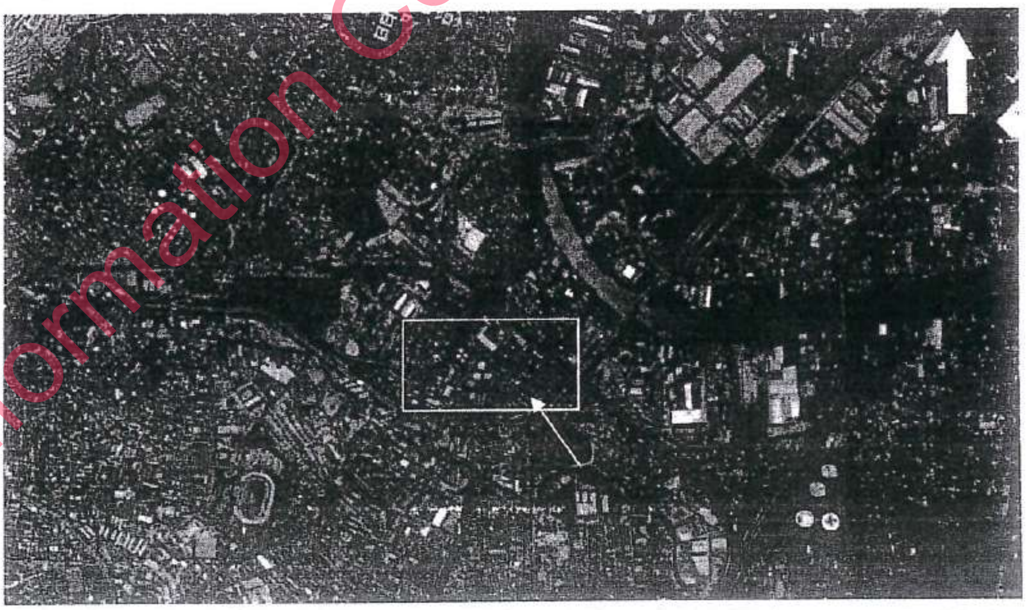


**Figure 1(a): Proposed Investigated Area**


**Figure 1(b): Locations of the Boreholes**

## 3.0 Field Investigation

### 3.1 Borehole Drilling

The field investigation was consisted of advancing 02 boreholes at the location marked as BH-01 and BH 02 in Figure 1(b). The field investigation was commenced on 05th of September, 2016 and completed on 11th of September, 2016. The summary of the borehole investigation is given in the table below.

The boreholes were advanced by means of a rotary - drilling machine. The drilling was carried out by means of overburden cutting tools and adopting the wash boring process to remove the cuttings from the bottom of the borehole. Representative , disturbed samples were taken at corresponding depths where the SPT test was done, using a split barrel, 50 mm outer diameter sampler obtained by a 63.5kg hammer dropping through 760mm distance.

Standard Penetration Test (SPT) was carried out in regular intervals in the overburden. This test was carried out as specified in BS 1377.Disturbed samples of soil were collected both from the SPT tube and the cuttings collected from the washings.

Following table summarizes an account of the detail of drilling at the site.

| Borehole No | Depth to ground water (m) | Over burden Drilling (m) | Rock Drilling (m) | Total Depth (m) |
|---|---|---|---|---|
| BH-01 | 0.55 | 25.90 | 4 | 29.90 |
| BH-02 | 0.60 | 17.50 | 4 | 21.50 |

## 3.2 Ground water conditions

Ground water measurements were obtained from the open boreholes where the water levels were obtained after a considerable response time. The ground water levels obtained can fluctuate with the seasons, periods of precipitation and temperature.

## 3.3 Laboratory Tests

Laboratory investigations were taken place in order to the sub surface assessment in geotechnical investigation. In connection with the entire laboratory testing the performance has been made as per BS 1377 unless otherwise stated. The detailed results of the laboratory investigation are given in Annexures.

### 3.3.1 Laboratory Tests on Soil Samples

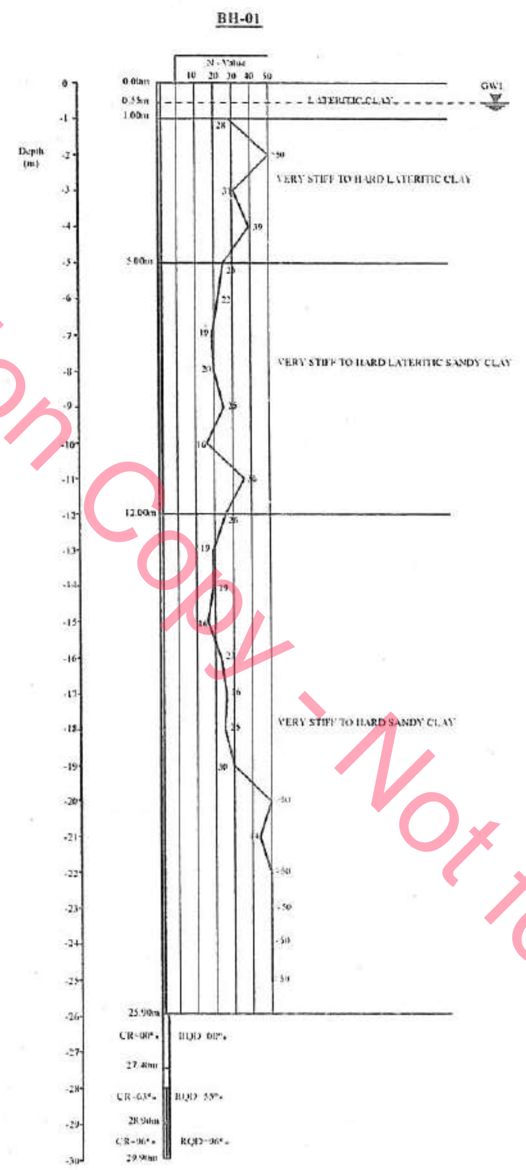
- Grain size distribution
- Atterburg Limits

### 3.3.2 Laboratory Tests on Rock Samples

- UCS test

## 4.0 Subsurface Conditions

The sub surface conditions encountered at the site are graphically presented in the borehole logs attached in Annex I. The soil horizons identified at the borehole locations are inferred from the samples taken from the borehole locations. Soil horizons/layers generally represent a transition from one soil type to another and that should not be assumed to be representing an exact plane of geological change. Further, the conditions may vary between and beyond the borehole locations.




NOTES: Profile is plotted only according to the data obtained from the borehole locations and actual soil profile may vary from this profile

PROJECT: Soil investigation for the Proposed substation at Kalanithissa

FIGURE 2(a): Possible Soil Profile across the borehole, BH-01

PAGE : 05

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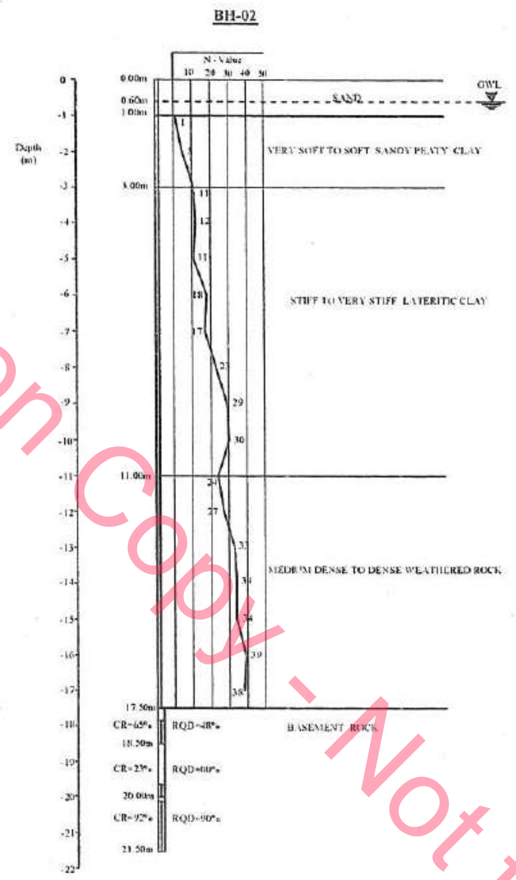




NOTES: Profile is plotted only according to the data obtained from the borehole locations and actual soil profile may vary from this profile

PROJECT: Soil investigation for the Proposed substation at Kalanithissa

FIGURE 2(b): Possible Soil Profile across the borehole, BH-02



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## 5.0 Interpretation Report with Recommendations for foundations

This report should be read in conjunction with the Factual Report of the Soil Investigation carried out at the site and reported in October, 2016.

### 5.1 Project & Site details

The investigation was for the construction of a new Control Room at the Kelanitissa 33kV GIS Substation, as part of the Greater Colombo Transmission and Distribution Loss Reduction Project of the CEB.

As per the details provided the new Control Room would be a 2-storey building inclusive of a semi-basement.

The site is situated within a relatively flat region of the existing Grid Sub-station. Some of the existing structures in its vicinity are:

- One storey Panel Board Room; and
- An existing Transformer.

### 5.2 Borehole Investigations

Two boreholes have been advanced in the construction area at locations BH-01 and BH 02 shown in Fig. 1b. The boreholes was initially advanced up to hard rock and further advanced in to the rock by coring the rock using a double tube core barrel. The details of depths of drilling, including the depth to ground water level (GWL), are indicated below.

| Location | BH-01 | BH-02 |
|---|---|---|
| Depth to GWL (m) | 0.55 | 0.60 |
| Depth to rock (m) | 25.90 | 17.50 |
| Depth of borehole (m) | 29.90 | 21.50 |

Rock coring in the boreholes had given the following results for the Core Recovery (CR) and the Rock Quality Designation (RQD):

| Borehole No. | Depth (m) | CR (%) | RQD (%) |
|---|---|---|---|
| BH-01 | 25.90-27.40<br>27.40-28.90<br>28.90-29.90 | 00<br>63<br>96 | 00<br>55<br>96 |
| BH-02 | 17.50-18.50<br>18.50-20.00<br>20.00-21.50 | 65<br>23<br>92 | 48<br>00<br>90 |

The uniaxial compressive strength (UCS) of two of the rock cores was determined. Their results are summarized below.

| BH No. | Sampling depth(m) | UCS (N/mm2) |
|---|---|---|
| BH-01 | 28.50-28.90 | 29.09 |
| BH-02 | 20.00-20.20 | 10.47 |

### 5.3 Sub-surface conditions

From a study of the borehole logs, it is concluded that the overburden at BH-02 can be modeled by successive layers as indicated below.

| Layer No. | Position (m) | Layer description | Average SPT |
|---|---|---|---|
| 1 | 0.0-1.0 | Uncontrolled Fill | - |
| 2 | 1.0-3.0 | Weak alluvial deposits (*) | 1 |
| 3a | 3.0-6.0 | Lateritic soils I | 10 |
| 3b | 6.0-11.0 | Lateritic soils II | 20 |
| 4a | 11.0-15.0 | Completely weathered rock - I | 30 |
| 4b | 15.0-17.5 | Completely weathered rock - II | 38 |
| 5 | >17.5 | Basement rock | - |

(*) Layer No. 2 included very soft organic clay between depths of 1.0m and 2.0m

Ground water level (GWL) was encountered at a depth of 0.6m.

There were major variations in the layering at BH 01, with the main differences being that:

a) Layer Nos. 1 and 2 were not present; and
b) Layer No. 3a was also not present.

## 5.4 Recommendations for geotechnical design parameters

Recommendations for the geotechnical design parameters for sub-surface layers are given in the table below based on the visual observation of the soil samples collected, the measured SPT values, and experience with similar sub-surface conditions.

| Layer description | Average SPT | Shear strength parameters | Ultimate bearing capacity ($kN/m^2$) | Elastic Modulus E ($kN/m^2$) |
|---|---|---|---|---|
| Lateritic soils I | 10 | c' = 6 kPa, φ' = 26 | 260 | 8000 |
| Lateritic soils II | 20 | c' = 8 kPa, φ' = 29 | 420 | 15000 |
| Completely weathered rock - I | 30 | c' = 10 kPa, φ' = 30 | 420 | 15000 |
| Completely weathered rock - II | 38 | c' =10 kPa, φ' = 33 | 750 | 20000 |

## 5.5 Recommendations of foundations for the Control Room

### 5.5.1 Factors affecting selection of foundations

The significant factors affecting the selection of the foundations are:

a) There were major differences across the site within the upper 3m. Whereas, a very strong lateritic formation was present at BH-01, at the location of BH-02 there were very weak alluvial deposits inclusive or organic clay;

b) Ground water level is at a depth of around 0.5m.

c) The loads to be transferred from the Control building, which is a (1-2)-storied structure consisting of a semi-basement floor (over one section only), and ground floor.

### 5.5.2. Recommendations for foundation type and design

#### 5.5.2.1 Recommendations for foundations in the semi-basement area

It is recommended that initially, the ground in this area be excavated to the designed basement floor level (i.e. up to a depth of about 2.5m below FGL) with sides of the excavation retained with proper retaining structures.

Two cases will be considered.

<u>Case 1</u> **Excavated bottom is on virgin lateritic formation**

No ground improvement is necessary. It is recommended to adopt a raft foundation at the excavated basement floor level and designed for an allowable bearing capacity of bearing capacity of 100kN/m$^2$.

<u>Case 2</u> **Excavated bottom is on weak alluvial deposits**

It is recommended to carry out ground improvement under the foundation area up to the bottom of the very soft organic clay. Thereafter, the excavation should be filled back up to foundation level under control conditions as indicated below.

In the ground improvement procedure, the GWL should first be lowered to the bottom of the excavation, and the excavation then filled back with sand or quarry dust or ABC material up to 0.3m above the lowered GWL. The backfill should then be compacted by means of a plate compactor or poker vibrator. The GWL should be allowed to rise slowly to the top of the fill, and the process repeated for every 0.3m of additional fill until foundation level is reached.

It is recommended to adopt a raft foundation at the excavated basement floor level and designed for an allowable bearing capacity of bearing capacity of 100kN/m$^2$.

.

**5.5.2.2 Recommendations for foundations in area without semi-basement**

Again, two cases will be considered.

<u>Case 1</u> **In area of virgin lateritic formation**

No ground improvement is necessary. It is recommended to adopt individual pad or strip footings at a depth of (1.0-3.0)m below Finish Ground Level (FGL), and design the same for an allowable bearing capacity of bearing capacity of 140kN/m$^2$. A limited amount of de-watering would be required for foundation construction.

<u>Case 2</u> **In area of weak alluvial deposits**

It is recommended to carry out ground improvement under the foundation area up to the bottom of the very soft organic clay. Thereafter, the excavation should be filled back up to foundation level under control conditions as indicated previously in Section 5.5.2.1

The recommendations for the foundations are as given previously for Case 1.

B. L. Tennekoon
..............................

Prof. B.L. Tennekoon
Emeritus Professor,
University of Moratuwa
20st December 2016

Annexure I –Borehole Logs

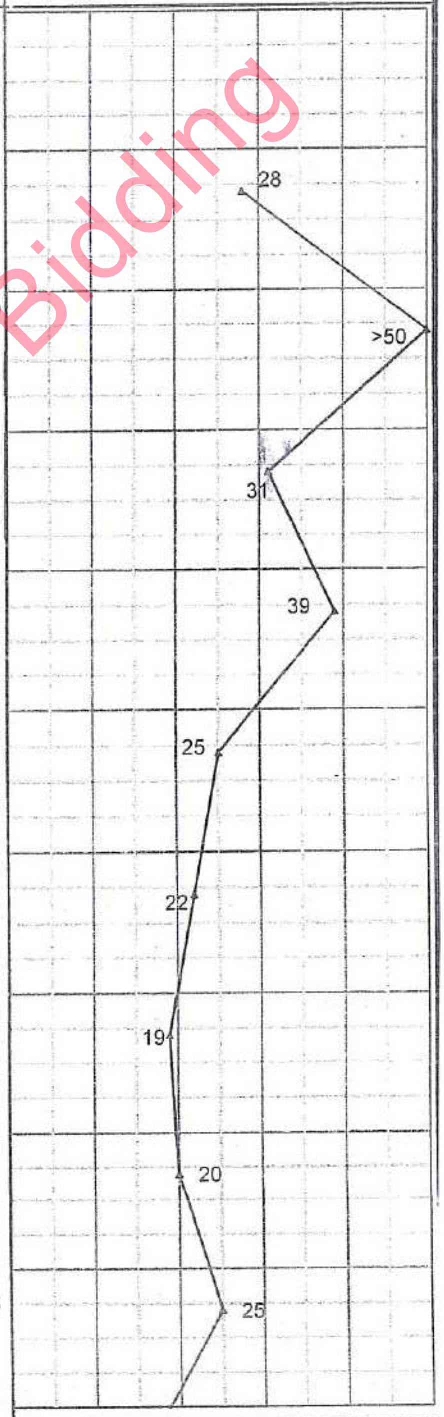
ENGINEERING & LABORATORY SERVICES (PVT) LTD.
SITE INVESTIGATIONS DIVISION
NO 62/3, Neelammahara Road,
Katuwawala, Sri Lanka.
Tel: 0114 309 494

| | | | | | |
|---|---|---|---|---|---|
| Project | Geotechnical Investigation for the proposed substation A at Kalanithissa | | | Borehole No | BH-01 |
| Client | Hyosung Corporation | | | Sheet | 1 of 3 |
| Location | Kalanithissa | Rig | Track wheel | Core Diameter | 54mm |
| Date of Started | 05.09.2016 | Drilling Method | Rotary | Cased Depth | 29.90m |
| Date of Finished | 08.09.2016 | Casing Diameter | 76mm | Elevation | |
| Ground Water Level | = 0.55m | X- Coordinate | - | Y- Coordinate | - |

| Depth (m) | Sa. Cond | Sa.NO. | Sa.Type | g - g/cc Other Tests | Depth (m) | Legend | Soil Description | 15cm | 15cm | 15cm | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | | | | | | Ground level | | | | |
| | | D1 | DS | | 0.00 | | Reddish brown lateritic CLAY with gravel | | | | |
| 1.00 | | D2 | SS | GWL at 0.55m | 1.00 | | Very stiff brownish red lateritic CLAY with gravel | 10 | 12 | 16 | 28 |
| | | | TC | | | | | | | | |
| 2.00 | | D3 | SS | | 2.00 | | Hard brownish red lateritic CLAY with gravel | 11 | 22 | 38 | >50 |
| | | | TC | | | | | | | | |
| 3.00 | | D4 | SS | | | | | 13 | 10 | 21 | 31 |
| | | | TC | | | | | | | | |
| 4.00 | | D5 | SS | | | | | 11 | 18 | 21 | 39 |
| | | | TC | | | | | | | | |
| 5.00 | | D6 | SS | | 5.00 | | Very stiff reddish yellow lateritic CLAY with gravel | 5 | 12 | 13 | 25 |
| | | | TC | | | | | | | | |
| 6.00 | | D7 | SS | | | | | 6 | 9 | 13 | 22 |
| | | | TC | | | | | | | | |
| 7.00 | | D8 | SS | | | | | 6 | 8 | 11 | 19 |
| | | | TC | | | | | | | | |
| 8.00 | | D9 | SS | | | | | 6 | 8 | 12 | 20 |
| | | | TC | | | | | | | | |
| 9.00 | | D10 | SS | | | | | 5 | 9 | 16 | 25 |
| | | | TC | | | | | | | | |
| 10.00 | | | | | | | | | | | |

Field Records (SPT)

Moisture Content - %
Undrained Shear Strength - t/m$^2$
10 20 30 40 50 60 70 80 90
SPT Resistance - Blows/ft
5 10 15 20 25 30 35 40 45




**Sample Key / Test Key**

SPT Where full 0.3m penetration has not been achieved the number of blows for the quoted penetration is given (not N-value)
GWL Ground Water Level observed inside the Borehole, after the saturation
HB -Hammer Bounce
FD - Free Down

D - Disturbed Sample
SS -SPT Sample
W - Water Sample
WS-Wash Sample
UD- Undisturbed Sample
CS- Core Sample
Cr - Core Recovery (%)
RQD-Rock Quality Designation (%)

N - Natural Moisture Content
L - Atterberg Limit Test
G - Grain Size Analysis
SG -Specific Gravity Test
B - Bulk Density
V - Vane Shear Test

C - Consolidation
UCT-Unconfined Compression
CU - Consolidated Undrained
UU-Unconsolidated Undrained
pH - Chemical
O - Organic content
$SO_4^{2-}$ - Sulphate Content
$Cl^-$ - Cloride Content

**Remarks**
Existing ground level considered as the zero level

Logged By : Ramesh
Supervised By: Dhanesh
Drilled By: Suranga

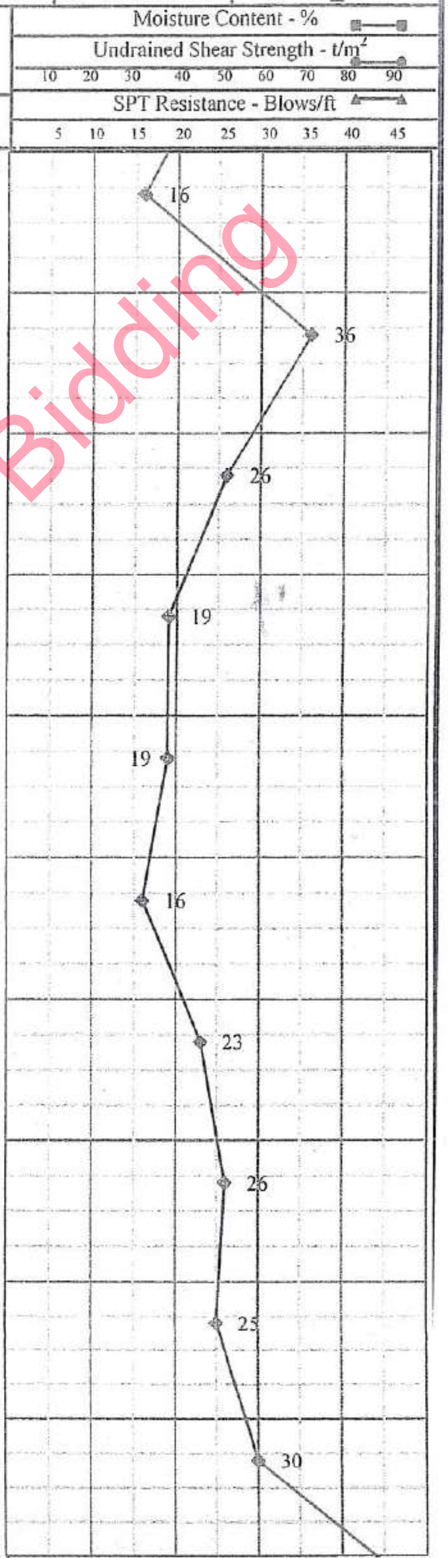
Made Ground | Silt | Gravel | Laterite Nodules | Completely Weathered Rock | Fresh Rock
Clay | Sand | Organic Matter | Silty Sand | Highly Weathered Rock

| | | |
|---|---|---|
| ELS | **ENGINEERING & LABORATORY SERVICES (PVT) LTD.**<br>SITE INVESTIGATIONS DIVISION | NO 62/3, Neelammahara Road,<br>Katuwawala, Sri Lanka.<br>Tel: 0114 309 494 |

| | | | | | |
|---|---|---|---|---|---|
| **Project** | Geotechnical Investigation for the proposed substation A at Kalanithissa | | | Borehole No | BH-01 |
| **Client** | Hyosung Corporation | | | Sheet | 2 of 3 |
| Location | Kalanithissa | Rig | Track whee | Core Diameter | 54mm | Ground Water Level | = 0.55m |
| Date of Started | 05.09.2016 | Drilling Method | Rotary | Cased Depth | 29.90m | X- Coordinate | _ |
| Date of Finished | 08.09.2016 | Casing Diameter | 76mm | Elevation | | Y- Coordinate | _ |

| Depth (m) | Sa. Cond | Sa.NO. | Sa.Type | g - g/cc Other Tests | Depth (m) | Legend | Soil Description | 15cm | 15cm | 15cm | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.00 | | | | | | | Continue from Page 1 | | | | |
| | | D11 | SS | | | | Same as previous descripyion | 6 | 7 | 9 | 16 |
| | | | TC | | | | | | | | |
| 11.00 | | D12 | SS | | 11.00 | | Hard whitish yellow fine to medium sub angular to angular sandy CLAY | 5 | 12 | 24 | 36 |
| | | | TC | | | | | | | | |
| 12.00 | | D13 | SS | | 12.00 | | Very stiff fine to coarse sub angular to angular sandy CLAY; Colour changes from yellowish red, greyish white to whitish yellow | 6 | 11 | 15 | 26 |
| | | | TC | | | | | | | | |
| 13.00 | | D14 | SS | | | | | 3 | 7 | 12 | 19 |
| | | | TC | | | | | | | | |
| 14.00 | | D15 | SS | | | | | 5 | 8 | 11 | 19 |
| | | | TC | | | | | | | | |
| 15.00 | | D16 | SS | | | | | 5 | 6 | 10 | 16 |
| | | | TC | | | | | | | | |
| 16.00 | | D17 | SS | | | | | 8 | 11 | 12 | 23 |
| | | | TC | | | | | | | | |
| 17.00 | | D18 | SS | | | | | 8 | 12 | 14 | 26 |
| | | | TC | | | | | | | | |
| 18.00 | | D19 | SS | | | | | 7 | 13 | 12 | 25 |
| | | | TC | | | | | | | | |
| 19.00 | | D20 | SS | | | | | 11 | 12 | 18 | 30 |
| | | | TC | | | | | | | | |
| 20.00 | | | | | | | | | | | |

Field Records (SPT)




**Sample Key / Test Key**

| | | | | | |
|---|---|---|---|---|---|
| SPT Where full 0.3m penetration has not been achieved the number of blows for the quoted penetration is given (not N-value)<br>GWL Ground Water Level observed inside the Borehole, after the saturation<br>HB -Hammer Bounce<br>FD - Free Down | D - Disturbed Sample<br>SS -SPT Sample<br>W - Water Sample<br>WS-Wash Sample<br>UD- Undisturbed Sample<br>CS- Core Sample<br>Cr - Core Recovery (%)<br>RQD-Rock Quality Designation (%) | N - Natural Moisture Content<br>L - Atterberg Limit Test<br>G - Grain Size Analysis<br>SG -Specific Gravity Test<br>B - Bulk Density<br>V - Vane Shear Test | C - Consolidation<br>UCT-Unconfined Compression<br>CU - Consolidated Undrained<br>UU-Unconsolidated Undrained<br>pH - Chemical<br>O - Organic content<br>$SO_4^{2-}$ - Sulphate Content<br>Cl - Cloride Content | **Remarks**<br>Existing ground level considered as the zero level | **Logged By:** Ramesh<br>**Supervised By:** Dhanesh<br>**Drilled By:** Suranga |

| | | | | | |
|---|---|---|---|---|---|
| Made Ground | Silt | Gravel | Laterite Nodules | Completely Weathered Rock | Fresh Rock |
| Clay | Sand | Organic Matter | Silty Sand | Highly Weathered Rock | |

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SITE INVESTIGATIONS DIVISION

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| | | | | | |
|---|---|---|---|---|---|
| Project | Geotechnical Investigation for the proposed substation A at Kalanithissa | | | Borehole No | BH-01 |
| Client | Hyosung Corporation | | | Sheet | 3 of 3 |
| Location | Kalanithissa | Rig | Track wheel | Core Diameter | 54mm | Ground Water Level = 0.55m |
| Date of Started | 05.09.2016 | Drilling Method | Rotary | Cased Depth | 29.90m | X- Coordinate |
| Date of Finished | 08.09.2016 | Casing Diameter | 76mm | Elevation | | Y- Coordinate |

Continue from Page I

| Depth (m) | Sa. Cond | Sa. NO. | Sa. Type | g - g/cc Other Tests | Depth (m) | Soil Description | 15cm | 15cm | 15cm | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 20.00 | X | D21 | SS | | 20.00 | Hard whitish yellow fine to medium sub angular to angular sandy CLAY | 10 | 16 | HB | >50 |
| | | | TC | | | | | | | |
| 21.00 | X | D22 | SS | | | | 13 | 16 | 28 | 44 |
| | | | TC | | | | | | | |
| 22.00 | X | D23 | SS | | | | 12 | 18 | HB | >50 |
| | | | TC | | | | | | | |
| 23.00 | X | D24 | SS | | | | 15 | HB | | >50 |
| | | | TC | | | | | | | |
| 24.00 | X | D25 | SS | | | | HB | | | >50 |
| | | | TC | | | | | | | |
| 25.00 | X | D26 | SS | | | | HB | | | >50 |
| | | | TC | | | Completely Weathered Rock<br>ROCK LEVEL | | | | |
| 26.00 | | | | | 25.90 | Foliated grayish black highly weathered highly fractured fine to medium grained BIOTTIE GNEISS | CR=00% | | RQD=00% | |
| 27.00 | CS | | | | | | | | | |
| 28.00 | CS | | | | 27.40 | Foliated grayish black highly weathered highly fractured fine to medium grained BIOTTIE GNEISS | CR=63% | | RQD=55% | |
| 29.00 | CS | | | | 28.90 | Foliated grayish black highly weathered highly fractured fine to medium grained BIOTTIE GNEISS<br>The bore hole was terminated at a depth of 29.90m | CR=96% | | RQD=96% | |
| 30.00 | | | | | | | | | | |

Moisture Content - %
Undrained Shear Strength - t/m²: 10 20 30 40 50 60 70 80 90
SPT Resistance - Blows/ft: 5 10 15 20 25 30 35 40 45
>50, 44, >50, >50

**Sample Key / Test Key**

SPT Where full 0.3m penetration has not been achieved the number of blows for the quoted penetration is given (not N-value)
GWL Ground Water Level observed inside the Borehole, after the saturation
HB -Hammer Bounce
FD - Free Down

D - Disturbed Sample
SS -SPT Sample
W - Water Sample
WS-Wash Sample
UD- Undisturbed Sample
CS- Core Sample
Cr - Core Recovery (%)
RQD-Rock Quality Designation (%)

N - Natural Moisture Content
L - Atterberg Limit Test
G - Grain Size Analysis
SG -Specific Gravity Test
B - Bulk Density
V - Vane Shear Test

C - Consolidation
UCT-Unconfined Compression
CU - Consolidated Undrained
UU-Unconsolidated Undrained
pH - Chemical
O - Organic content
$SO_4^{2-}$ - Sulphate Content
$Cl^-$ - Cloride Content

**Remarks**
Existing ground level considered as the zero level

**Logged By:** Ramesh
**Supervised By:** Dhanesh
**Drilled By:** Suranga

Made Ground, Silt, Gravel, Laterite Nodules, Completely Weathered Rock, Clay, Sand, Organic Matter, Silty Sand, Highly Weathered Rock, Fresh Rock

ENGINEERING & LABORATORY SERVICES (PVT) LTD.
SITE INVESTIGATIONS DIVISION

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Katuwawala, Sri Lanka.
Tel: 0114 309 494

| | | | | | |
|---|---|---|---|---|---|
| Project | Geotechnical Investigation for the proposed substation A at Kalanithissa | | | Borehole No | BH-02 |
| Client | Hyosung Corporation | | | Sheet | 1 of 3 |
| Location | Kalanithissa | Rig | Track wheel | Core Diameter | 54mm |
| | | | | Ground Water Level | 0.60m |
| Date of Started | 09.09.2016 | Drilling Method | Rotary | Cased Depth | 21.50m |
| | | | | X- Coordinate | - |
| Date of Finished | 11.09.2016 | Casing Diameter | 76mm | Elevation | |
| | | | | Y- Coordinate | - |

| Depth (m) | Sa. Cond | Sa.NO. | Sa.Type | g - g/cc Other Tests | Depth (m) | Soil Description | 15cm | 15cm | 15cm | N |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | | | | | Ground level | | | | |
| | | D1 | DS | | 0.00 | Greyish brown fine to medium SAND with rock, cement and brick particles | | | | |
| 1.00 | | D2 | SS | GWL at 0.60m | 1.00 | Very soft black organic CLAY | 0 | 1 | 0 | 1 |
| | | | WS | | | | | | | |
| 2.00 | | D3 | SS | | 2.00 | Soft blackish brown fine to medium sub angular to angular sandy CLAY with gravel | 4 | 3 | 2 | 5 |
| | | | WS | | | | | | | |
| 3.00 | | D4 | SS | | 3.00 | Stiff latritic CLAY with gravel; Colour changes from yellowish brown to brownish red | 3 | 4 | 7 | 11 |
| | | | TC | | | | | | | |
| 4.00 | | D5 | SS | | | | 3 | 6 | 6 | 12 |
| | | | WS | | | | | | | |
| 5.00 | | D6 | SS | | | | 4 | 5 | 6 | 11 |
| | | | WS | | | | | | | |
| 6.00 | | D7 | SS | | 6.00 | Very stiff reddish yellow lateritic CLAY | 5 | 7 | 11 | 18 |
| | | | TC | | | | | | | |
| 7.00 | | D8 | SS | | | | 6 | 8 | 9 | 17 |
| | | | TC | | | | | | | |
| 8.00 | | D9 | SS | | | | 7 | 11 | 12 | 23 |
| | | | TC | | | | | | | |
| 9.00 | | D10 | SS | | | | 8 | 13 | 16 | 29 |
| | | | TC | | | | | | | |
| 10.00 | | | | | | | | | | |

Field Records (SPT)

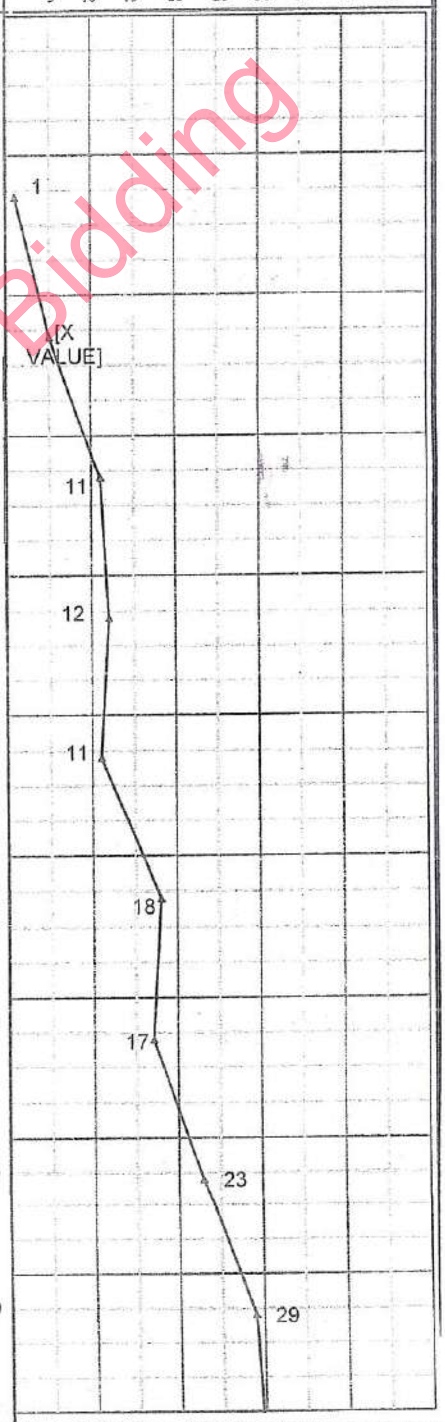
Moisture Content - %

Undrained Shear Strength - t/m²

10 20 30 40 50 60 70 80 90

SPT Resistance - Blows/ft

5 10 15 20 25 30 35 40 45




Sample Key / Test Key

SPT Where full 0.3m penetration has not been achieved the number of blows for the quoted penetration is given (not N-value)

GWL Ground Water Level observed inside the Borehole, after the saturation

HB -Hammer Bounce

FD - Free Down

D - Disturbed Sample
SS -SPT Sample
W - Water Sample
WS-Wash Sample
UD- Undisturbed Sample
CS- Core Sample
Cr - Core Recovery (%)
RQD-Rock Quality Designation (%)

N - Natural Moisture Content
L - Atterberg Limit Test
G - Grain Size Analysis
SG -Specific Gravity Test
B - Bulk Density
V - Vane Shear Test

C - Consolidation
UCT-Unconfined Compression
CU - Consolidated Undrained
UU-Unconsolidated Undrained
pH - Chemical
O - Organic content
$SO_3^{2-}$ - Sulphate Content
Cl - Cloride Content

Remarks: Existing ground level considered as the zero level.

Logged By: Ramesh
Supervised By: Dhanesh
Drilled By: Suranga

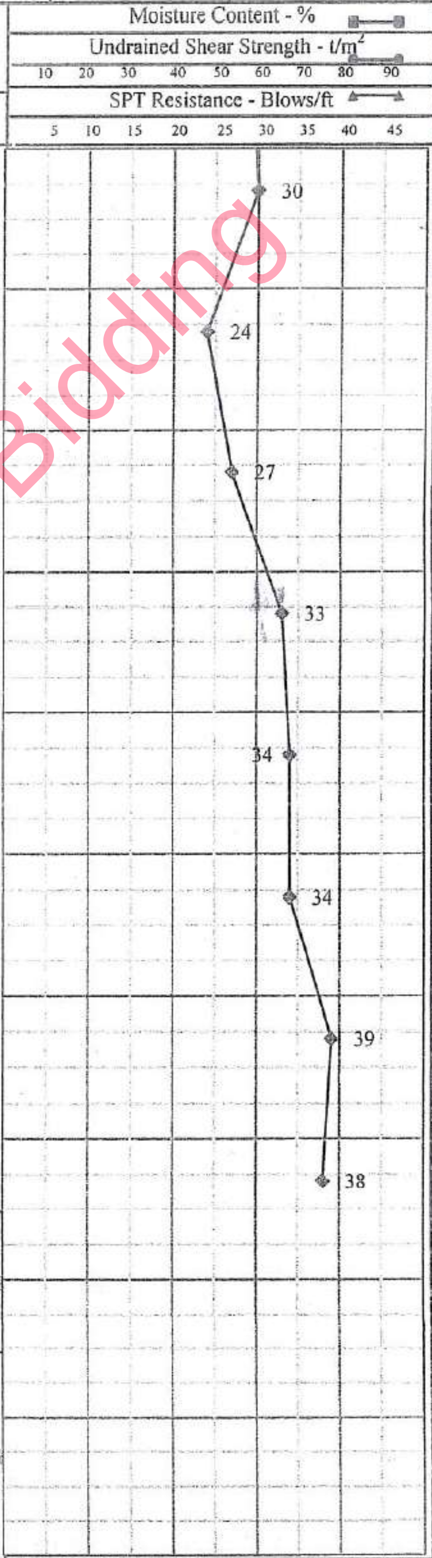
Made Ground | Silt | Gravel | Laterite Nodules | Completely Weathered Rock | Fresh Rock
Clay | Sand | Organic Matter | Silty Sand | Highly Weathered Rock

| | | |
|---|---|---|
| ENGINEERING & LABORATORY SERVICES (PVT) LTD. SITE INVESTIGATIONS DIVISION | | NO 62/3, Neelammahara Road, Katuwawala, Sri Lanka. Tel: 0114 309 494 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Project** | Geotechnical Investigation for the proposed substation A at Kalanithissa | | | | | Borehole No | BH-02 |
| **Client** | Hyosung Corporation | | | | | Sheet | 2 of 3 |
| Location | Kalanithissa | Rig | Track whee | Core Diameter | 54mm | Ground Water Level | = 0.60m |
| Date of Started | 09.09.2016 | Drilling Method | Rotary | Cased Depth | 21.50m | X- Coordinate | - |
| Date of Finished | 11.09.2016 | Casing Diameter | 76mm | Elevation | | Y- Coordinate | - |

| Depth (m) | Sa. Cond | Sa.NO. | Sa.Type | g - g/cc Other Tests | Depth (m) | Legend | Soil Description | 15cm | 15cm | 15cm | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.00 | | | | | | | Continue from Page 1 | | | | |
| | | D11 | SS | | | | Same as previous descripyion | 8 | 14 | 16 | 30 |
| | | | TC | | | | | | | | |
| 11.00 | | D12 | SS | | 11.00 | | Medium dense brownish white weathered rock | 4 | 11 | 13 | 24 |
| | | | TC | | | | | | | | |
| 12.00 | | D13 | SS | | | | | 5 | 11 | 16 | 27 |
| | | | TC | | | | | | | | |
| 13.00 | | D14 | SS | | 13.00 | | Dense whitish brown weathered rock | 7 | 14 | 19 | 33 |
| | | | TC | | | | | | | | |
| 14.00 | | D15 | SS | | | | | 8 | 14 | 20 | 34 |
| | | | TC | | | | | | | | |
| 15.00 | | D16 | SS | | | | | 11 | 16 | 18 | 34 |
| | | | TC | | | | | | | | |
| 16.00 | | D17 | SS | | | | | 12 | 18 | 21 | 39 |
| | | | TC | | | | | | | | |
| 17.00 | | D18 | SS | | | | ROCK LEVEL | 13 | 18 | 20 | 38 |
| 18.00 | | | | | 17.50 | | Foliated grayish black highly weathered highly fractured fine to medium grained BIOTTIE GNEISS | CR=65% | | RQD=48% | |
| 19.00 | | | | | 18.50 | | Foliated grayish black highly weathered highly fractured fine to medium grained BIOTTIE GNEISS | CR=23% | | RQD=00% | |
| 20.00 | | | | | | | | | | | |

Field Records (SPT)




**Sample Key / Test Key**

SPT Where full 0.3m penetration has not been achieved the number of blows for the quoted penetration is given (not N-value)
GWL Ground Water Level observed inside the Borehole, after the saturation
HB -Hammer Bounce
FD - Free Down

D - Disturbed Sample
SS -SPT Sample
W - Water Sample
WS-Wash Sample
UD- Undisturbed Sample
CS- Core Sample
Cr - Core Recovery (%)
RQD-Rock Quality Designation (%)

N - Natural Moisture Content
L - Atterberg Limit Test
G - Grain Size Analysis
SG -Specific Gravity Test
B - Bulk Density
V - Vane Shear Test

C - Consolidation
UCT-Unconfined Compression
CU - Consolidated Undrained
UU-Unconsolidated Undrained
pH - Chemical
O - Organic content
$SO_4^{2-}$ - Sulphate Content
Cl - Cloride Content

**Remarks**
Existing ground level considered as the zero level

**Logged By** Ramesh
**Supervised By** Dhanesh
**Drilled By** Suranga

Made Ground | Silt | Gravel | Laterite Nodules | Completely Weathered Rock
Clay | Sand | Organic Matter | Silty Sand | Highly Weathered Rock | Fresh Rock

NO 62/3, Neelammahara Road,
Katuwawala, Sri Lanka.
Tel: 0114 309 494

# ENGINEERING & LABORATORY SERVICES (PVT) LTD.
## SITE INVESTIGATIONS DIVISION

| | | | |
|---|---|---|---|
| Project | Geotechnical Investigation for the proposed substation A at Kalanithissa | Borehole No | BH-02 |
| Client | Hyosung Corporation | Sheet | 3 of 3 |
| Location | Kalanithissa; Rig: Track wheel; Core Diameter: 54mm | Ground Water Level | 0.60m |
| Date of Started | 09.09.2016; Drilling Method: Rotary; Cased Depth: 21.50m | X- Coordinate | – |
| Date of Finished | 11.09.2016; Casing Diameter: 76mm; Elevation: | Y- Coordinate | – |

Moisture Content - %
Undrained Shear Strength - t/m²: 10 20 30 40 50 60 70 80 90
SPT Resistance - Blows/ft: 5 10 15 20 25 30 35 40 45

Continue from Page 1

| Depth (m) | Sa. Cond | Sa.NO. | Sa.Type | g - g/cc Other Tests | Depth (m) | Legend | Soil Description | Field Records (SPT) 15cm | 15cm | 15cm | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.00 | | | | | 20.00 | | Foliated grayish black highly weathered highly fractured fine to medium grained BIOTTIE GNEISS | CR=92% | RQD=90% | | |
| 21.00 | | | | | | | | | | | |
| | | | | | 21.50 | | The bore hole was terminated at a depth of 21.50m | | | | |
| 22.00 | | | | | | | | | | | |
| 23.00 | | | | | | | | | | | |
| 24.00 | | | | | | | | | | | |
| 25.00 | | | | | | | | | | | |
| 26.00 | | | | | | | | | | | |
| 27.00 | | | | | | | | | | | |
| 28.00 | | | | | | | | | | | |
| 29.00 | | | | | | | | | | | |
| 30.00 | | | | | | | | | | | |

**Sample Key / Test Key**

SPT Where full 0.3m penetration has not been achieved the number of blows for the quoted penetration is given (not N-value)
GWL : Ground Water Level observed inside the Borehole, after the saturation
HB -Hammer Bounce
FD - Free Down

D - Disturbed Sample
SS -SPT Sample
W - Water Sample
WS-Wash Sample
UD- Undisturbed Sample
CS- Core Sample
Cr - Core Recovery (%)
RQD-Rock Quality Designation (%)

N - Natural Moisture Content
L - Atterberg Limit Test
G - Grain Size Analysis
SG -Specific Gravity Test
B - Bulk Density
V - Vane Shear Test

C - Consolidation
UCT-Unconfined Compression
CU - Consolidated Undrained
UU-Unconsolidated Undrained
pH - Chemical
O - Organic content
$SO_4^{2-}$ - Sulphate Content
$Cl^-$ - Cloride Content

**Remarks**
Existing ground level considered as the zero level

**Logged By:** Ramesh
**Supervised By:** Dhanesh
**Drilled By:** Suranga

Made Ground, Clay, Silt, Sand, Gravel, Organic Matter, Laterite Nodules, Silty Sand, Completely Weathered Rock, Highly Weathered Rock, Fresh Rock

Annexure II– Lab test results

| ELS | UNCONFINED COMPRESSIVE STRENGTH TEST ON INTACT ROCK CORE SPECIMENS<br>TEST METHOD -ASTM D 2938 | Test Format No: | ELS-ML-36 |
|---|---|---|---|
| | | Revision No. | 00 |

**Project data:**

| | |
|---|---|
| **Client:** | Hyosong Corporation |
| **Project:** | Soil Investigation for the Proposed Substation at Kelanitissa |

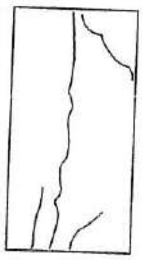
**Sample data:**

| | | | |
|---|---|---|---|
| Sample description: | Rock | Lab Ref. No. | ML/Si/836 |
| Borehole No: | BH 01 | Job No: | ELS/3837 |
| | | Date of Testing: | 11.10.2016 |
| | | Date of Report: | 11.10.2016 |

**Test Data:**

| | | |
|---|---|---|
| BH No. | | BH 01 |
| Sampling Depth(m) | | 28.50-28.90 |
| Specimen Diameter | cm | 5.48 |
| Specimen Length | cm | 11.38 |
| Sectional area of the Specimen | $cm^2$ | 23.59 |
| Volume of Specimen | $cm^3$ | 268.41 |
| Weight of specimen | g | 710.0 |
| Unit Weight | $g/cm^3$ | 2.65 |
| Failure Load | kN | 68.3 |
| Measured Compressive Strength | $N/mm^2$ | 28.96 |
| Correction Factor for height to diameter ratio | | 0.996 |
| Corrected Compressive Strength | $N/mm^2$ | **29.09** |

Mode of Failure



Note: Sample for Unconfined Compressive Strength test was taken at the depth of 28.54m

| Tested by: | Checked by | Certified by: |
|---|---|---|
| S.Y.M.Udantha<br>Lab Technician | R.I.C.De J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |

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| | UNCONFINED COMPRESSIVE STRENGTH TEST ON INTACT ROCK CORE SPECIMENS<br>TEST METHOD -ASTM D 2938 | Test Format No: | ELS-ML-36 |
|---|---|---|---|
| | | Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at Kelanitissa |

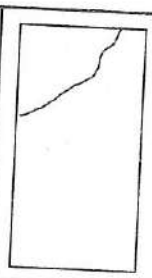
**Sample data:**

| | | | |
|---|---|---|---|
| Sample description: | Rock | | |
| Borehole No: | BH 02 | Lab Ref. No. | ML/SI/836 |
| | | Job No: | ELS/3837 |
| | | Date of Testing: | 11.10.2016 |
| | | Date of Report: | 11.10.2016 |

**Test Data:**

| | | |
|---|---|---|
| BH No. | | BH 02 |
| Sampling Depth(m) | | 20.00-20.20 |
| Specimen Diameter | cm | 5.43 |
| Specimen Length | cm | 11.32 |
| Sectional area of the Specimen | $cm^2$ | 23.13 |
| Volume of Specimen | $cm^3$ | 261.82 |
| Weight of specimen | g | 737.0 |
| Unit Weight | $g/cm^3$ | 2.81 |
| Failure Load | kN | 24.1 |
| Measured Compressive Strength | $N/mm^2$ | 10.42 |
| Correction Factor for height to diameter ratio | | 0.995 |
| Corrected Compressive Strength | $N/mm^2$ | **10.47** |

Mode of Failure



Note:Sample for Unconfined Compressive Strength test was taken at the depth of 20.04m

| Tested by: | Checked by: | Certified by: |
|---|---|---|
| for<br>S.Y.M.Udantha<br>Lab Technician | R.I.C.De J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |

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# PARTICLE SIZE DISTRIBUTION OF SOIL TEST METHOD BS 1377:PART 2

| | |
|---|---|
| Test Format No: | ELS-ML-02 |
| Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Clayey Sandy Gravel | Job ref. No. | ELS/3837 |
| Borehole No: | BH-01 | Lab ref. No: | ML/SI/836 |
| Depth (m): | 3.00-3.45 | Date of testing: | 20.10.2016 |
| | | Date of Report: | 24.10.2016 |

**Test Data:**

| Sieve Size mm | Weight Retained g | Retained % | Cum. % Retained | % Passing (P) |
|---|---|---|---|---|
| 28.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 20.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 10.00 | 14.05 | 14.05 | 14.05 | 85.95 |
| 5.00 | 18.45 | 18.45 | 32.50 | 67.50 |
| 2.000 | 16.42 | 16.42 | 48.92 | 51.08 |
| 1.180 | 5.27 | 5.27 | 54.19 | 45.81 |
| 0.600 | 4.79 | 4.79 | 58.98 | 41.02 |
| 0.425 | 1.00 | 1.00 | 59.98 | 40.02 |
| 0.300 | 1.45 | 1.45 | 61.43 | 38.57 |
| 0.150 | 1.12 | 1.12 | 62.55 | 37.45 |
| 0.063 | 0.59 | 0.59 | 63.14 | 36.86 |
| Pan | 0.12 | | | |
| Total | 63.26 | | | |

Initial weight of sample (g) = 100.00

| | |
|---|---|
| Hydrometer No | 4816 |
| Dry Weight of sample (W) g | 100.00 |
| Particle Density of soil ($Mg/m^3$) | 2.73 |
| Viscosity of water at $29^0C$ | 0.816 |

| | |
|---|---|
| Dispersing Agent correction $R'_0$ | 2 |
| Meniscus correction $C_m$ | 1 |
| Calibration Equation | Hr = 202.5-4.021Rh |

| Time (24h) | Elapse Time min | Hydrometer Reading $R'_H$ | $R_h = R'_H + C_m$ | Effective Depth, $H_r$ mm | Diameter of Particle mm | $R_d = R'_h - R'_0$ | Percentage finer than D k (%) |
|---|---|---|---|---|---|---|---|
| 11.35 am | 0.5 | 23 | 24.0 | 106.00 | 0.05535 | 21.0 | 33.16 |
| 11.36 | 1 | 23 | 24.0 | 106.00 | 0.03914 | 21.0 | 33.16 |
| 11.37 | 2 | 22 | 23.0 | 110.02 | 0.02819 | 20.0 | 31.58 |
| 11.39 | 4 | 21 | 22.0 | 114.04 | 0.02030 | 19.0 | 30.00 |
| 11.43 | 8 | 21 | 22.0 | 114.04 | 0.01435 | 19.0 | 30.00 |
| 12.05 | 30 | 20 | 21.0 | 118.06 | 0.00754 | 18.0 | 28.42 |
| 13.35 | 120 | 18 | 19.0 | 126.10 | 0.00390 | 16.0 | 25.26 |
| 19.35 | 480 | 16 | 17.0 | 134.14 | 0.00201 | 14.0 | 22.10 |
| 11.35 am | 1440 | 14 | 15.0 | 142.19 | 0.00119 | 12.0 | 18.95 |

Note : * Sample description is by Unified Soil Classification System

| Tested by | Checked by | Certified by |
|---|---|---|
| S.Y.M.Udantha<br>Lab Technician | R.I.C. De J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |

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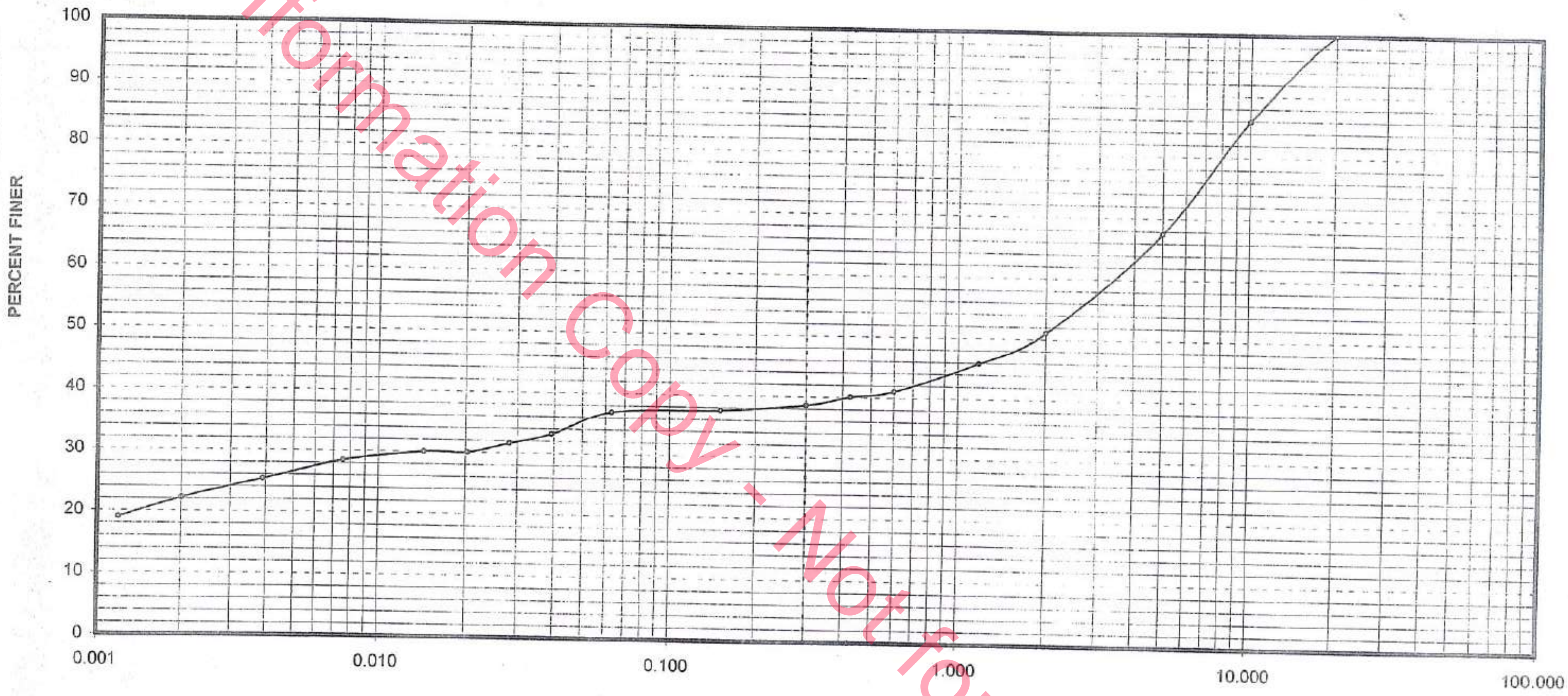
## PARTICLE SIZE DISTRIBUTION




| Client : | Hyosong Corporation | Job ref : | ELS/3837 | Depth (m) | 3.00-3.45 |
|---|---|---|---|---|---|
| Project : | Soil Investigation for the Proposed Substation at kelanitissa | Location | BH-01 | | |

Tested by:..........................
S.Y.M.Udantha
Lab Technician

Checked by:..........................
R.I.C. De J.Seneviratne
Geotechnical Engineer

Certified by:..........................
J.W.S.T.W.Jayasingha
Laboratory Engineer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# PARTICLE SIZE DISTRIBUTION OF SOIL TEST METHOD BS 1377:PART 2

| | |
|---|---|
| Test Format No: | ELS-ML-02 |
| Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Inorganic Silts of high Plasticity | Job ref. No. | ELS/3837 |
| Borehole No: | BH-01 | Lab ref. No: | ML/SI/836 |
| Depth (m): | 12.00-12.45 | Date of testing: | 20.10.2016 |
| | | Date of Report: | 24.10.2016 |

**Test Data:**

| Sieve Size mm | Weight Retained g | Retained % | Cum. % Retained | % Passing (P) |
|---|---|---|---|---|
| 28.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 20.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 10.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| 5.00 | 0.75 | 1.84 | 1.84 | 98.16 |
| 2.000 | 4.02 | 9.85 | 11.68 | 88.32 |
| 1.180 | 3.19 | 7.81 | 19.50 | 80.50 |
| 0.600 | 2.58 | 6.32 | 25.81 | 74.19 |
| 0.425 | 0.49 | 1.20 | 27.01 | 72.99 |
| 0.300 | 0.91 | 2.23 | 29.24 | 70.76 |
| 0.150 | 1.09 | 2.67 | 31.91 | 68.09 |
| 0.063 | 0.55 | 1.35 | 33.26 | 66.74 |
| Pan | 0.00 | | | |
| Total | 13.58 | | | |

Initial weight of sample (g) = 40.83

| | |
|---|---|
| Hydrometer No | 4816 |
| Dry Weight of sample (W) g | 40.83 |
| Particle Density of soil (Mg/m$^3$) | 2.63 |
| Viscosity of water at 29$^0$C | 0.816 |

| | |
|---|---|
| Dispersing Agent correction $R'_0$ | 2 |
| Meniscus correction $C_m$ | 1 |
| Calibration Equation | Hr = 202.5-4.021Rh |

| Time (24h) | Elapse Time min | Hydrometer Reading $R'_H$ | $R_h = R'_H + C_m$ | Effective Depth, $H_r$ mm | Diameter of Particle mm | $R_d = R'_h - R'_0$ | Percentage finer than D k (%) |
|---|---|---|---|---|---|---|---|
| 11.55 am | 0.5 | 18 | 19.0 | 126.10 | 0.06220 | 16.0 | 63.26 |
| 11.56 | 1 | 18 | 19.0 | 126.10 | 0.04398 | 16.0 | 63.26 |
| 11.57 | 2 | 17 | 18.0 | 130.12 | 0.03159 | 15.0 | 59.31 |
| 11.59 | 4 | 16 | 17.0 | 134.14 | 0.02268 | 14.0 | 55.36 |
| 12.03 | 8 | 15 | 16.0 | 138.16 | 0.01628 | 13.0 | 51.40 |
| 12.25 | 30 | 14 | 15.0 | 142.19 | 0.00853 | 12.0 | 47.45 |
| 13.55 | 120 | 13 | 14.0 | 146.21 | 0.00432 | 11.0 | 43.49 |
| 19.55 | 480 | 12 | 13.0 | 150.23 | 0.00219 | 10.0 | 39.54 |
| 11.55 am | 1440 | 10 | 11.0 | 158.27 | 0.00130 | 8.0 | 31.63 |

Note : * Sample description is by Unified Soil Classification System

| Tested by | Checked by | Certified by |
|---|---|---|
| for S.Y.M.Udantha<br>Lab Technician | R.I.C. De J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |

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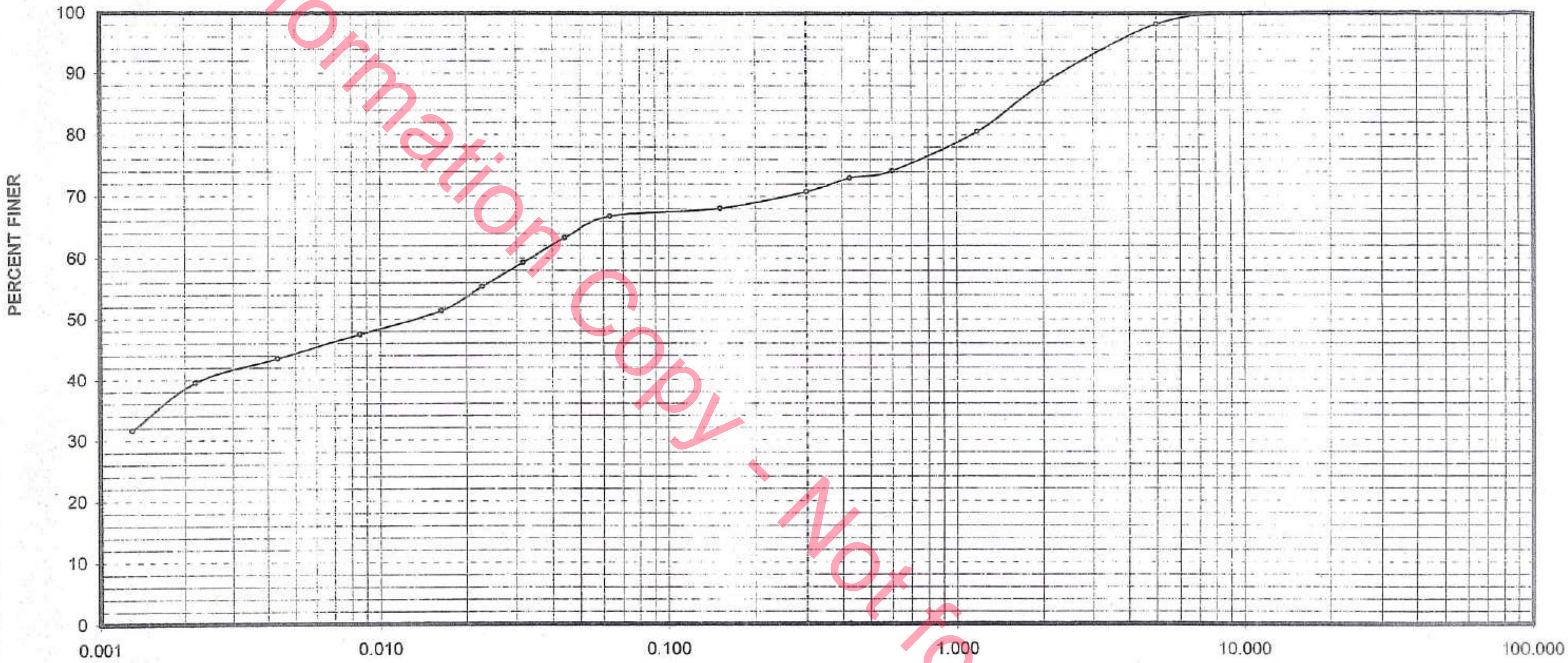
## PARTICLE SIZE DISTRIBUTION




| | | | | | |
|---|---|---|---|---|---|
| Client : | Hyosong Corporation | Job ref : | ELS/3837 | Depth (m) | 12.00-12.45 |
| Project : | Soil Investigation for the Proposed Substation at kelanitissa | Location | BH-01 | | |

Tested by: ............................ for
S.Y.M.Udantha
Lab Technician

Checked by: ............................
R.I.C. De J.Seneviratne
Geotechnical Engineer

Certified by: ............................
J.W.S.T.W.Jayasingha
Laboratory Engineer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# PARTICLE SIZE DISTRIBUTION OF SOIL TEST METHOD BS 1377:PART 2

| | |
|---|---|
| Test Format No: | ELS-ML-02 |
| Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Clayey Sands with Gravel | Job ref. No. | ELS/3837 |
| Borehole No: | BH-02 | Lab ref. No: | ML/SI/836 |
| Depth (m): | 3.00-3.45 | Date of testing: | 20.10.2016 |
| | | Date of Report: | 24.10.2016 |

**Test Data:**

| Sieve Size mm | Weight Retained g | Retained % | Cum. % Retained | % Passing (P) |
|---|---|---|---|---|
| 28.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 20.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 10.00 | 8.03 | 8.03 | 8.03 | 91.97 |
| 5.00 | 26.96 | 26.96 | 34.99 | 65.01 |
| 2.000 | 25.19 | 25.19 | 60.18 | 39.82 |
| 1.180 | 5.96 | 5.96 | 66.14 | 33.86 |
| 0.600 | 2.62 | 2.62 | 68.76 | 31.24 |
| 0.425 | 1.09 | 1.09 | 69.85 | 30.15 |
| 0.300 | 3.09 | 3.09 | 72.94 | 27.06 |
| 0.150 | 3.81 | 3.81 | 76.75 | 23.25 |
| 0.063 | 1.89 | 1.89 | 78.64 | 21.36 |
| Pan | 0.00 | | | |
| Total | 78.64 | | | |

Initial weight of sample (g) = 100.00

| | |
|---|---|
| Hydrometer No | 4816 |
| Dry Weight of sample (W) g | 100.00 |
| Particle Density of soil ($Mg/m^3$) | 2.71 |
| Viscosity of water at 29$^0$C | 0.816 |

| | |
|---|---|
| Dispersing Agent correction $R'_0$ | 2 |
| Meniscus correction $C_m$ | 1 |
| Calibration Equation | Hr = 202.5-4.021Rh |

| Time (24h) | Elapse Time min | Hydrometer Reading $R'_H$ | $R_h = R'_H + C_m$ | Effective Depth, $H_r$ mm | Diameter of Particle mm | $R_d = R'_h - R'_0$ | Percentage finer than D k (%) |
|---|---|---|---|---|---|---|---|
| 11.26 am | 0.5 | 14 | 15.0 | 142.19 | 0.06439 | 12.0 | 19.01 |
| 11.27 | 1 | 14 | 15.0 | 142.19 | 0.04553 | 12.0 | 19.01 |
| 11.28 | 2 | 13 | 14.0 | 146.21 | 0.03265 | 11.0 | 17.42 |
| 11.30 | 4 | 12 | 13.0 | 150.23 | 0.02340 | 10.0 | 15.84 |
| 11.34 | 8 | 12 | 13.0 | 150.23 | 0.01655 | 10.0 | 15.84 |
| 11.56 | 30 | 11 | 12.0 | 154.25 | 0.00866 | 9.0 | 14.26 |
| 13.26 | 120 | 10 | 11.0 | 158.27 | 0.00439 | 8.0 | 12.67 |
| 19.26 | 480 | 9 | 10.0 | 162.29 | 0.00222 | 7.0 | 11.09 |
| 11.26 am | 1440 | 7 | 8.0 | 170.33 | 0.00131 | 5.0 | 7.92 |

Note : * Sample description is by Unified Soil Classification System

| Tested by | Checked by | Certified by |
|---|---|---|
| for S.Y.M.Udantha<br>Lab Technician | R.I.C. De J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |

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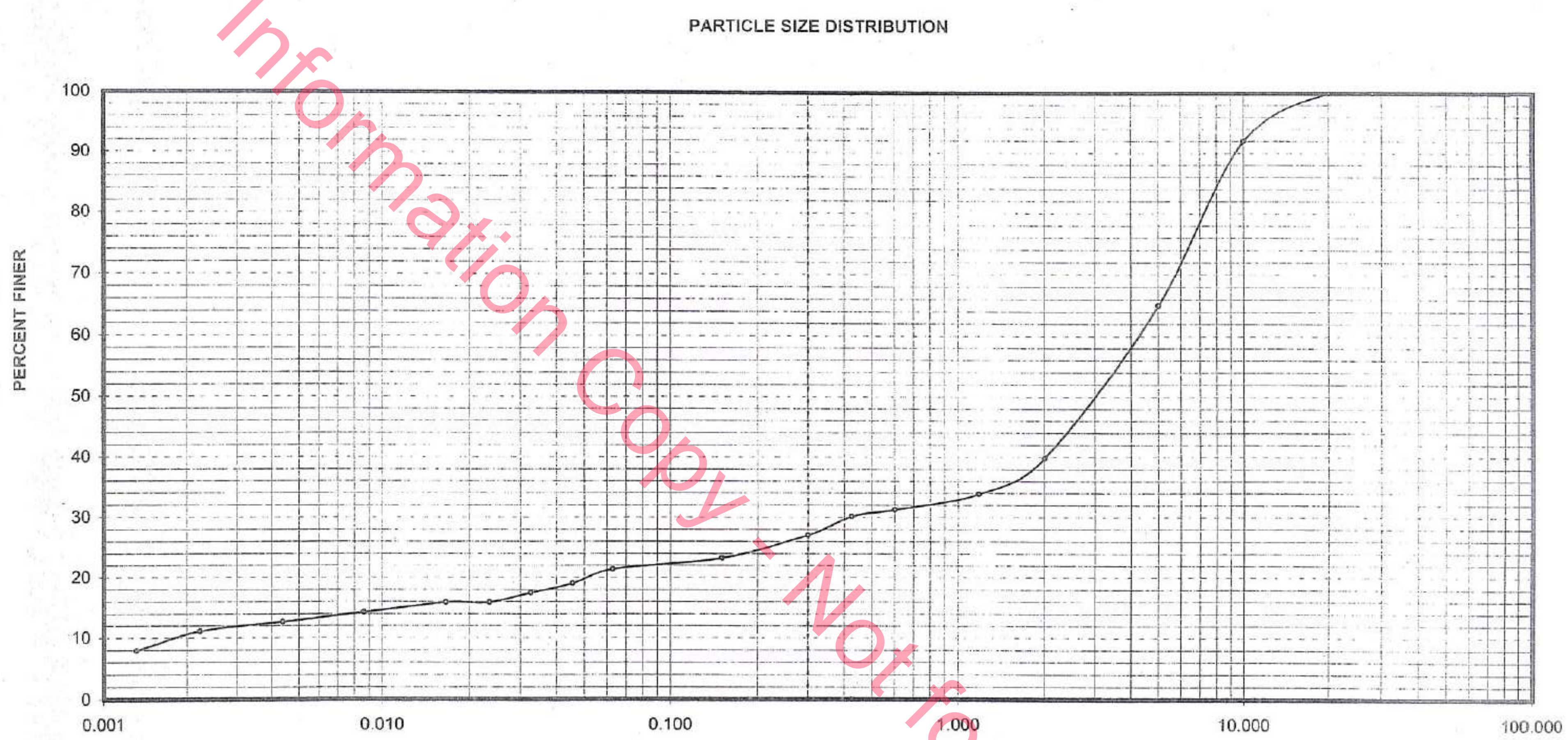


| Client : | Hyosong Corporation | Job ref : | ELS/3837 | Depth (m) | 3.00-3.45 |
|---|---|---|---|---|---|
| Project : | Soil Investigation for the Proposed Substation at kelanitissa | Location | BH-02 | | |

Tested by:.................................
S.Y.M.Udantha
Lab Technician

Checked by:.................................
R.I.C. De J.Seneviratne
Geotechnical Engineer

Certified by:.................................
J.W.S.T.W.Jayasingha
Laboratory Engineer

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# PARTICLE SIZE DISTRIBUTION OF SOIL TEST METHOD BS 1377:PART 2

| | |
|---|---|
| Test Format No: | ELS-ML-02 |
| Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Clayey Sands | Job ref. No. | ELS/3837 |
| Borehole No: | BH-02 | Lab ref. No: | ML/SI/836 |
| Depth (m): | 9.00-9.45 | Date of testing: | 20.10.2016 |
| | | Date of Report: | 24.10.2016 |

**Test Data:**

| Sieve Size mm | Weight Retained g | Retained % | Cum. % Retained | % Passing (P) |
|---|---|---|---|---|
| 28.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 20.0 | 0.00 | 0.00 | 0.00 | 100.00 |
| 10.00 | 0.00 | 0.00 | 0.00 | 100.00 |
| 5.00 | 0.83 | 1.66 | 1.66 | 98.34 |
| 2.000 | 11.00 | 22.00 | 23.66 | 76.34 |
| 1.180 | 4.39 | 8.78 | 32.44 | 67.56 |
| 0.600 | 6.70 | 13.40 | 45.84 | 54.16 |
| 0.425 | 0.98 | 1.96 | 47.80 | 52.20 |
| 0.300 | 2.95 | 5.90 | 53.70 | 46.30 |
| 0.150 | 2.60 | 5.20 | 58.90 | 41.10 |
| 0.063 | 1.68 | 3.36 | 62.26 | 37.74 |
| Pan | 0.00 | | | |
| Total | 31.13 | | | |

Initial weight of sample (g) = 50.00

| | |
|---|---|
| Hydrometer No | 4816 |
| Dry Weight of sample (W) g | 50.00 |
| Particle Density of soil (Mg/m$^3$) | 2.66 |
| Viscosity of water at 29$^0$C | 0.816 |

| | |
|---|---|
| Dispersing Agent correction $R'_0$ | 2 |
| Meniscus correction $C_m$ | 1 |
| Calibration Equation | Hr = 202.5-4.021Rh |

| Time (24h) | Elapse Time min | Hydrometer Reading $R'_H$ | $R_h$ = $R'_H + C_m$ | Effective Depth, $H_r$ mm | Diameter of Particle mm | $R_d = R'_h - R'_0$ | Percentage finer than D k (%) |
|---|---|---|---|---|---|---|---|
| 12.07 am | 0.5 | 13 | 14.0 | 146.21 | 0.06623 | 11.0 | 35.22 |
| 12.08 | 1 | 13 | 14.0 | 146.21 | 0.04683 | 11.0 | 35.22 |
| 12.09 | 2 | 12 | 13.0 | 150.23 | 0.03357 | 10.0 | 32.02 |
| 12.11 | 4 | 12 | 13.0 | 150.23 | 0.02373 | 10.0 | 32.02 |
| 12.15 | 8 | 11 | 12.0 | 154.25 | 0.01701 | 9.0 | 28.82 |
| 12.37 | 30 | 10 | 11.0 | 158.27 | 0.00890 | 8.0 | 25.61 |
| 14.07 | 120 | 9 | 10.0 | 162.29 | 0.00450 | 7.0 | 22.41 |
| 20.07 | 480 | 8 | 9.0 | 166.31 | 0.00228 | 6.0 | 19.21 |
| 12.07 am | 1440 | 7 | 8.0 | 170.33 | 0.00133 | 5.0 | 16.01 |

Note : * Sample description is by Unified Soil Classification System

| Tested by | Checked by | Certified by |
|---|---|---|
| S.Y.M.Udantha<br>Lab Technician | R.I.C. De J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |

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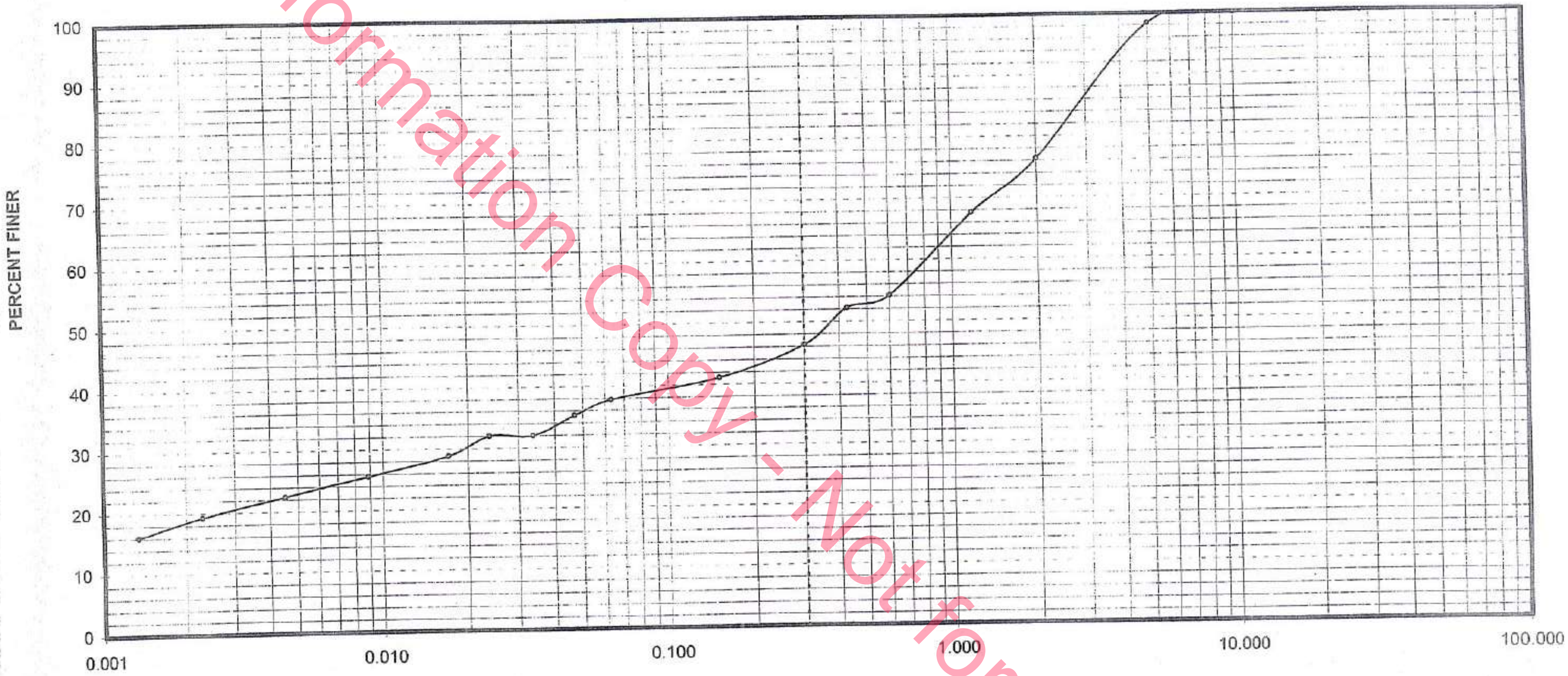
## PARTICLE SIZE DISTRIBUTION




| Client : | Hyosong Corporation | Job ref : | ELS/3837 | Depth (m) | 9.00-9.45 |
|---|---|---|---|---|---|
| Project : | Soil Investigation for the Proposed Substation at kelanitissa | Location | BH-02 | | |

Tested by:............ S.Y.M.Udantha, Lab Technician

Checked by:............ R.I.C. De J.Seneviratne, Geotechnical Engineer

Certified by:............ J.W.S.T.W.Jayasingha, Laboratory Engineer

**ENGINEERING & LABORATORY SERVICES ( PVT ) LTD**
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Telephone : 0094 011 4309494/ 2517037 / 2517365, Fax : 0094 01 2509806, E-Mail : els@elslanka.com.

| | | | |
|---|---|---|---|
| ELS | **LIQUID LIMIT AND PLASTIC LIMIT OF SOIL** <br> **TEST METHOD BS 1377:PART 2** | **Test Format No:** | **ELS-ML-04** |
| | | **Revision No.** | **00** |

**Project data:**

| | |
|---|---|
| **Client:** | Hyosong Corporation |
| **Project:** | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Clayey Sandy Gravel | Lab ref. No. | ML/SI/836 |
| Borehole No: | BH-01 | Job No: | ELS/3837 |
| Depth (m): | 3.00-3.45 | Date of Testing | 13.10.2016 |
| | | Date of Report: | 14.10.2016 |

**Test Data:**

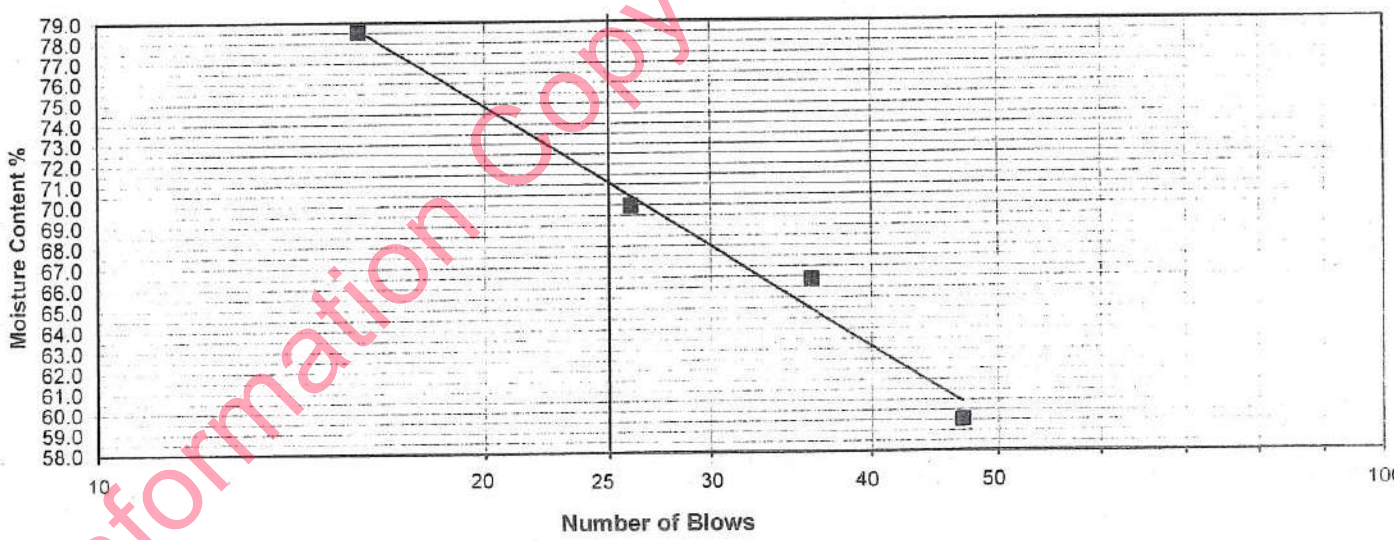
Sample Description:

| Test No. | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Number of Blows | | 16 | 26 | 36 | 47 |
| Can No. | | FG | DP | AI | M2 |
| Weight of Can + Wet Soil | g | 35.01 | 32.03 | 30.88 | 29.13 |
| Weight of Can + Dry Soil | g | 24.81 | 24.79 | 24.45 | 24.29 |
| Weight of Can | g | 11.82 | 14.44 | 14.76 | 16.16 |
| Weight of Water | g | 10.20 | 7.24 | 6.43 | 4.84 |
| Weight of Dry Soil | g | 12.99 | 10.35 | 9.69 | 8.13 |
| Moisture Content | % | 78.52 | 69.95 | 66.36 | 59.53 |

**Plastic Limit**

| 1 | 2 | Average |
|---|---|---|
| | | |
| B | BK | |
| 20.02 | 19.77 | |
| 18.92 | 18.72 | |
| 15.31 | 15.22 | |
| 1.10 | 1.05 | |
| 3.61 | 3.50 | |
| 30.47 | 30.00 | 30.24 |

**Liquid Limit Graph**




**Liquid Limit** 71 **Plastic Limit** 30 **Plasticity Index** 41

Note: * Sample description is by Unified Soil Classification System

| Tested by: | Checked By: | Certified By: |
|---|---|---|
| for S.Y.M.Udantha <br> Lab Technician | R.I.C. de J.Seneviratne <br> Geotechnical Engineer | J.W.S.T.W.Jayasingha <br> Laboratory Engineer |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# LIQUID LIMIT AND PLASTIC LIMIT OF SOIL

## TEST METHOD BS 1377:PART 2

| | |
|---|---|
| Test Format No: | ELS-ML-04 |
| Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Inorganic Silts of high Plasticity | Lab ref. No. | ML/SI/836 |
| Borehole No: | BH-01 | Job No: | ELS/3837 |
| Depth (m): | 12.00-12.45 | Date of Testing | 13.10.2016 |
| | | Date of Report: | 14.10.2016 |

**Test Data:**

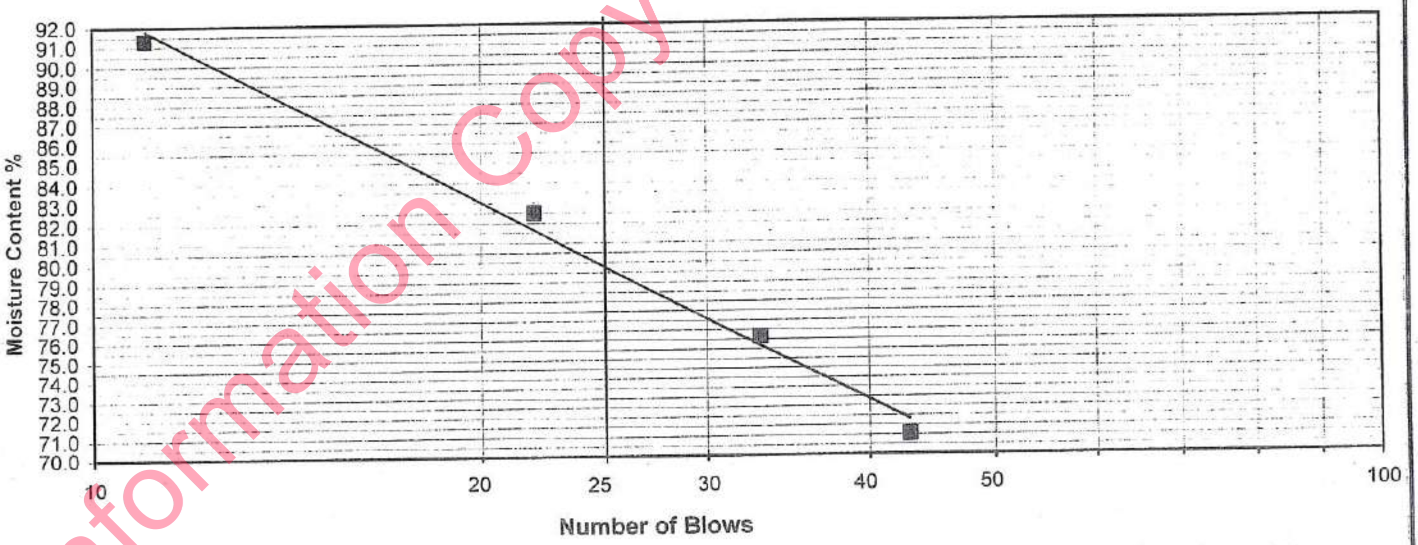
Sample Description:

| Test.No. | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Number of Blows | | 11 | 22 | 33 | 43 |
| Can No. | | JK | MU | L1 | H1 |
| Weight of Can + Wet Soil | g | 39.66 | 38.31 | 36.16 | 33.99 |
| Weight of Can + Dry Soil | g | 27.49 | 28.19 | 27.8 | 27.08 |
| Weight of Can | g | 14.16 | 15.92 | 16.82 | 17.35 |
| Weight of Water | g | 12.17 | 10.12 | 8.36 | 6.91 |
| Weight of Dry Soil | g | 13.33 | 12.27 | 10.98 | 9.73 |
| Moisture Content | % | 91.30 | 82.48 | 76.14 | 71.02 |

**Plastic Limit**

| 1 | 2 | Average |
|---|---|---|
| | | |
| BUB | UP | |
| 19.27 | 19.16 | |
| 18.05 | 17.94 | |
| 14.98 | 14.87 | |
| 1.22 | 1.22 | |
| 3.07 | 3.07 | |
| 39.74 | 39.74 | 39.74 |

**Liquid Limit Graph**




| Liquid Limit | 80 | Plastic Limit | 40 | Plasticity Index | 40 |
|---|---|---|---|---|---|

Note: * Sample description is by Unified Soil Classification System

| Tested by: | Checked By: | Certified By: |
|---|---|---|
| for S.Y.M.Udantha<br>Lab Technician | R.I.C. de J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |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# LIQUID LIMIT AND PLASTIC LIMIT OF SOIL

## TEST METHOD BS 1377:PART 2

| | |
|---|---|
| Test Format No: | ELS-ML-04 |
| Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Clayey Sands with Gravel | Lab ref. No. | ML/SI/836 |
| Borehole No: | BH-02 | Job No: | ELS/3837 |
| Depth (m): | 3.00-3.45 | Date of Testing | 12.10.2016 |
| | | Date of Report: | 14.10.2016 |

**Test Data:**

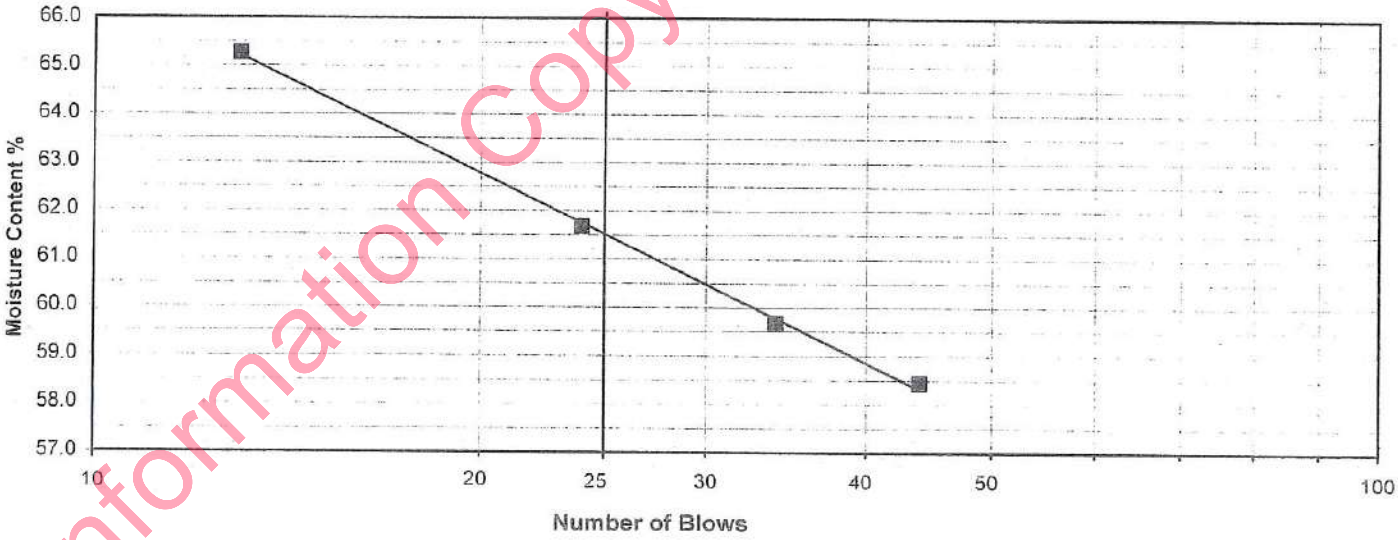
Sample Description:

| Test No. | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Number of Blows | | 13 | 24 | 34 | 44 |
| Can No. | | 33 | KL | Fa | P |
| Weight of Can + Wet Soil | g | 38.32 | 35.23 | 34.62 | 33.53 |
| Weight of Can + Dry Soil | g | 28.21 | 27.33 | 27.4 | 27.16 |
| Weight of Can | g | 12.72 | 14.52 | 15.30 | 16.26 |
| Weight of Water | g | 10.11 | 7.90 | 7.22 | 6.37 |
| Weight of Dry Soil | g | 15.49 | 12.81 | 12.10 | 10.90 |
| Moisture Content | % | 65.27 | 61.67 | 59.67 | 58.44 |

**Plastic Limit**

| 1 | 2 | Average |
|---|---|---|
| | | |
| Q | S | |
| 23.27 | 24.08 | |
| 22.38 | 23.09 | |
| 18.20 | 18.91 | |
| 0.89 | 0.99 | |
| 4.18 | 4.18 | |
| 21.29 | 23.68 | 22.49 |

**Liquid Limit Graph**




**Liquid Limit** 62 **Plastic Limit** 22 **Plasticity Index** 40

Note: * Sample description is by Unified Soil Classification System

| Tested by: | Checked By: | Certified By: |
|---|---|---|
| S.Y.M.Udantha | R.I.C. de J.Seneviratne | J.W.S.T.W.Jayasingha |
| Lab Technician | Geotechnical Engineer | Laboratory Engineer |

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| | LIQUID LIMIT AND PLASTIC LIMIT OF SOIL<br>TEST METHOD BS 1377:PART 2 | Test Format No: | ELS-ML-04 |
|---|---|---|---|
| | | Revision No. | 00 |

**Project data:**

| | |
|---|---|
| Client: | Hyosong Corporation |
| Project: | Soil Investigation for the Proposed Substation at kelanitissa |

**Sample data:**

| | | | |
|---|---|---|---|
| Sample Description: | Clayey Sands | Lab ref. No. | ML/SI/836 |
| Borehole No: | BH-02 | Job No: | ELS/3837 |
| Depth (m): | 9.00-9.45 | Date of Testing | 13.10.2016 |
| | | Date of Report: | 14.10.2016 |

**Test Data:**

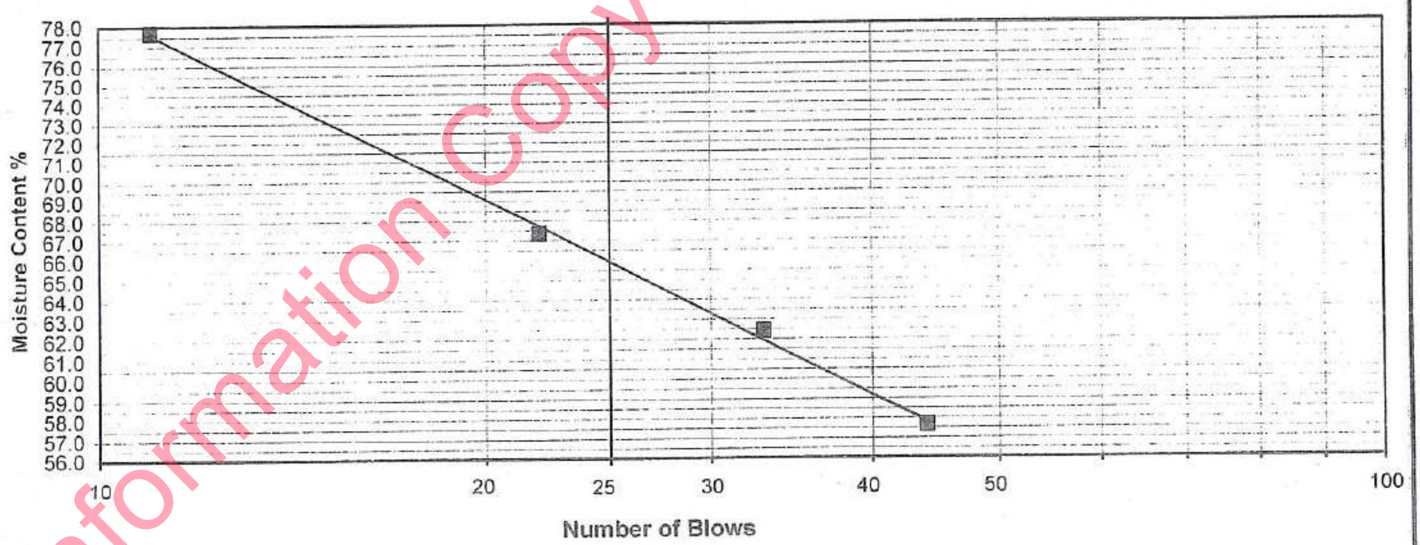
Sample Description:

| Test No. | | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Number of Blows | | 11 | 22 | 33 | 44 |
| Can No. | | 11 | HI | T | B |
| Weight of Can + Wet Soil | g | 33.16 | 30.71 | 29.50 | 28.07 |
| Weight of Can + Dry Soil | g | 25.15 | 24.42 | 24.62 | 24.19 |
| Weight of Can | g | 14.84 | 15.08 | 16.80 | 17.46 |
| Weight of Water | g | 8.01 | 6.29 | 4.88 | 3.88 |
| Weight of Dry Soil | g | 10.31 | 9.34 | 7.82 | 6.73 |
| Moisture Content | % | 77.69 | 67.34 | 62.40 | 57.65 |

**Plastic Limit**

| 1 | 2 | Average |
|---|---|---|
| | | |
| E | ML | |
| 19.90 | 19.76 | |
| 18.89 | 18.76 | |
| 15.55 | 15.47 | |
| 1.01 | 1.00 | |
| 3.34 | 3.29 | |
| 30.24 | 30.40 | 30.32 |

**Liquid Limit Graph**




| Liquid Limit | 66 | Plastic Limit | 30 | Plasticity Index | 36 |
|---|---|---|---|---|---|

Note: * Sample description is by Unified Soil Classification System

| Tested by: | Checked By: | Certified By: |
|---|---|---|
| S.Y.M.Udantha<br>Lab Technician | R.I.C. de J.Seneviratne<br>Geotechnical Engineer | J.W.S.T.W.Jayasingha<br>Laboratory Engineer |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## SUMMARY OF LABORATORY TESTS ON BOREHOLE SAMPLES

| | | | |
|---|---|---|---|
| **Client:** | Hyosong Corporation | **Job ref:** | ELS/3837 |
| **Project:** | Soil Investigation for the Proposed Substation at Kelanitissa | **Lab ref:** | ML/SI/836 |
| | | **Date:** | 21.11.2016 |

| BH No. | Depth (m) | Sample Type | Sample Description (by Visual Observation) | Sample Description (According to Unified Soil Classification System) | Unified Soil Class | UCT N/mm$^2$ | Sieve Analysis | | | Atterberg Limits | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fines < 0.063mm % | Sand (4.75-0.063)mm % | Gravel >4.75mm % | LL % | PL % | PI % |
| BH-01 | 3.00-3.45 | SPT | - | Clayey Sandy Gravel | GC | - | 36.86 | 29.14 | 34.0 | 71 | 30 | 41 |
| | 12.0-12.45 | SPT | - | Inorganic Silts of high Plasticity | MH | - | 66.74 | 30.26 | 3.0 | 80 | 40 | 40 |
| | 28.50-28.90 | Rock | - | - | - | 29.9 | - | - | - | - | - | - |
| BH-02 | 3.00-3.45 | SPT | - | Clayey Sands with Gravel | SC | - | 21.36 | 39.64 | 39.0 | 62 | 22 | 40 |
| | 9.00-9.45 | SPT | - | Clayey Sands | SC | - | 37.74 | 59.26 | 3.0 | 66 | 30 | 36 |
| | 20.00-20.20 | Rock | - | - | - | 10.47 | - | - | - | - | - | - |

Note: * N/P- Non Plastic Material
** Not Sufficient Sample

Prepared by:
..............................
R.I.C.De J.Seneviratne
Geotechnical Engineer

Checked & Certifed by:
..............................
J.W.S.T.W.Jayasingha
Laboratory Engineer

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Annexure III – Photos of core boxes

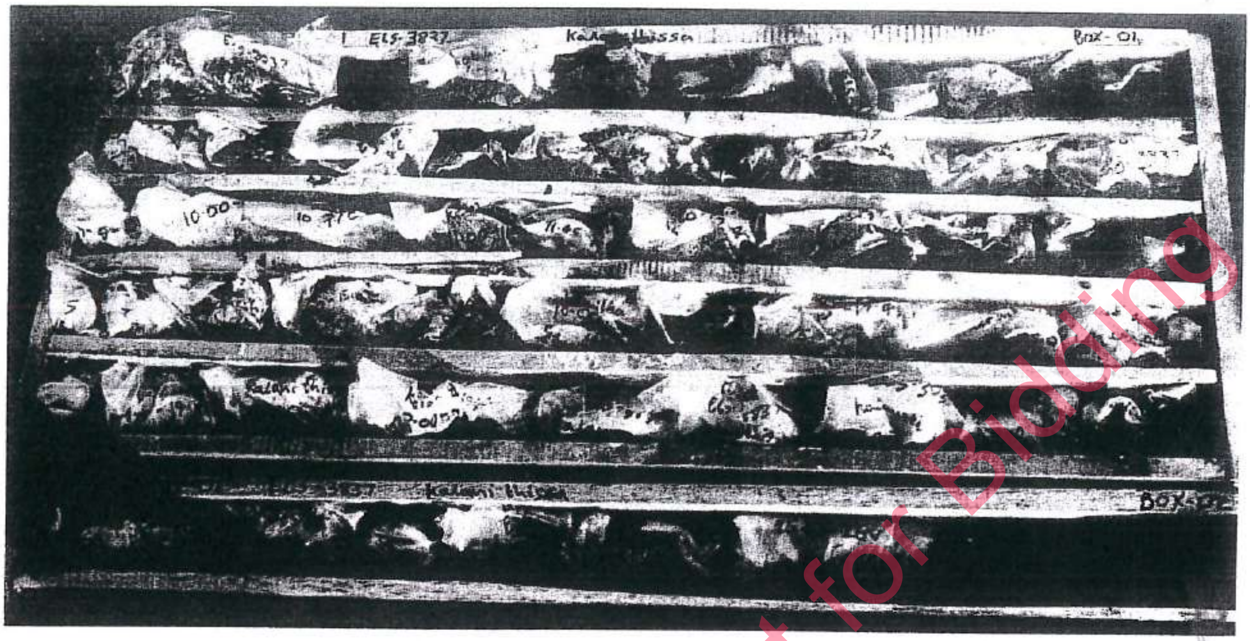


Figure 3a: BH 01 (a)

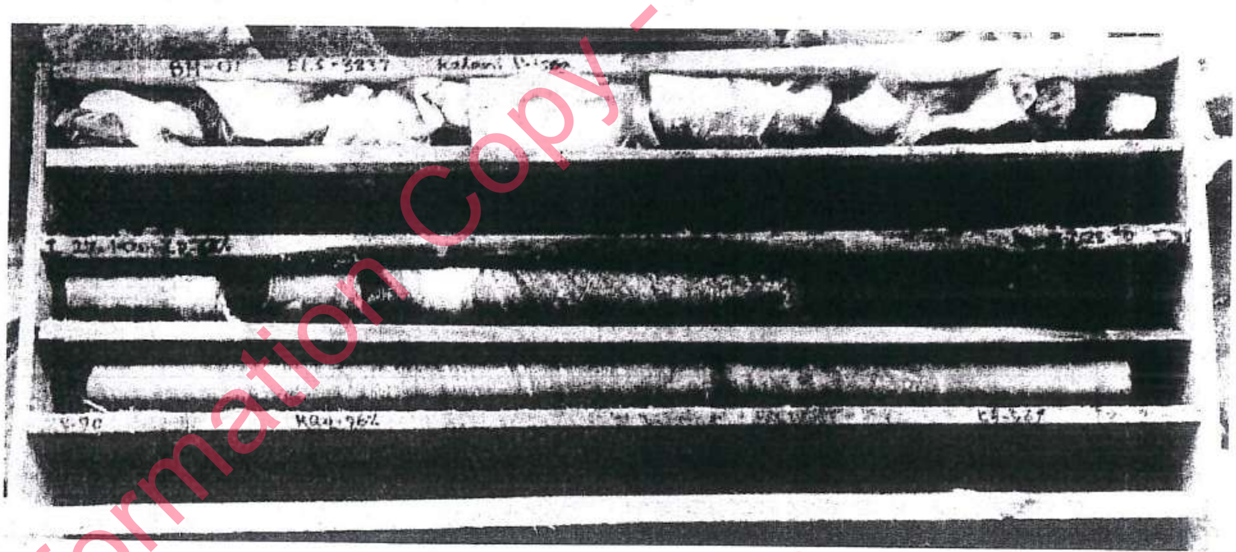


Figure 3b: BH 01 (b)

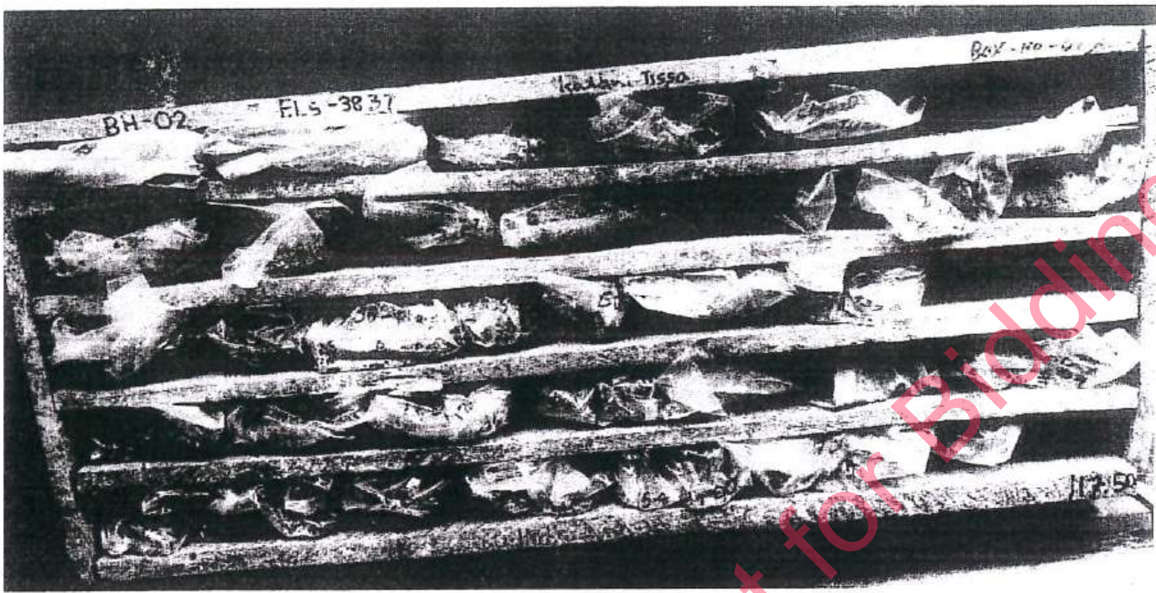
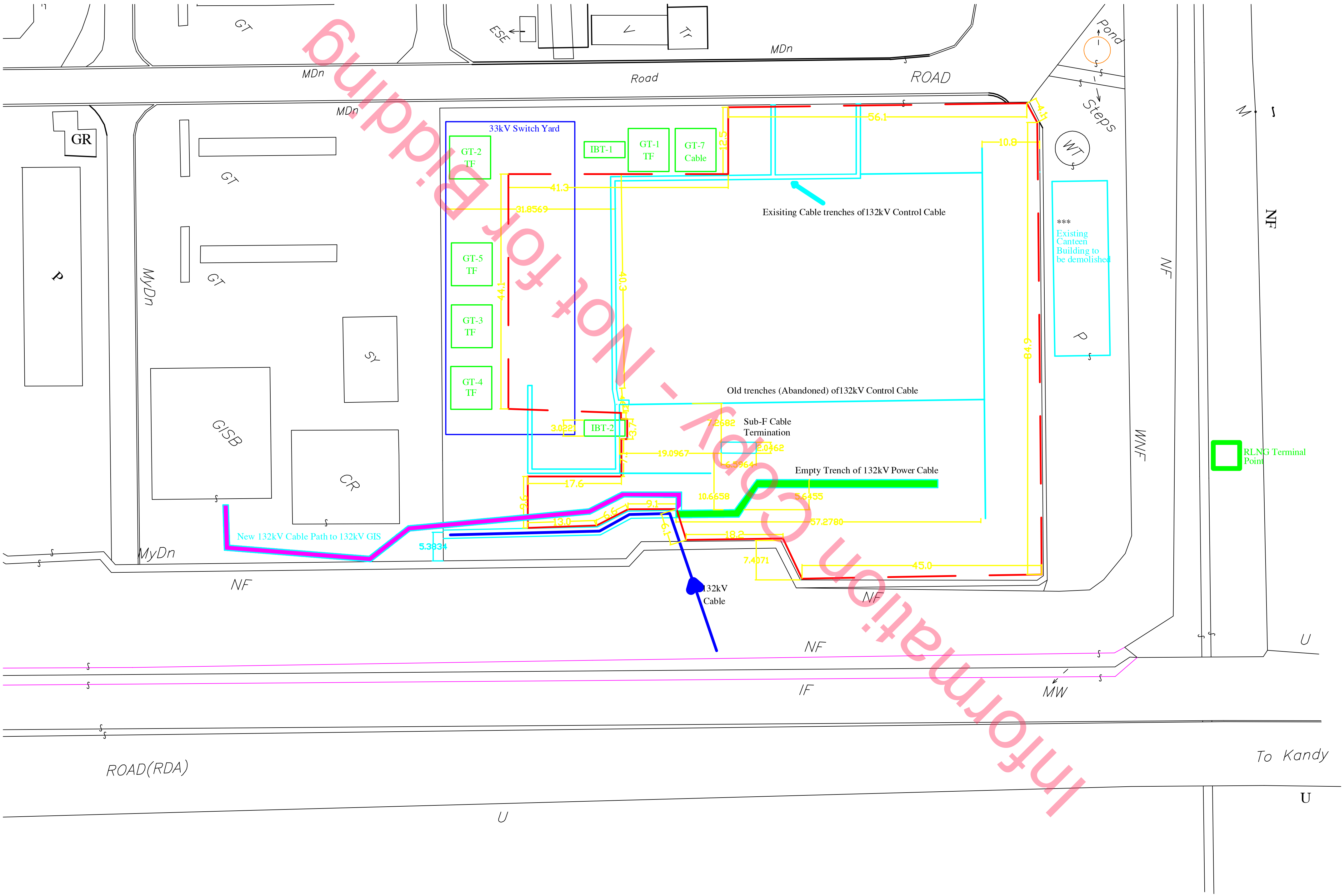
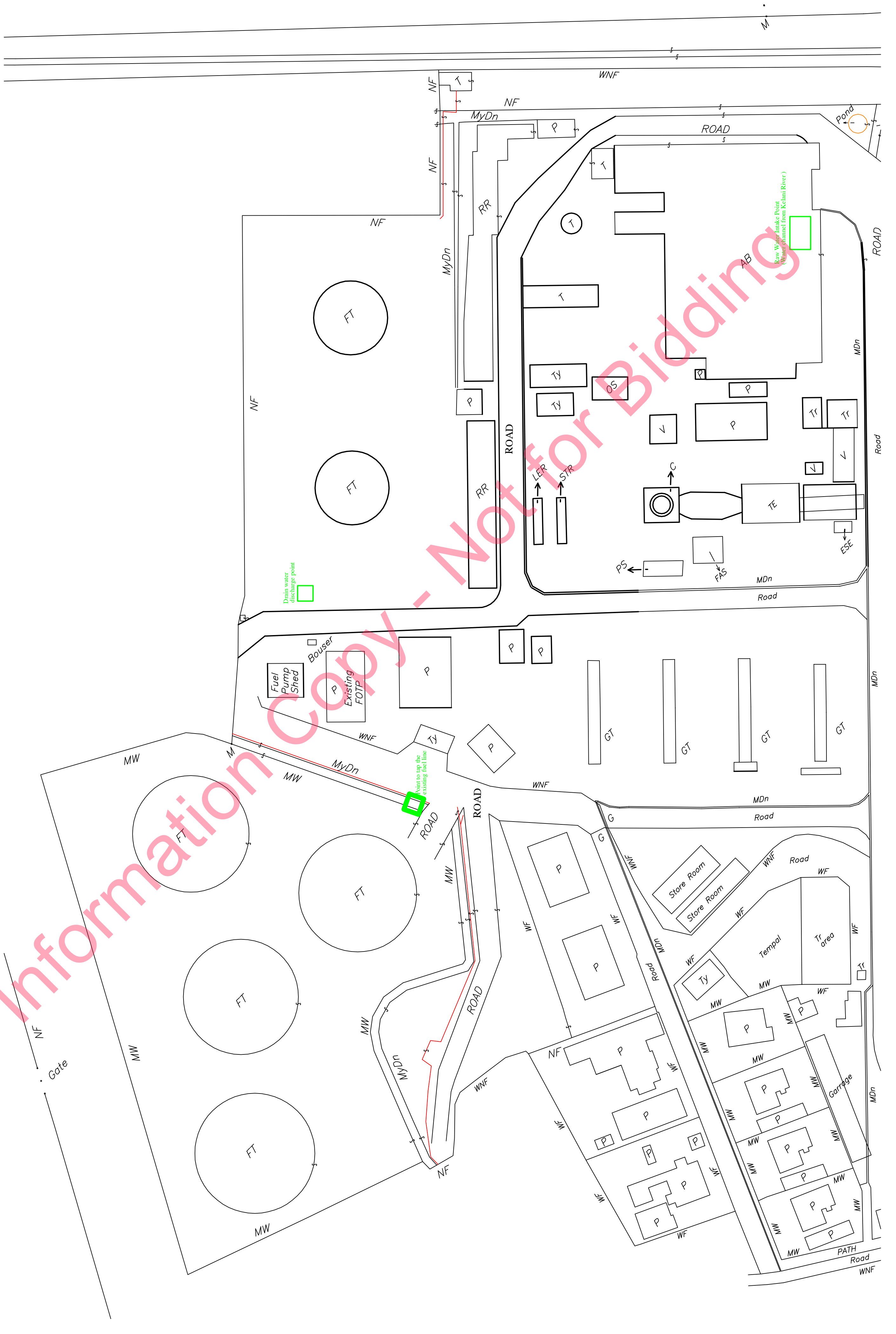



Figure 3a: BH 02 (a)

Figure 3b: BH 02 (b)



33kV Switch Yard
GT-2 TF
GT-5 TF
GT-3 TF
GT-4 TF
IBT-1
IBT-2
GT-1 TF
GT-7 Cable
Exisiting Cable trenches of132kV Control Cable
Old trenches (Abandoned) of132kV Control Cable
Sub-F Cable Termination
Empty Trench of 132kV Power Cable
New 132kV Cable Path to 132kV GIS
132kV Cable
*** Existing Canteen Building to be demolished
RLNG Terminal Point
GISB
CR
SY
GT
GR
P
MyDn
MDn
Road
ROAD
ROAD(RDA)
To Kandy
NF
WNF
IF
MW
WT
Steps
Pond
ESE
U
56.1
41.3
31.8569
44.1
40.3
84.9
10.8
12.5
17.6
13.0
9.1
18.2
45.0
57.2780
7.4971
10.6658
5.3834
3.0223
19.0967



M
WNF
NF
T
MyDn
P
ROAD
Pond
T
RR
AB
Raw Water Intake Point (Water channel from Kelani River)
ROAD
FT
FT
T
MDn
Ty
Ty
OS
P
P
P
V
Tr
Tr
V
ROAD
Road
C
LER
STR
RR
TE
ESE
PS
FAS
MDn
Road
Drain water discharge point
Bouser
Fuel Pump Shed
P
Existing FOTP
P
P
P
GT
GT
GT
GT
MDn
WNF
Ty
P
MW
M
MyDn
MW
Point to tap the existing fuel line
ROAD
WNF
MDn
Road
G
G
FT
FT
FT
FT
MW
Store Room
Store Room
Road
WF
WNF
WNF
P
P
WF
WF
Tempal
Tr area
Tr
Ty
MDn
Road
ROAD
MyDn
MW
NF
Gate
MW
MW
NF
WNF
P
P
P
P
P
P
P
P
P
P
P
Garrage
PATH
Road
WNF
WF
MW
NF

# Appendix - G


Scale of 1:1000
Site Map of the KPS

Reference

- B - Bank
- FT - Fuel Tanks
- GR - Guard Room
- WP - Waste Park
- P - Permanent building
- TP - Truck Parking
- M - Mark
- WT - Water Tank
- MyDn - Masonry Drain
- MW - Masonry Wall
- Tr - Transformer
- NF - Net Fence
- ZF - Zinc Fence
- ROAD(RDA) - ROAD(Road Development Authority)
- WLF - Wired Live Fence
- MW - Masonry wall

**Sequence of Feeder Energization in Power Restoration - Sri Lanka**

**Appendix - H**

| | Sequence | GT capability | | *Feeder Parametes as in PSSE - PU values based on 132kV for whole length(* | | | *T/F reactance (pu)* | *Feeder Length, km* | *Calculated parameters for whole length* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | MW | MAVar | R | X | B (charging) | | | R (Ohms) | X (Ohms) | C (F) |
| 1 | Energization of Kelanithissa-Kolonnawa cct (O/H) | 0 | -3 | 0.00119 | 0.00513 | 0.00108 | | 2.2 | 0.207346 | 0.893851 | 1.97E-08 |
| 2 | Energization of Kolonnawa 132/33 kV T/F (Stanly) and Connect load of 3 MW and 0 MVAr | 3.0075 | -2.156 | | | | 0.157618 | | | | |
| 3 | Energization of Kolonnawa 132/33 kV T/F (GIS) and Connect load of 8 MW and 0 MVAr | 11.009 | -1.983 | | | | 0.103809 | | | | |
| 4 | Energization of Kelanithissa-Sub C Cable | 11.009 | -4.6509 | 0.00037 | 0.00195 | 0.02518 | | 2 | 0.064469 | 0.339768 | 4.6E-07 |
| 5 | Energization of Sub C 132/11 kV T/F and Connect load of 4 MW and 0 MVAr | 15.0204 | -4.5294 | | | | 0.460317 | | | | |
| 6 | Energization of Kolonnawa-Sub E(Kolpity) Cable | 15.0114 | -16.7048 | 0.00158 | 0.00294 | 0.1212 | | 5.4 | 0.275299 | 0.512266 | 2.21E-06 |
| 7 | Energization of Sub E 132/11 kV T/F and Connect load of 5 MW and 0 MVAr | 20.0134 | -16.6171 | | | | 0.321445 | | | | |
| 8 | Energization of Kolonnawa-Sub N Cable | 20.0172 | -26.3148 | 0.000542 | 0.006484 | 0.073994 | | 5.458 | 0.094438 | 1.129772 | 1.35E-06 |
| 9 | Energization of Sub N -Sub F Cable | 20.0195 | -30.0344 | 0.000391 | 0.00344 | 0.030529 | | 2.703 | 0.068128 | 0.599386 | 5.58E-07 |
| 10 | Energization of Sub F 132/11 kV T/F and Connect load of 7 MW and 0 MVAr | 26.921 | -29.8579 | | | | 0.32225 | | | | |
| 11 | Energization of Sub F -Sub L Cable | 27.0246 | -31.6839 | 0.000125 | 0.001439 | 0.016079 | | 1.186 | 0.02178 | 0.250731 | 2.94E-07 |
| 12 | Energization of Sub L 132/11 kV T/F and Connect load of 5 MW and 0 MVAr | 32.0288 | -31.5772 | | | | 0.32225 | | | | |
| 13 | Energization of Kolonnawa -Sub I (Maradana) Cable | 32.0323 | -36.8044 | 0.00061 | 0.00431 | 0.06295 | | 4.6 | 0.106286 | 0.750974 | 1.15E-06 |
| 14 | Energization of Maradana 132/11 kV T/F and Connect load of 6 MW and 0 MVAr | 37.9418 | -36.6232 | | | | 0.3041 | | | | |
| 15 | Energization of Sub I -Sub A (Havlock) Cable | 38.0428 | -43.3717 | 0.00118 | 0.00613 | 0.07932 | | 6.3 | 0.205603 | 1.068091 | 1.45E-06 |
| 16 | Energization of Sub A 132/11 kV T/F and Connect load of 7 MW and 0 MVAr | 44.9542 | -43.1168 | | | | 0.30414 | | | | |

**Proof of Ability** **Appendix - J**

Note: Bidder shall provide the full details requested in the given format for the following equipment;
A) Plant Control and Supervisory Systems (DCS) supplied internationally for Thermal Power Plants by the proposed supplier for the past Three (03) years

| No. | Model of DCS system supplied | Capacity of the plant (MW) | Brief Description of equipment with specification | Purchaser's Name & Address | Purchasers contact No. | Date Supplied | Operational hours | Current operational condition |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

B) Electric Overhead Travelling Crane (EOT) units with equal or higher capacities supplied internationally for Thermal Power Plants by the proposed supplier for the past Ten (10) years – Note: This would be applicable, only if Gas Turbines are installed inside a building.

| No. | Model of the Overhead Crane supplied | Capacity (Tons) | Brief Description of equipment with specification | Purchaser's Name & Address | Purchasers contact No. | Date Supplied | No. of operational hours completed | Current operational condition |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

C) Inlet Air Chilling unit of Gas turbine with equal or higher capacities supplied by the proposed supplier for the past five (5) years

| No. | Model of the Inlet Cooling System | Type and Capacity | Brief Description of equipment with specification | Purchaser's Name & Address | Purchasers contact No. | Date Commissioned | No. of operational hours completed | Current operational condition |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

D) Black Start Generator offered shall have 5 years satisfactory international operational experience

| No. | Model of Black start generator supplied | Capacity (MW) | Brief Description of equipment with specification | Purchaser's Name & Address | Purchasers contact No. | Date Supplied | Operational hours/MWh | Current operational condition |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

E) Emergency Diesel Generator offered shall have 5 years satisfactory international operational experience

| No. | Model of Emergency generator supplied | Capacity (MW) | Brief Description of equipment with specification | Purchaser's Name & Address | Purchasers contact No. | Date Supplied | Operational hours/MWh | Current operational condition |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

F) Energy meters supplied

| No. | Model of Energy meter supplied | Capacity of plant (MW) | Brief Description of equipment with specification | Purchaser's Name & Address | Purchasers contact No. | Date Supplied | No. of operational hours completed | Current operational condition |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |