SECTION VI

TECHNICAL SPECIFICATIONS AND DRAWINGS FOR
SUBSTATIONS
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Lot 3-132/33 kV Substations and Switching Stations
Volume 2 Section—VI Employer’s Requirements
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1. SCOPE OF WORK

1.1. GENERAL

The Scope of Work for 132/33kV Substations complete with 132kV and 33kV buses, Line bays and transformers bays comprises the detailed engineering design, manufacture, supply, delivery to and off-loading at Site, erection, testing, setting to work/commissioning and completion and any remedial work required under an 18 month defects liability period (DLP) of the following Facilities and all other work incidental thereto.

- Eight new 132/33kV substations complete with new 132kV and 33 kV buses, line bays as detailed in these Employer’s Requirements; all having the technical particulars set out in the Technical Data Schedules and Drawings attached hereto as part of these Employer’s Requirements.

- Six 132kV Outgoing bays as detailed in these Employer’s Requirements; all having the technical particulars set out in the Technical Data Schedules and Drawings attached hereto as part of these Employer’s Requirements.

- The Facilities are to be complete and functional in all respects, including all detailed engineering, site topographic and setting out survey works, soils investigations, all civil works including site preparation earthworks, building and sanitation works and site roads, fencing and security lighting; all primary and secondary Plant, related power and control cabling, all earthing, all Plant steel support structure including respective foundations’ works and the gantry type line landing structures on which Transmission Line circuits and OPGW will be terminated by others under 132kV Transmission Lines Contracts under Lot 1 and Lot 2. Interconnection of Plant with the transmission lines’ terminating circuits at the landing structure is an integral part of the scope of Substations and is to be provided for accordingly in completion of all Facilities.

- All Facilities and Plant shall be priced accordingly for the estimated quantities stated under the Schedule of Rates and Prices, duly noting that quantities stated therein are figures only for the purpose of Bid and Contract pricing; these will be subject to adjustment and final payment made on the basis of quantities finally erected and confirmed by measurement approved by the Employer/Project Manager.

- **Lot 1** – Construction of Lessos – Kabarnet, Nanyuki – Nyahururu, Olkaria – Narok, Sotik – Bomet 132kV Transmission Lines with a total length of 245Km.

- **Lot 2** – Construction of Ishiara – Kieni, Mwingi – Kitui – Wote – Sultan Hamud 132kV Transmission Lines with a total Length of 186Km.

- **Lot 3** – Eight new 132/33kV Substations at Kieni, Kabarnet, Nyahururu, Narok, bomet, Kitui, Wote and Sultan Hamud and six 132kV Outgoing bays at Ishiara, Lessos, Nanyuki, Olkaria, Sotik and Mwingi.
Lot 3 above is divided into two Lots (Lot 3A and Lot 3B) as follows:

a) Lot 3A:
   i) 132/33kV Substations;
      a) Narok
      b) Bomet
      c) Kabarnet
      d) Nyahururu
   ii) 132kV Buses and Line Bays;
      a) Olkaria
      b) Sotik
      c) Lessos
      d) Nanyuki

b) Lot 3B:
   i) 132/33kV Substations;
      a) Kieni
      b) Kitui
      c) Wote
      d) Sultan Hamud
   ii) 132kV Buses and Line Bays
      a) Ishiara
      b) Mwingi

All the above Packages shall be executed on a Design, Supply Erection and Commissioning contractual basis and the 132/33kV Substations Plant set out below shall form fully operable Facilities within the Employer’s Transmission Grid.

The details of all the substation facilities included in Lot 3A and Lot 3B are as follows;

1.2. LOT 3A:

1.2.1. NAROK NEW 1 X 23 MVA 132/33 KV SUBSTATION

The new Narok 132/33kV substation is to be a conventional outdoor air insulated step-down substation. The Narok 132kV switchyard shall be designed as a single bus bar system with one (1) 132kV line bay for the proposed OHL from Olkaria-I with space for a future 132kV feeder bay to Bomet. One (1) transformer bay with a 1X 23 MVA transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1 (one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33 kv transformer bay will also be provided. The 33kV
switchyard shall be implemented in a single bus bar system with four(4) 33kV CBs for the out-going feeders.

Conceptual design SLD No.5083020-NRK-001 and GA No. 5083020-NRK-002 are attached.

1.2.2. **BOMET NEW 1 X 23 MVA 132/33 KV SUBSTATION**

The new Bomet 132/33kV substation is to be a conventional outdoor air insulated step-down substation. The Bomet 132kV switchyard shall be designed as a single bus bar system with one (1) 132kV line bay for the proposed OHL from Sotik switching station with space for a future 132kV feeder bay to Narok. One(1) transformer bay with a 1X 23 MVA transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1(one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kV switchyard shall be implemented in a single bus bar system with four (4) 33kV CBs for the out-going feeders.

Conceptual design SLD No.5083020-BMT-001 and GA No. 5083020-BMT-002 are attached.

1.2.3. **KARBANET NEW 1 X 23 MVA 132/33 KV SUBSTATION**

The new Kabarnet 132/33/kV substation is to be a conventional outdoor air insulated step-down substation. The Kabarnet 132kV switchyard shall be designed as a single bus bar system with one (1) 132kV line bay for the proposed OHL from Lessos substation with space for a future 132kV feeder bay to Narok. One(1) transformer bay with a 1X 23 MVA transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1(one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kV switchyard shall be implemented in a single bus bar system with four (4) 33kV CBs for the out-going feeders.

Conceptual design SLD No.5083020-KBN-001 and GA No. 5083020-KBN-002 are attached.

1.2.4. **NYAHURURU NEW 1 X 23 MVA 132/33 KV SUBSTATION**

The new Nyahururu 132/33kV substation is to be a conventional outdoor air insulated step-down substation. The Nyahururu 132kV switchyard shall be designed as a single bus bar system with one (1) 132kV line bay for the proposed OHL from Nanyuki substation with space for a future 132kV feeder bay. One(1) transformer bay with a 1X 23 MVA Transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1(one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kV switchyard shall be implemented in a single bus bar system with four(4) 33kV CBs for the out-going feeders.

Conceptual design SLD No.5083020-NYU-001 and GA No. 5083020-NYU-002 are attached.

1.2.5. **BAY EXTENSION AT OLKARIA-1 11/132 KV SUBSTATION**

The Olkaria-1 new 132kV line bay shall be designed as conventional air-insulated, fully equipped line bay, with its control and protection auxiliary equipment as well as communications interfacing with the existing olkaria-1 control room.
Thus the new Olkaria -1 132kV line bay will be fed from either the reserve or the main bus bar of the new substation. A second 132kV bus bar at Olkaria will be installed to facilitate switching operations. The existing substation has to be reconfigured to meet the correct safe operational incorporation of the Olkaria-Narok 132kV Line Bay taking into account the two transformer input to new double bus bar and their operation and maintenance. Installation shall be done with minimum interference with the existing equipment up until when the connection to the new installation is done. Related fibre optic communication equipment, fibre optic cabling and interfaces with the new overhead lines fibre optic ground wire (OPGW) installation of a new 132kV Tower and associated Gantries to cater for the new 132kV Transmission Line to Narok will also be undertaken.

Due to physical constraints onsite, the Contractor shall explore the possibility of using 132kV underground high voltage cable as specified. The cost of laying (including cost of installation) 1km shall be included in the bid.

Conceptual design SLD No.5083020-OLK-001 and GA No. 5083020-OLK-002 are attached.

1.2.6. BAY EXTENSION AT SOTIK 132 KV SWITCH-STATION

The new Sotik 132kV switch-station shall be designed as conventional outdoor air insulated 132kV line bay structure with additional structures to facilitate needed down leads and their clearance from the existing Chemosit – Kisii 132kV Transmission line to connect with the proposed Sotik – Bomet 132kV Transmission line section.

This switch station will be located in close proximity to the existing Sotik 33/11kV substation and adjacent to the east side of the existing Chemosit – Kisii line. It includes full fencing and a control building housing control and protection, communication and auxiliary equipment.

This new switch station will require but not limited to the following equipment and related installation works:

- Three (3) Full line bays complete with, Motorised Disconnectors, 132kV single pole outdoor SF6 Circuit Breakers, 3 core metering/protection CT, motorised line disconnectors with manually operated Earth Switches, CVTs and Lightning Arrester/Surge Diverters and associated switchgears as appropriate.
- Associated control and protection panel complete with solid state numerical relays and all associated external switchyard cabling including DC and LV AC supply to/from the existing Sotik 33/11kV substation and new switch station supplies;
- Control building to house line switch bay’s control and protection, communications and auxiliary equipment; equipment into Olkaria-I operational controls; and OPGW fibre optic communication equipment cabling and interface/interconnection of the Bomet 132kV and Chemosit - Kisii lines’ fibre optic ground wire (OPGW).

Conceptual design SLD No. 5083020-STK-001 and GA 5083020-STK-002 are provided.

1.2.7. BAY EXTENSION AT LESSOS 132/33 KV SUBSTATION

The existing Lessos 220/132kV substation is a conventional outdoor, air insulated substation with a ring bus system. A new 132kV single line bay shall be constructed to terminate to the proposed Kabarnet 132kV line. The above works shall require the following works but not limited to for complete functionality:

- One (1) Full line bay complete with, Motorised Disconnectors, 132kV single pole outdoor SF6 Circuit Breaker, metering/protection CT, motorised line disconnectors with manually operated
Earth Switches, CVTs and Lightning Arrestor/Surge Diverters 132kV Gantry and associated switchgears as appropriate.

- Associated control and protection panel complete with solid state numerical relays and all associated external switchyard cabling including DC and LV AC supply to/ from the existing Lessos station supplies;
- Control and protection, communications and auxiliary equipment; equipment into Lessos operational controls; and OPGW fibre optic communication equipment cabling and interface/interconnection of the Kabarnet 132kV and Lessos lines’ fibre optic ground wire (OPGW).

Conceptual design SLD No.5083020-LES-001 and GA No. 5083020-LES-002 are attached.

1.2.8. **BAY EXTENSION AT NANYUKI 132/33 KV SUBSTATION**

The existing Nanyuki 132/33 kV substation is a conventional air insulated fully equipped line bay. A new 132kV Line bay shall be constructed to terminate the Nyahururu line. The above works shall require the following works but not limited to for complete functionality:

- One (1) Full line bay complete with, Motorised Disconnectors, 132kV single pole outdoor SF6 Circuit Breaker, metering/protection CT, motorised line disconnectors with manually operated Earth Switches, CVTs and Lightning Arrestor/Surge Diverters 132kV Gantry and associated switchgears as appropriate.
- Associated control and protection panel complete with solid state numerical relays and all associated external switchyard cabling including DC and LV AC supply to/ from the existing Nanyuki station supplies;
- Control and protection, communications and auxiliary equipment; equipment into Lessos operational controls; and OPGW fibre optic communication equipment cabling and interface/interconnection of the Nyahururu 132kV and Nanyuki lines’ fibre optic ground wire (OPGW).

Due to existing access track, a flying (raise height) bus bar is recommended to give enough clearance.

Conceptual design SLD No.5083020-NYK-001 and GA No. 5083020-NYK-002 are attached.

1.3. **LOT 3B:**

1.3.1. **NEW KIENI 132/33 KV SUBSTATION**

The new Kieni 132/33/kV substation is to be a conventional outdoor air insulated step-down substation. The Kieni 132kV switchyard shall be designed as a single bus bar system with one (1) 132kV line bay for the proposed OHL from Ishara switching station with space for a future 132kV feeder bay. One(1) transformer bay with a 1X 23 MVA Transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1(one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kv switchyard shall be implemented in a single bus bar system with two(2) 33kV CBs for the outgoing feeders with space for future 2 (two) 33kV feeder bays.

Conceptual design SLD No.5083020-KIN-001 and GA No. 5083020-KIN-002 are attached.
1.3.2. NEW KITU 1 X 23 MVA 132/33 KV SUBSTATION

The new Kitui 132/33/kV substation is to be a conventional outdoor air insulated step-down substation. The Kitui 132kV switchyard shall be designed as a single bus bar system with two (2) 132kV line bays for the proposed OHL from Wote and Mwingi substation with space for a future 132kV feeder bay. One (1) transformer bay with a 1x23 MVA Transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1 (one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kV switchyard shall be implemented in a single bus bar system with four (4) 33kV CBs for the out-going feeders.

Conceptual design SLD No.5083020-KIT-001 and GA No. 5083020-KIT-002 are attached.

1.3.3. NEW WOTE 1 X 23 MVA 132/33 KV SUBSTATION

The new Wote 132/33/kV substation is to be a conventional outdoor air insulated step-down substation. The Wote 132kV switchyard shall be designed as a single bus bar system with two (2) 132kV line bays for the proposed OHL from Wote and Mwingi substation with space for a future 132kV feeder bay. One (1) transformer bay with a 1x23 MVA Transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1 (one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kV switchyard shall be implemented in a single bus bar system with four (4) 33kV CBs for the out-going feeders.

Conceptual design SLD No.5083020-WOT-001 and GA No. 5083020-WOT-002 are attached.

1.3.4. NEW SULTAN HAMUD 1X 23 MVA 132/33KV SUBSTATION

The new Sultan Hamud 132/33/kV substation is to be a conventional outdoor air insulated step-down substation. The Sultan Hamud 132kV switchyard shall be designed as a double bus bar system with a Main and Reserve Busbar. The existing 132kV Juja Rabai Line will come in and out of the Busbars. There is provision for a bus-coupler. Three (3) 132kV line bays for the proposed OHL from Wote, incoming line from Juja and outgoing Line to Rabai substations with space for a future 132kV feeder bay. One (1) transformer bay with a 1x23 MVA Transformer complete with on-load tap changer and standard equipment including 1 (one) 132kV and 1 (one) 33kV CBs, associated disconnectors, CTs and VTs for protection and metering purposes and Surge Arresters. Space for future 132/33kV transformer bay will also be provided. The 33kV switchyard shall be implemented in a single bus bar system with four (4) 33kV CBs for the out-going feeders.

Conceptual design SLD Drawing No. 5083020-SHD-001 covering the works is provided.

1.3.5. ISHIARA NEW 132KV SWITCH-STATION

Ishiara is located along the 132 kV line presently from Kamburu to Meru. A switching station is to be established at Ishiara. The Ishiara switching station will consist of 3 new 132kV line bays to cater for incoming line from Kamburu and outgoing lines to Meru and Kieni with a single bus arrangement.

An 11/0.415kV auxiliary transformer to be feed from an existing nearby 33kV line. The new Ishiara 132kV switch station shall be designed as conventional outdoor air insulated 132kV line bay structure with additional structures to facilitate needed down leads and their clearance from the
existing Kamburu – Meru 132kV Transmission line. This new switch station will require but not limited to the following equipment and related installation works:

- Three (3) Full line bays complete with, Motorised Disconnectors, 132kV single pole outdoor SF6 Circuit Breakers, metering/protection CTs, motorised line disconnectors with manually operated Earth Switches, CVTs and Lightning Arrester/Surge Diverters and associated switchgears as appropriate.

- Associated control and protection panel complete with solid state numerical relays and all associated external switchyard cabling including DC and LV AC supply from the nearby existing 11kV distribution system. An auxiliary 100KVA, 11/0.415kV transformer is proposed.

- Control building to house line switch bay’s control and protection, communications and auxiliary equipment; and OPGW fibre optic communication equipment cabling and interface/interconnection of the Kieni 132kV and Kamburu-Meru lines’ fibre optic ground wire (OPGW).

Conceptual design SLD No.5083020-ISR-001 and GA No. 5083020-ISR-002 are attached.

1.3.6. BAY EXTENSION AT MWINGI 132/33 KV SUBSTATION

The Mwingi 132/33kV substation is a conventional outdoor, air insulated substation with a step-down 132/33kV transformer and a 132kV line to Kindaruma station.

The works at Mwingi substation will involve but not limited to the following:

- Full line bay complete with, Motorised Disconnectors, 3x132kV single pole outdoor SF6 Circuit Breakers, minimum 3 core metering/protection CT, motorised disconnector with manually operated Earth Switch, CVT and a Lightning Arrester/Surge Diverter for the new Mwingi-Kitui 132kV Transmission line.

- Associated control and protection panel complete with solid state numerical relays and all associated external switchyard cabling including DC and LV AC supply from the existing Mwingi 132/33kV substation and new switch station supplies;

- Line switch bay’s control and protection, communications and auxiliary equipment and OPGW fibre optic communication equipment cabling and interface/interconnection with the existing system.

Conceptual design SLD No.5083020-MWG-001 and GA No. 5083020-MWG-002 are attached.

The 132/33kV Substations Plant set out below shall form fully operable Facilities within the Employer’s Transmission Grid.

1.4. SYSTEM, EQUIPMENT AND WORKS TO BE SUPPLIED

All systems, equipment and works needed for a complete and operating substation shall be included in the Contractor’s scope of supply. The scope of supply must therefore in principle include, but not be limited, to the following:

1) Electrical Systems
a) 132 kV and 33kV switchgear
b) Step-down transformers with automatic on-load-voltage regulation
c) Station service transformers
d) Busbar materials
e) Low-voltage AC switchgear for supply and distribution of station service auxiliary power
f) Batteries, rectifiers, battery fuse boxes, UPS units
g) Low-voltage DC switchgear needed for DC Auxiliary supplies
h) UPS switchgears
i) Low-voltage cables, control and communication cables, data cables and optical fibre cables
j) Cable support systems (ladders, trays, conduits, profiles, ducts, trenches, etc.).
k) Wall and floor penetrations for cables and pipes
l) Fire protection and shielding of cables
m) Complete Substation earthing system complete with Earth electrodes (embedded in the ground), earthing and bonding network, as required by relevant standards and safety regulations.
n) Control and protection system, overall for the substation
o) Telecommunication equipment and substation automation
p) Control and protection systems individually for 132 kV, 33 kV, transformers and low-voltage AC and DC Systems
q) Illumination, indoor and outdoor
r) Socket-outlets for general services, and electric power supplies to non-electrical services
s) Fire detection and protection system
t) Access control and intrusion alarm system

2) Other Systems
   a) Ventilation and air-conditioning
   b) Domestic water system
c) Toilets and sanitary system
d) Fire-fighting equipment

3) Civil works are outlined as follows
   a) Site survey and ground investigations
   b) Access road
c) Ground preparation, fill-up and levelling for switchyard and buildings
d) Ground stabilisation and retention
e) Drillings for, and embedment of, earth-electrodes
f) Drainage system with oil separating facility
g) Fence and gates
h) Foundations for outdoor switchgear and gantry structures
i) Foundations, oil collector pits and fire barrier walls for transformers
j) Steel supports and gantry structures for outdoor switchgears and incoming overhead lines
k) Cable channels, ducts and trenches in the switchyard
l) Cable trenches outside the switchyard (for cables to any overhead lines terminated outside the switchyard)
m) Building(s) for housing switchgear, control systems, low-voltage systems and other services
n) Building for watchman
o) Landscaping, planting and tidying up the Site, both inside and outside the fence.

4) Temporary Site Facilities
   a) Office (air-conditioned)
   b) Workshop
   c) Store
   d) Water supply
   e) Toilet
   f) Security

1.5. SUBSTATIONS AND TRANSMISSION LINE INTERFACES

The separate Contracts in Lot 1 and Lot 2 for Transmission line facilities include provision of down lead conductor tails for each line phase for use by the Substations Contractor for interconnection with its line bay facilities at new substations and existing substation and switchyard expansion works.

Similarly, the Transmission Contractor will terminate its OPGW in junction boxes to be mounted on the substation and switchyard gantry structures. Connections from the junction boxes towards the substations are to be provided for under the Contract for Substations Works.

1.6. OTHER WORKS

The Contractor shall note the Scope of Works of this Contract Lot 3A and Lot 3B (132/33kV Substations and 132kV Buses and Line Bays Extension) forms an extension to or expansion of existing parts of the Employer’s electricity grid. Where these Facilities interface with the works of others engaged by the Employer in respect to its transmission system across its Kenya operations region, the Contractor shall coordinate its works with any such other works in consultation and to approval of the Project Manager.

In this regard, the Contractor is to further note requirements in the following Chapter 3, General Requirements, Sub-chapter 3.9.3, exchange of Interface Information.

1.7. TRANSMISSION LINE WORK

This Contract does not include any transmission line work.
1.8. INSPECTIONS AND TESTS

1.8.1. GENERAL

These tests are for equipment included in the Employer’s Requirements and for the interfacing of control and monitoring systems with other contractors. The Contractor shall coordinate and liaise with the Engineer in planning and performing tests of his equipment.

All costs associated with Inspection and Tests on plant shall be included in the unit prices quoted for each item in the Price Schedules.

1.8.2. TESTS DURING MANUFACTURE

All plant and equipment shall be subject to tests during manufacture in accordance with the Standard Technical Requirements, plus any additional requirements for specific items as detailed in this Clause.

1.8.3. TESTS AT SITE

The Contractor shall conduct the tests at Site in accordance with Standard Technical Requirements, plus any additional requirements for specific items as detailed in this Clause.

1.8.4. PROGRAM OF PERFORMANCE

The Scope of Works for provision of the Facilities set out above and further specified in the bid through Employer’s Requirements, shall be completed within 24 months from the Effective Date and shall be subject to a Defects Liability Period of 18 months.
2. GENERAL TECHNICAL REQUIREMENTS

2.1. SITE AND SERVICE CONDITIONS

The climatic characteristics prevailing at Site are indicated below, which together with other climatic service and/or loading conditions nominated elsewhere in these Employer’s Requirement’s shall be applicable in respect of design; except where other specific climatic service or loading conditions are specified and take precedence over those below:

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient Air Temperature, Outdoor</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>+36°C</td>
</tr>
<tr>
<td>24 Hour Average Maximum</td>
<td>+31.5°C</td>
</tr>
<tr>
<td>Minimum</td>
<td>+12°C</td>
</tr>
<tr>
<td>Ambient Air Temperature, Indoor</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>+40°C</td>
</tr>
<tr>
<td>24 Hour Average Maximum</td>
<td>+30°C</td>
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<tr>
<td>Minimum</td>
<td>+10°C</td>
</tr>
<tr>
<td>Rainfall</td>
<td></td>
</tr>
<tr>
<td>Average Annual Rainfall</td>
<td>1300 mm</td>
</tr>
<tr>
<td>Maximum Monthly Rainfall</td>
<td>500-600 mm</td>
</tr>
<tr>
<td>Thunderstorm days per year (isokeraunic level)</td>
<td>280</td>
</tr>
<tr>
<td>Wind</td>
<td></td>
</tr>
<tr>
<td>Maximum wind velocity</td>
<td>120 km/hr</td>
</tr>
<tr>
<td>Maximum wind pressure on cylindrical objects</td>
<td>86 kg/m²</td>
</tr>
<tr>
<td>Maximum wind pressure on conductors and earth wire/optical ground wire (OPGW)</td>
<td>53 kg/m²</td>
</tr>
<tr>
<td>Maximum wind pressure on steel members on 1.5 times projected area</td>
<td>103.2 kg/m²</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td>60-95%</td>
</tr>
<tr>
<td>Indoor</td>
<td>90%</td>
</tr>
<tr>
<td>Humidity 13 mg/m³ absolute and 90% relative before storms with vapour pressure of 17 mmHg</td>
<td></td>
</tr>
<tr>
<td>Altitude above Mean Sea Level</td>
<td>1200 m</td>
</tr>
<tr>
<td>Typical Air Pressure</td>
<td>860 mbar</td>
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<td>Seismicity</td>
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<tr>
<td>Peak Ground Acceleration</td>
<td>0.15g</td>
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<tr>
<td>Environment EMC Class (IEC 61000)</td>
<td>Industrial</td>
</tr>
<tr>
<td>Maximum Temperature Rise of Conductors Above Ambient (40°C)</td>
<td>+40°C</td>
</tr>
</tbody>
</table>

For cables in the ground maximum temperature specified in the table above shall be taken as design value for ambient (ground) temperature.
Wherever any of the maximum or 24 hour average temperatures specified above exceed the normal service condition temperatures specified in any of the applicable international standards, the permissible temperature rises shall be those in the applicable international standards reduced by the difference between the above specified and the normal service condition temperatures.

For design of substation insulation, the altitude specified above (1200 meters above mean sea level) with typical air pressure 860 mbar shall be assumed. The de-rating factor as per IEC 60071 shall be applied to ensure that supplied plant and equipment operates correctly at this altitude.

### 2.2. SYSTEM DESIGN PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Frequency</td>
<td>50 Hz ±2.5%, 3-phase</td>
</tr>
<tr>
<td>Neutral point earthing</td>
<td>Solidly earthed</td>
</tr>
<tr>
<td>Nominal system voltage (IEC 60038) (kV)</td>
<td>33, 132</td>
</tr>
<tr>
<td>Highest system voltage (IEC 60038) (kV)</td>
<td>36, 145</td>
</tr>
<tr>
<td>Minimum short circuit &amp; earth fault breaking current, symmetrical rms value (kA)</td>
<td>25, 31.5</td>
</tr>
<tr>
<td>Short circuit and earth fault current, symmetrical r.m.s. value (min breaking current) not less than, 3 seconds (kA)</td>
<td>25, 31.5</td>
</tr>
<tr>
<td>Minimum dynamic peak making current (kA)</td>
<td>63, 80</td>
</tr>
<tr>
<td>Standard lightning impulse withstand voltage (peak kV)</td>
<td>170, 650</td>
</tr>
<tr>
<td>Standard short-duration power frequency withstand voltage (rms kV)</td>
<td>70, 275</td>
</tr>
<tr>
<td>Minimum rated current of busbars and bus coupler switchgear unless otherwise specified (A)</td>
<td>1250, 2000</td>
</tr>
<tr>
<td>Minimum rated current of feeder and incomer switchgear unless otherwise specified including isolating switches if not given in Scope of Work</td>
<td>800, 1250</td>
</tr>
<tr>
<td>Minimum rated current of Transformers</td>
<td></td>
</tr>
<tr>
<td>Minimum nominal specific creepage distance (mm/kV) (IEC 60815 Table 11)</td>
<td>25 (inland), 31 (Transformers)</td>
</tr>
<tr>
<td>The following minimum clearances shall apply to conductors in substations (mm)</td>
<td></td>
</tr>
<tr>
<td>Phase to earth</td>
<td>500, 1500</td>
</tr>
<tr>
<td>Phase to phase</td>
<td>500, 1600</td>
</tr>
<tr>
<td>Between bays</td>
<td>4600, 8000</td>
</tr>
<tr>
<td>Minimum height of live parts from ground</td>
<td>2900, 3900</td>
</tr>
<tr>
<td>Minimum distance from the net fence</td>
<td>1350, 2000</td>
</tr>
<tr>
<td>Minimum height from the net fence</td>
<td>2650, 2600</td>
</tr>
<tr>
<td>Height of lowest parts of insulators above ground</td>
<td>2500</td>
</tr>
</tbody>
</table>
2.3. **SEISMICITY**

<table>
<thead>
<tr>
<th>Event</th>
<th>OBE</th>
<th>MCE</th>
<th>MDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal PGS (peak ground acceleration) (ah)</td>
<td>0.173g</td>
<td>0.750g</td>
<td>0.548g</td>
</tr>
<tr>
<td>Horizontal Seismic Coefficient (ah)</td>
<td>0.012</td>
<td>0.051</td>
<td>0.037</td>
</tr>
<tr>
<td>Vertical PGS (peak ground acceleration) (av)</td>
<td>0.115g</td>
<td>0.500g</td>
<td>0.365g</td>
</tr>
<tr>
<td>Vertical Seismic Coefficient (av)</td>
<td>0.008</td>
<td>0.034</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Where $g = \text{acceleration due to gravity}$

$9.781 \text{ m/s}^2$

OBE = operation base earthquake

MCE = maximum credible earthquake

MDE = maximum design earthquake

2.4. **ACCOMMODATION, STORAGE AND SITE SERVICES**

2.4.1. **SITE ACCOMMODATION**

The Contractor shall make his own arrangements with regard to living and office accommodation for staff and labour during the construction of the Facilities together with all associated work including storage and workshop facilities.

All dwellings and buildings, existing or erected by the Contractor shall comply with local regulations with regard to construction, water supply, sanitation and other requirements. Where temporary construction camps are provided by a Contractor, it shall ensure such camps are provided with proper sanitation and other necessary facilities. All such accommodation, office, storage and workshops erected by the Contractor shall be removed when no longer required. Following removal of such facilities, the grounds they occupied shall be left in a clean and tidy condition.

Where the Contractor provides temporary living accommodation in remote areas for its personnel, it shall also provide living accommodation and messing facilities for use by the Employer and Project Manager for up to six persons, of which up to three may occupy such accommodation on a long-term basis, equivalent to that of Contractor’s use of such temporary living accommodation.

Similarly where the Contractor provides temporary office accommodation in remote areas for its personnel, it shall also provide office facilities for use by the Employer and Project Manager for up to four persons. Temporary office accommodation shall include a room, which can be used for meetings and which may be used by the Employer from time to time.

The Contractor shall supply safe drinking water for all living/office accommodation and at all work sites.

The cost for site accommodation shall be deemed to be included in the Contract Price.
2.4.2. SITE STORAGE FACILITIES AND SERVICES

The Contractor shall make his own arrangements for site facilities including electricity, water, communications and crane lifting facilities.

All storage, facilities workshop or labour camp locations shall only be made by appropriate arrangements with the relevant property owners, at the Contractor's own expense.

The Contractor shall in all cases obtain the approval of the Project Manager in respect of the locations of any of the above temporary including facilities.

Particular attention shall be paid to places along transmission line route where it intends to distribute line materials, even when within the transmission line Right-of-Way (RoW). In no case will this be outside a transmission line RoW, unless appropriate arrangements are made with the owners of the affected property, which shall be at the Contractor’s own expense.

All such arrangements for the use of land outside the line route and its RoW shall be subject to consultation with and to the approval of the Project Manager.

The Contractor shall arrange for protection of all Plant; shipping and transport packaging to be robust and placed in suitable outdoor storage until incorporation into the Facilities. All packages shall be placed on packing, to raise them above ground level. If any package or plant is unsuitable for outdoor storage, the Contractor shall arrange for indoor storage elsewhere.

The Contractor shall exercise special care in the storage of electrical plant.

2.4.3. MEDICAL FACILITIES

The Contractor shall provide at all accommodation and work sites, medical and first aid facilities for its employees. The extent of medical facilities at each location shall be agreed with the Project Manager.

The Contractor’s particular attention is drawn to its obligations in respect of its staff and employees’ health and related medical facilities under the General Conditions (GC) of Contract, Clause 22.2.7.

2.4.4. VEHICLES

The Contractor shall provide, for the use of the Engineer, on a 24 hour basis, the vehicles specified in the Price Schedules. The Contractor shall provide the services of one driver mechanic per vehicle whose remuneration shall be approved by employer; maintain in efficient working condition, repair, replace defective parts and tyres and provide fuel and oil and other consumables, all documentation in accordance with Kenya Law, including full comprehensive insurance cover at all times for all vehicles and all drivers for unlimited Third Party claims, at the rates stated in Volume 2.

The vehicles provided under the contract for use by the Employer/Engineer are to be available for use by the Employer/Engineer's site supervisors (including reasonable personal use) within the general area of the entire project and be available for their use 24 hours per day, seven days per week and shall be provided immediately after the contract becomes effective. Although the maintenance, condition and roadworthiness of the vehicles are the responsibility of the Contractor, the movements of the vehicles will be entirely under the control of the Employer/Engineer’s site supervisors.

The vehicles shall be new, purchased locally and shall be approved by the Engineer before purchase. Each vehicle shall comply with all relevant road traffic laws and be right hand drive. The Contractor will be required to make the vehicles available at all times during the Contract Period and until
completion of the specified maintenance period and to provide replacement vehicles when the servicing or repair time (including accidents) exceeds a period of 24 hours. The provision of such replacement vehicles will not be subject to additional payment. When a vehicle is out of action for any cause the Contractor shall make a similar vehicle available for the Engineer's use at the Contractor's expense.

The types of vehicle shall be as follows but alternative vehicles to a similar specification will be considered:

Vehicle Type 1:

Medium SUV type, 2.7 litre engine, Toyota Fortuner or equivalent. This shall be available for use in Lot 1, 2 and 3.

Vehicle Type 2:

Regular Station Wagon with 2.5 litre diesel engine, Toyota Double Cabin or equivalent.

In addition, the contractor shall also provide 5 new motor bikes of 100cc to be used by way leave officers. The Contractor shall fuel the motorbikes for the entire project period.

The vehicles, Type 1 and 2 shall be 4 wheel drive with additional low ratio gears for cross-country work and each vehicle shall be fitted with the following standard equipment: alternator, ammeter, oil pressure gauge, water temperature gauge, speedometer (kph) with trip, ash tray, fire extinguisher (including fixing bracket and screws), exterior sun visors, external wing-mirrors, windshield wiper unit (passenger side), rubber pads for clutch and brake pedals, spare wheel carrier on dished deluxe bonnet with provision for lock, bonnet lock, lock for spare wheel on bonnet, lock for fuel filler, locking doors and windows, radio interference suppressors, towing pintle, steering damper, front axle with reinforced casing, radiator chaff guard and cross-country tyres. Each vehicle shall be supplied with the basic maintenance tools together with spare belts (fan, cam serpentine and power steering), top and bottom radiator hoses, 6 fuses, a high lift jack, felling axe, cutlass, trenching tool, 15 m of 0.75 tonne fibre rope, inspection lamp and 5 m of 2 core cable.

The Contractor will ensure that one spare tyre is available for each vehicle throughout the duration of the contract. All tyres will be of a roadworthy condition and comply fully with Kenyan Law. Each vehicle shall be fitted with driver and passenger air bags.

If required, any one of vehicles Type 1 and 2 shall be equipped with a hydraulic winch.

2.4.5. COMMUNICATIONS

Mobile Phones:

The Contractor shall also provide up to five (5) mobile telephone sets and one (1) I-Pad (approved by the Employer) for use in Project oversight by the Employer's Project Implementation Team with all usage charges relevant to the transmission project paid for by the Contractor. Mobile telephone coverage is to be provided for the length of the line by a major Kenyan mobile telephone service provider which provides coverage across the country.
The costs of providing, mobile telephones (approved by the Employer) and a reasonable monthly air time allowance is deemed incorporated into the appropriate item Schedule 4.

LOGISTICS AND ROADS

2.4.6. CONTRACTOR’S RESPONSIBILITIES

The Contractor shall be responsible for the transport of all Plant and its personnel to and from the Site. The Contractor shall investigate the adequacy of all access to the site and shall obtain any necessary approvals and/or make any necessary arrangements with relevant authorities.

If there is a requirement for any strengthening or upgrading of roads or bridges to allow for transport of plant supplied by the Contractor, then such upgrading, including the obtaining of any necessary approvals, shall be the responsibility of the Contractor.

2.4.7. SITE ACCESS AND PORT OF ENTRY

Mombasa in Kenya is recognized as the principal seaport for shipment of bulk materials and heavy construction plant for all project sites.

The Mombasa Port in Kenya is operated by Kenya Ports Authority and can handle any required loads landed by barge. Wharf crane capacity is reported to be limited to 70 tonnes.

The Contractor shall determine the port(s) of entry to be used and shall comply fully with all associated import, export and port entry procedures and regulations of Kenya, in respect of all Plant and materials.

From Mombasa, goods may be transported by rail for heavy materials such as steel structures and conductors; or by truck using the existing paved highway network. Rail freight is understood to be less costly to road/truck transport; however road freight is more reliable and easier to monitor.

2.5. ASSOCIATED FACILITIES

Lot 1 and Lot 2 of this project, which is composed of the transmission lines, shall be concurrently undertaken with the Substation Contracts of Lot 3A and Lot 3B.

The designs and utilization of space available will have to cater for requirements of these transmission lines in terms of proper orientation of the relevant bay equipment. This shall require close consultation and coordination with the Employer and Project Manager as well as the contractors carrying out the above works.

2.5.1. EXCHANGE OF INTERFACE INFORMATION

Lot 3-The Contractor shall where needed supply in a timely manner all interface information to its subcontractors/suppliers, the Employer/Project Manager and/or other Contractors engaged by the Employer in other Facilities on the overall power system. The Contractor is in particular required to check that all foundations and related fixing of its plant are sufficiently dimensioned and designed to withstand the applied loads by line terminations.

Where substation works on the substation on the alternate end of the line is being done by others, close cooperation and coordination shall be required regarding such equipment as protection and
communication equipment to ensure the compatibility of the equipment supplied on either side of the lines. The OPGW termination equipment as well as inter-trip functions shall need to be coordinated.

If the Contractor lacks such information from other contractors, he is obliged to request such from the Project Manager. The Contractor cannot claim liability exemption for his own contractual responsibilities because of actions performed or omitted by other sub-contractors.

2.6. FACILITIES PROGRAM

The Contractor shall provide an overall Program of Performance (Work Program) in line with Contract’s General Conditions (Clause 18.2 refers). This program shall be a management style, time-scaled and activity linked Gantt chart for the Facilities. Software such as Micro-soft Project 2007 would meet this criterion. It should present all activities/tasks to complete the specified Facilities and Plant in full. The program shall reflect all work items/phases and details related to all Facilities, Plant and manufacture, delivery and erection and all Contractor’s Plant to be used in respect of completion of the Facilities, within the Time for Completion. Such a program may require concurrent programming of tasks across the specified substations and commensurate resources.

The substation engineering, design and site surveys shall be substantially completed within 75 days from the Effective Date, or such other time that shall be agreed at contract negotiations, at which time the Contractor shall review and revise (if necessary) its Program of Performance accordingly in consultation with and with the approval of the Employer or Project Manager. The Contractor shall similarly ensure substantial completion of all engineering within 90 days of the Effective Date (excluding final line design) at which time any needed review or revision of this Program of Performance by the Contractor shall be carried out in consultation with and with the approval of the Employer or Project Manager.

The Program of Performance shall be in the format indicated above and as a minimum provide for principal milestones as follows:

- Essential information to be delivered by Employer including Site access;
- Documentation for approval from Contractor to Employer including time allowance for such documentation approval;
- Release of factory and related quality assurance documentation;
- Factory Tests;
- Shipments;
- Site ready for erection;
- Start erection;
- Ready for pre-commissioning;
- Completion;
- Operational Acceptance;
- Submittal of Final Records and Documents.

The Employer or Project Manager’s approved Program of Performance shall be used to monitor and determine progress and the Contractor shall include in each of his monthly progress reports the Facilities program annotated to indicate actual progress for each task at the end of the reporting month.
2.7.  CORRESPONDENCE, MEETINGS AND REPORTS

2.7.1.  CORRESPONDENCE

The Contractor shall address all correspondence on matters arising out of the Contract, to the Project Manager with two copies to be sent to the Employer unless otherwise revised and agreed.

2.7.2.  PROGRESS REPORTS

After approval of the Program of Performance by the Project Manager, the Contractor shall submit formal, detailed progress reports in an approved format, indicating the status of design, material procurement including, manufacture, testing, delivery, transport and erection Facilities, at monthly intervals. The reports shall clearly identify any delay in progress and its cause including its sub-contractors or manufacturers and suppliers, with intended remedial action to recover programmed progress.

These reports shall clearly state all the Contractor’s resources including manpower and Contractor’s Plant employed by the Contractor during the reporting period. These reports shall be forwarded promptly so that on receipt by the Project Manager the information contained therein is not more than 7 days out-of-date.

The monthly progress reports shall also include an appendix presenting a reasonable number of photographs depicting the progress of the Facilities during the report period, including any unique or irregular aspects of construction work carried out during the reporting period. The photographs size and finish shall be as agreed with the Project Manager. When requested, the Contractor shall provide up to 3 additional copies of the progress photographs to the Project Manager for use by the Employer.

Monthly reports shall be provided in bound hardcopy and softcopy (pdf) format. The progress photographs shall be provided in hardcopy colour prints and softcopy (jpg) format and accompany the report due within seven days of the defined reporting period.

2.7.3.  MEETINGS

The Contractor shall participate in regular project progress meetings with the Employer and the Project Manager. In addition to the regular monthly meetings, the Contractor shall participate in meetings called by the Employer or Project Manager, where specific aspects of work in progress require particular attention whether technical, commercial or where the Employer or Project Manager consider the progress position of any section of the work to be unsatisfactory.

All meetings will be held at Site in the Office accommodation provided by the Contractor per may be held either at the Employer or Project Manager’s offices or at the Contractor’s Facilities, as deemed appropriate by the Employer or Project Manager.

Access to the Contractor’s and sub-contractor’s Facilities shall be granted to the Project Manager and Employer at all reasonable times for the purpose of ascertaining progress and for supervisory Facilities.
2.8. **STANDARDS**

Standards shall be the latest amendments of the Standards of the International Electro-technical Commission ("IEC") and the International Standardization Organization ("ISO") or as otherwise referenced in these Employer’s Requirements for all materials and Plant used and provided under this Contract.

Suppliers who do not normally manufacture to IEC or ISO or Employer specified Standards may offer plant in accordance with other recognised International Standards provided that they draw attention to any essential differences between the proposed and IEC/ISO or Specified Standards and that they certify the plant offered is not to a standard less than that required of IEC/ISO or Employer specified Standards.

Acceptance of any standards other than those referenced within these Specifications, will be subject to the Project Manager’s approval and on satisfaction that quality, finish and performance of the plant offered shall be comparable to plant that complies with IEC, ISO or other Specified Standards.

2.9. **FACILITIES DESIGN AND PRINCIPLES**

The Facilities shall be designed for reliable, long and continuous service and safe operation under all conditions, with high economy and low maintenance cost. Facilities shall be available to simplify inspection, testing, maintenance and repair of the Plant. The design shall also include all necessary provisions ensuring the safety of the operating and maintenance personnel.

All materials and plant used under this Contract shall be new and of the best quality; workmanship shall be of the highest class throughout the Facilities. All outdoor Plant including towers, insulators, busbar conductor, hardware and fittings shall be designed so that water cannot collect at any point. Welding, filling, plugging or any repairs to defective items of Plant or parts thereof shall not be permitted without the approval in writing of the Project Manager.

2.10. **DRAWINGS AND INFORMATION TO BE PROVIDED BY THE CONTRACTOR**

2.10.1. **GENERAL**

The Contractor shall prepare and shall be fully responsible for the correctness of all drawings and other documents which are necessary for the manufacture, supply, delivery, erection, operation, commissioning and maintenance of the Facilities.

The Contractor shall use the English language in all drawings, information and documents pertaining to the Contract and in all correspondence between the Contractor the Employer and the Project Manager. Whenever anything is required under the terms of the Contract to be written, marked, printed or engraved, the English language is to be used except where otherwise may be provided in these Employer’s Requirements.

‘Preliminary drawings’ means drawings to be provided by the Contractor to the Project Manager for review and comment.

‘Final drawings’ means all approved drawings embodying, where required, all design modifications as approved by the Project Manager.
‘Work-as-executed drawings’ means drawings showing the arrangement of the Facilities in the final and complete state as installed or to be installed at the time of Take-Over of the Facilities.

Submission by the Contractor of drawings for approval, including those prepared by others, shall be deemed to mean that the Contractor has fully examined such drawings and that they comply with the requirements of the Contract.

Approval of a drawing by the Project Manager will imply that:

- General arrangement and layout drawings and key diagrams have been examined and appear to be in accordance with the basic design concept as provided for by the Employer’s Requirements;
- Other drawings of plant and plant have only been examined in relation to compatibility of the plant and plant with the Employer’s Requirements;
- Approval of a drawing shall not relieve the Contractor of his responsibilities under the Contract.

The Project Manager will not normally require copies of detailed manufacturing drawings, but the Contractor shall make these available to the Project Manager if so requested.

The Project Manager may require the Contractor to make changes to the drawings which are necessary, in the opinion of the Project Manager, to make the Facilities conform to the intent of the Contract.

2.10.2. DRAWING MANAGEMENT

Drawings/sketches shall be ISO standard size, between A1 and A4 and shall be completely legible when printed at the appropriate size.

All drawings and other documents shall be identified using a systematic document numbering system which gives a unique identifier for each document, shown on each sheet of the document.

The Contractor shall maintain a drawing and other document register, which identifies each document and the date and reference of submission of the original and each revision. The register shall be in electronic format and shall include a facility by which associated groups of documents may be readily identified and retrieved, for example, one such group could be transmission tower foundation drawings. The document register shall be maintained at current status and an electronic copy submitted with each of the Contractor’s monthly reports.

The number and format of documents to be submitted to the Project Manager shall be agreed with the Project Manager and may be varied from time to time. At commencement of the Contract, two paper copies and one electronic copy shall be submitted.

If a document includes generic material provided by any plant supplier, that material shall be clearly marked to identify which portions are applicable to the Contract.

All drawings and other documents shall be included in the operation and maintenance instruction manuals (see “Standard Technical Requirements). In addition, the Contractor shall provide two
complete sets of drawings and other documents revised to ‘Work-as-Executed’ status in the same electronic format as the source file (e.g. AutoCAD or MS Word).

2.10.3. SUBMISSION OF DRAWINGS AND INFORMATION

The Contractor shall submit drawings and information for approval as set out below. Late submission of documents for approval will be subject to the guarantees in the Schedules and to liquidated damages in accordance with the Particular Conditions of Contract.

a) Progressively up to 2½ months after the Effective Date:

- A detailed program of the phases of design, material supply, manufacture, delivery, erection and commissioning of the Facilities;
- An estimation of the frequency and magnitude of payments under the Contract;
- Project Procedures Manual - Procedures for design, document numbering, approvals, procurement, construction, scheduling, progress reports;
- Contractor’s quality assurance (QA) manual;
- List of drawings and other documents to be submitted by the Contractor together with a schedule for submission of the same;
- Substations Design Statements - Overall design concept, system and detailed design criteria for electrical, structural and services Facilities, loading conditions;
- Drawings – Loading drawings for plant, civil structures/foundations, and general arrangement drawings showing the physical arrangement of the main components.

b) Progressively up to 6 months after the Effective Date:

- Schedule of all inspections and tests to be carried out on major plant and the associated inspection and test plans;
- All civil and mechanical designs;
- Electrical clearances diagrams;
- Detailed general arrangement drawings, specifications and calculations of all principal components;
- Substations foundation design calculations, foundation loading data, conductor/busbar clearance diagrams, general arrangement drawings, erection diagrams and material lists for each support/gantries extension giving total mass of steelwork above and below ground and showing all types of foundations and details of insulators, conductors/busbars and earthing details;
- Site Access Mapping and Plan per engineering surveys;
- Soil investigation reports, including earth resistivity at substation sites.

c) Sixteen months after the Effective Date:

- Draft of the complete operation and maintenance instructions;
- Site testing and commissioning plans.
d) One month after Operational Acceptance:
   - Work-as-Executed drawings;
   - Operation and Maintenance Manuals, updated as a result of erection and commissioning experience;
   - Schedules of settings for all control, alarm and protection devices, if applicable.

2.11. INSULATION LEVELS AND CLEARANCES

The insulation levels and clearances shall be as sown in Section 2.2; Design Parameters.

2.12. ERECTION AND COMMISSIONING REQUIREMENTS

2.12.1. SITE SUPERVISION

The Contractor shall provide a sufficient number of suitable personnel throughout the erection and maintenance periods to supervise efficiently all work carried out under the Contract. The personnel shall have had thorough experience in the erection, commissioning, operation and maintenance of plant comparable with that being supplied under the Contract.

The Contractor shall nominate a “Contractor’s Representative” who shall be engaged solely in a supervisory capacity and shall be capable of dealing with and making decisions in relation to all matters arising in connection with the execution of the Facilities and Temporary Facilities on the Site. He shall have had previous experience in supervising Facilities of a similar type and magnitude and shall co-ordinate the work of the Contractor and its Sub-Contractors at the Site. He shall maintain to the satisfaction of the Project Manager a reasonable standard of discipline amongst the Contractor’s and his Sub-Contractor’s employees whilst they are on the Site.

Similarly and in addition to its Representative, the Contractor shall also appoint an appropriately qualified and experienced Construction Manager, from commencement of Facilities at Site until Completion. The Construction Manager shall supervise all work done at the Site by the Contractor and shall be present at the Site throughout normal working hours except when on leave, sick or absent for reasons connected with the proper performance of the Contract. Whenever the Construction Manager is absent from the Site, a suitable person shall be appointed to act as the Construction Manager’s deputy.

Both the Contractor’s Representative and/or Construction Manager shall remain in the Project area during the periods when erection or commissioning of any of the Facilities is taking place. He shall not leave the Project area during these periods without the approval of the Project Manager.

The Contractor shall maintain a Project Office at which its Representative is based. This Office shall be adequately staffed to enable the Representative to be conveniently contacted and the Site Facilities and properly co-coordinated. It shall have telephone, facsimile and internet communications facilities.

The Contractor shall keep in his Project Office a copy of the Contract including all variation orders and a copy of all standards, codes and statutory regulations relevant to execution of the Facilities and all related Installation Services.
The Contractor’s Representative and/or Construction Manager shall, when requested by the Project Manager, attend any meetings convened for the purpose of co-coordinating the Facilities.

The Contractor shall arrange for its Representative and Construction Manager may be contacted by telephone outside normal working hours throughout the erection and commissioning periods (and Defects Liability Period) if required by the Project Manager. The Contractor shall notify the Project Manager of the ‘after hours’ telephone number of its Contractor’s Representative and Construction Manager and of any change in those numbers.

2.12.2. SITE COMMUNICATIONS

The Contractor shall make arrangements for voice and Internet communication between his project office and all locations at which he has people working.

The cost of the site communication facilities shall be deemed to be included in the Contract Price.

2.12.3. CLEANING UP BY CONTRACTOR

Throughout the conduct of all work at Site, the Contractor shall maintain the Facilities, Plant, its Contractor’s Plant and all related Installation Services at all locations in a clean and tidy condition.

All Contractor’s Plant and/or Plant and its component materials not in use and/or no longer required for the Facilities completion and related Installation Services, all condemned materials and all rubbish shall be removed from the Site at the least once per week. Combustible rubbish shall be removed daily and may be burned in an area designated by the Project Manager.

Upon completion of the Facilities, the Contractor shall deliver any surplus Plant to the Employer in a manner agreed with the Project Manager.

The Contractor shall also remove all its Contractor’s Plant together with all manner of items or material associated to its Installation Services, whether specified or not, and any remaining rubbish which may have accumulated in the execution of the Contract and shall leave the whole of the Site in a clean and tidy condition.

If the Contractor fails to comply with any of the above requirements within 24 hours of notice in writing by the Project Manager, the work may be carried out by the Project Manager and the total cost to the Employer of the work will be charged to the Contractor.

2.12.4. MAKING GOOD

The Contractor shall take every reasonable care in the execution of the Facilities to avoid loss of or damage to any property of the Employer or of others, including landholders.

Where, in the performance of its obligations under the Contract, the Contractor causes loss of or damage to any property of the Employer or others, he shall make good such loss or damage to the reasonable satisfaction of the Project Manager.

2.12.5. FIRE PROTECTION AND FIRE FIGHTING

The Contractor shall be responsible for the fire protection of its Site facilities at all locations, whether living or office accommodation, storage facilities, Facilities, shops or other work areas, all Plant and Contractor’s Plant at any of these locations and any place at which it has Facilities.
Portable fire fighting plant shall be available at work sites at all times, when the Contractor’s employees are present and shall be kept available at other times as directed by the Project Manager.

The Contractor shall maintain the fire fighting plant in a condition satisfactory to the Project Manager and shall re-charge extinguishers after use, regardless of by whom they were discharged. Adequate stocks of fresh extinguisher charges including chemical charges shall be kept in readiness by the Contractor.

All fire fighting plant provided under this Clause shall be the property of the Contractor and shall be removed by the Contractor when requested by the Project Manager.

2.12.6. HEALTH SERVICES, FIRST AID AND SAFETY

The Contractor shall comply with all the relevant statutory regulations of Kenya with respect to safety and occupational health. Particular attention is drawn to the Contractor’s obligation under the General Conditions (GC) of Contract, Clause 22.2.7 in respect of health and safety.

All working areas shall be deemed safety helmet and safety boots areas and the Contractor shall provide all his employees with safety helmets, safety boots, and subject to task, safety gloves, disposable air/fume filtering facial masks and safety glasses or goggles.

Contractor’s personnel working at heights and aerial work of any kind must be equipped with safety belts/harness and their associated straps and safety rope lines and shall make available such plant to the Project Manager for associated inspections.

In the performance of the Facilities, the Contractor shall exercise every reasonable precaution to protect persons or property from injury.

The Contractor shall co-operate fully with the Project Manager’s supervising staff on all matters affecting safety.

The Project Manager may require the immediate removal from the Facilities of any person who in the opinion of the Project Manager fails properly to observe these provisions and such person shall not be employed upon the Facilities without the permission of the Project Manager.

2.13. OPERATION AND MAINTENANCE TRAINING

2.13.1. GENERAL

The Contractor shall instruct the Employer’s nominated staff in the operation and maintenance of the Facilities and plant. Such instruction shall be at the Contractor’s design office and Plant manufacturers’ factories during the manufacturing period and at Site. The training shall include lectures, demonstrations and practical training as required.

The cost for training at the manufacturer’s premises including fares, accommodation and living allowances as well as the cost for site training shall be included in the Contract Price.

Training at the Contractor’s design office shall provide a sound appreciation of the design principles of substations and support structures and their foundation and design with the contemporary design software used substations such as power flow, earthing design software etc.

Training at a manufacturer’s factory facilities shall include a sound appreciation of the manufacturer’s facilities, including witnessing of type or routine tests of related facilities, as well as manufacturing processes.
The cost for training of the following nominated Employer’s staff at the Contractor’s Head Office, and/or manufacturer’s premises including airfares, accommodation, ground transport and an individual living allowance of US$250/day, as well as the cost for site training, shall be included in the Contract Price.

<table>
<thead>
<tr>
<th>Description</th>
<th>Duration</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV Substation Design Engineers</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>HV Substation Operation and Maintenance Engineers</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>Protection and Control Engineers</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>HV Transmission system Control Engineers</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>HV Communications Equipment Engineers</td>
<td>4 weeks</td>
<td>4</td>
</tr>
</tbody>
</table>

These instruction services are to be provided for under the Schedule of Rate and Prices for Installation and Other Services and may or may not be used, at the Employer’s discretion.

The Contractor shall instruct the Employer’s nominated staff in the operation and maintenance of the Facilities and their key component Plant. Such instruction shall be at the manufacturer’s factory during the manufacturing period and at the Site as appropriate. The training shall include lectures, demonstrations and practical training as required.

Substation related training at the manufacturer’s factory shall include as a minimum the following plant components, duration and number of Employer’s staff for Lot 3A and lot 3B each.

<table>
<thead>
<tr>
<th>Description</th>
<th>Duration</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV Substation Design</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>HV Substations Operation and Maintenance</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>HV Substation Protection Equipment</td>
<td>4 weeks</td>
<td>4</td>
</tr>
<tr>
<td>HV Substation Control Equipment</td>
<td>4 weeks</td>
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</tr>
<tr>
<td>HV Substation Communications Equipment</td>
<td>4 weeks</td>
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</tr>
</tbody>
</table>

The training shall include formal lectures covering theory and design, simulation of operating functions, settings, logic configurations, explanation to interaction with the plant, maintenance and troubleshooting.

Training at the manufacturer’s Facilities can include witnessing of type or routine tests of towers, as well as their manufacturing processes and/or major performance testing such as that of complete insulator and hardware assemblies.

2.13.2. SITE TRAINING

Operation and maintenance training at Site shall consist of formal lectures and practical on-the-job training of the Employer’s staff during erection, testing and commissioning.

The Employer may nominate staff to be seconded to the Contractor to participate in the site training. The Contractor shall train such staff during erection activities and ensure that erection Facilities of important plant components involve the Employer’s nominated staff.
Substation training shall be provided for up to 10 staff and shall include detailed explanations based on the Operation and Maintenance instruction manuals issued by the Contractor related to dismantling, assembly of equipment and troubleshooting shall be provided. Instructions on maintenance intervals, minimum spare and wear and tear parts shall be provided.

The Contractor shall satisfy himself and the Project Manager that the Employer’s staff is fully capable of operating and maintaining the Plant. During the final inspection, the Contractor and Project Manager will make a joint assessment of the effectiveness of training and shall develop recommendations for further training, if this be appropriate.

2.13.3. QUALITY ASSURANCE

The Contractor shall have a documented quality assurance program which is accredited as complying with ISO9001 and which is capable of providing assurance that all plant, materials and services meet the specified requirements.

The Contractor shall have a quality assurance section responsible for establishing and conducting the quality assurance program. The program shall describe the quality assurance management, their responsibility and authority. Quality assurance personnel shall be independent from those personnel performing assigned activities and shall have the organisational freedom required to resolve quality assurance problems.

The program shall cover, as a minimum, the following areas:

- Design control
- Procurement control
- Document control
- Control of inventory, including component identification
- Control of special processes; e.g. Welding, NDT etc.

The Contractor’s quality assurance system shall apply to all work undertaken by subcontractors. The Contractor shall perform periodic documented reviews of his Facilities and quality controls to assure conformance to the program and contract requirements. The Contractor shall provide the Project Manager with access to its records so that the Project Manager may undertake quality audits and inspections.

2.13.4. ENVIRONMENTAL PROTECTION

The Contractor shall comply with all local and international laws and regulations applicable to the project area with respect to environmental matters.

The Contractor shall prepare and implement an environmental management plan which includes, but is not limited to, the following:

- The operation of the Contractor’s accommodation facilities
- The operation of any manufacturing facilities at site
- Operation of the site erection Facilities
- Waste management
- Storage of fuel, oil and other hazardous substances
• Internal environmental audit plan
• Emergency response plan.

The Contractor shall obtain all approvals required from Government authorities and agencies for his operations and activities.

The Contractor’s environmental management plan and associated records may be audited by the Project Manager or by a third party agency appointed by the Employer.

2.14. INSPECTION AND TESTING

2.14.1. INSPECTION AND TESTS AT SUPPLIER’S PREMISES

All materials and plant used in the Facilities may be inspected by the Employer or Project Manager at any time.

All plant shall be subjected to all routine tests set out in relevant IEC standards, including any optional tests which the Project Manager deems to be applicable.

One item of each type of plant shall be subjected to all type tests set out in relevant IEC standards. Such tests may be waived in cases where the Contractor submits reports of type tests conducted by third-party testing agencies and which are accepted by the Project Manager as adequately demonstrating that the plant complies with the relevant IEC requirements.

Mandatory factory acceptance tests (FAT) shall be performed for all major electrical plant such as transformers, switchgear, voltage and current transformers, protection, control, and communication equipment and any other such equipment that the Employer deems to require FAT. The specifications of individual equipment that form part of these bid documents provide all equipment requiring FAT. From these specifications, the Contractor shall prepare a comprehensive list of equipment that shall be subject to FAT and shall submit for approval an inspection and test plan, and associated procedures and record sheets, at least one month before the date of any planned factory tests.

The Contractor shall submit for approval an inspection and test plan, with associated procedures and record sheets, at least one month before the date of any planned factory tests.

Factory test reports shall include current calibration records of all measuring apparatus used in the tests.

No plant shall be despatched from the factory to site prior to receiving the Project Manager’s notification that the factory tests were satisfactory. The Project Manager may request that additional tests be conducted if he is not satisfied that the factory tests have demonstrated that the plant is acceptable.

The Contractor shall provide three representatives of the Employer two (2) and the Project Manager one (1) to attend each factory test per lot. The Contractor shall meet all associated travel, accommodation and living costs, which shall be deemed to be included in the Contract Price.

For each inspection, the following are to be provided for each representative:

1. Economy class returns air ticket (from Nairobi or the Engineer’s home office to Places of Test and/or Inspection).
2. Visa expenses, airport taxes and other incidental travel expenses as required.
3. Hotel accommodation, including full board plus daily allowances of US$ 150/day for incidental expenses for a minimum of 5 days for each trip. (US$150/day for KETRACO staff only)
At least 45 days notice of the date, time and place of all tests shall be given to the Employers so that arrangements can be made to have the test witnessed.

Prior to the tests, the Contractor shall submit an outline of the procedures and tests in its plans to demonstrate fulfilment of the requirements specified in the subsequent sections of the detailed technical specifications.

Any costs incurred by KETRACO and/or Engineer in attending a repeat type test brought about as a result of a failure of the subject under test and postponement of the test programme shall be to the account of the Contractor.

2.14.2. TESTS AT SITE AND COMMISSIONING

The Contractor shall perform site tests to demonstrate that plant and systems comply with the specified requirements. They shall include all site tests included in relevant IEC standards. They shall include functional tests of all plant and systems.

The Contractor shall submit for approval an inspection and test plan and associated procedures and record sheets at least one month before the date of any planned site tests. Site test reports shall identify all measuring apparatus used in the tests. Current calibration records of all measuring apparatus used on site shall be included in a separate report.

The Contractor shall provide all plant, materials and facilities needed for the site tests.

Testing at site shall be carried out by experienced test personnel and may be witnessed by the Project Manager and/or Employer.

All site tests shall have been completed to the satisfaction of the Project Manager prior to commissioning.

The Contractor shall submit for approval a commissioning plan, and associated procedures and record sheets, at least one month before the date of any planned commissioning. The Contractor shall coordinate with the Employer and the Project Manager to identify all third party involvement in commissioning and to develop any necessary switching sequences. The first stage of any commissioning shall be functional tests to confirm that plant operates correctly prior to energising.
3. POWER TRANSFORMERS

3.1. DESIGN

3.1.1. GENERAL

This section of the Employer’s Requirements covers the design, manufacturing, testing, transporting, installation and commissioning of the 132/33kV power transformers.

The Contractor shall provide 132/33 kV power transformers with proven experience of operation in service conditions as obtaining in Kenya or other designs and material that can demonstrate a similar proven in-service duty for the specified lifetime of equipment under the same service conditions as specified for this Project.

All materials, designs, details, fabrications and tests shall be in compliance with details on the drawings, with the requirements described hereafter and with the minimum design data specified in Section 2.2.

Design and detailing documentation shall be subject to approval by the Project Manager. However, the Contractor shall be wholly responsible for the trueness of the designs. Approval of the designs by the Project Manager shall not alleviate the Contractor from its full contractual responsibility for the design of the transformer and its accessories for full functionality.

All necessary modifications in details for the Project to conform to these Employer’s Requirements shall be carried out by the Contractor at no additional cost to the Employer.

All Transformers supplied shall be brand new and shall be outdoor, oil-immersed, with on-load tap-changer. Subject to transport constraints, transformers shall be three-phase. Transformers shall be designed to operate continuously under all the service conditions prevailing at the site. The temperature-rise limits set out in IEC 60076-2 and IEC 60354 shall be reduced to allow for the high ambient temperatures at the site.

Power transformers terminations shall be bushings for 132 kV and 33 kV.

The vector group of all the power transformers shall be DNyدd11

3.1.2. STANDARDS

The Transformers shall comply with the following IEC Publications unless otherwise specified herein.

- IEC 60060 “High-Voltage Test Techniques”
- IEC 60071 “Insulation Co-ordination”
- IEC 60076 “Power Transformers”
- IEC 60137 “Insulating Bushings for Alternating Voltages above 1kV”
- IEC 60156 “Method for Determination of Electric Strength of Insulating Oils”
- IEC 60168 “Tests on Indoor and Outdoor Post Insulators for Systems with Nominal Voltage Greater than 1 kV”
- IEC 60296 “Specification for New Insulating Oils for Transformers and Switchgear”
3.1.3. HARMONIC SUPPRESSION

Transformers shall be designed with particular attention to the suppression of harmonic voltages, especially the third, fifth and seventh harmonics and to minimise the associated harmful effects.

3.2. MAGNETIC CORE AND WINDINGS

3.2.1. MAGNETIC CORE

The core shall be built up of high-grade, non-ageing, low-loss, and high-permeability grain oriented steel sheets. Both sides of each steel sheet shall be insulated with durable, hot oil and heat resistant baked enamel varnish or other chemical treatment.

The cores shall be clamped and braced to withstand, without damage or deformation, the forces caused by short-circuit stresses, transportation, handling or seismic effects, and to prevent the shifting of the core laminations. The bolts, nuts, and end plates of the assembly and clamp structure shall be of a nonmagnetic type, and shall be effectively insulated and locked so that they ensure an even pressure on the whole core assembly and are not loosened by vibrations.

The supporting framework of the cores shall be designed to avoid the presence of pockets which could prevent complete draining of the tank or cause the trapping of air when filling during service.

Suitable axial cooling ducts shall be provided to ensure free circulation of oil and efficient cooling of the core.

Particular care shall be given to the design and construction of the corner joints between columns and yokes to avoid concentration of mechanical and magnetic stresses whilst allowing an easy dismantling of the joint for maintenance at site.

Adequate metallic bridges shall be provided between the core lamination packets in order to keep all portions of the core assembly at the same potential.

The maximum flux density in any magnetic component under any condition of voltage and frequency specified under all the operating conditions shall not exceed 1.9 Tesla.

The magnetic circuit shall be insulated from all structural parts, and shall be capable of withstand a test voltage to the core bolts and to the frame of 2.0 kV rms for 1 minute.

3.2.2. WINDINGS

The windings shall be of high conductivity electrolytic copper.

The coils, windings and leads shall be sufficiently braced and fastened to form rigid assemblies, preventing any relative movement due to transport, vibrations or other circumstances that may occur in service.

The windings shall be designed to reduce to a minimum the out-of-balance forces inherent in the transformers. Tapings shall be arranged at such positions on the windings as will preserve, as far as possible, electro-magnetic balance at all voltage ratios.

The winding shall be capable of withstanding the forces to which it is subjected under all conditions, particularly the forces due to a short circuit between terminals or between any terminal and earth, with full voltage maintained on all other windings.
The tertiary windings of the star/star connected transformers are stabilising windings for control of zero sequence current and for harmonic suppression. The stabilising winding shall be brought out by two bushings at one corner of the delta; these shall be connected and grounded in service.

3.2.3. INTERNAL EARTHING

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 earth potential.

The magnetic core 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. Disconnecting this link will enable the insulation between the core and clamping arrangement to be tested at voltages up to 2.0 kV. The removable link shall have adequate cross section to carry the earth fault current. The link shall have no detachable components and the connection to the link shall be on the same side of the core as the main earth connection. All insulating barriers within the magnetic core shall be bridged by means of aluminium or tinned copper strips so inserted as to maintain electrical continuity.

3.3. TANKS AND ANCILLARY EQUIPMENT

3.3.1. TRANSFORMER TANKS

The transformer tank shall be of welded construction with bolted cover, fabricated from carbon steel plates such that the transformer can be lifted and transported without permanent deformation or oil leakage. The tank shall comprise two oil-tight compartments, one for the transformer winding and other associated equipment, and another for installation of the OLTC diverter. Tank stiffeners and mounting brackets shall be continuously welded to the tank.

The transformer may be lifted by mobile crane into position on site or it may be skidded into position on rollers, greased plates or rails. The tank construction shall be such that both these methods are possible and the complete transformer unit can be moved in any direction without damage. A design which requires that slide rails be placed in a particular position shall not be used. The transformer shall be designed with a flat or skid base with provision of vibration dampers.

Inspection doors and openings shall be provided on the tank to give access to the coils, internal connections of bushings, winding connections and earth links. It shall be possible to remove any bushing without removing the tank cover. Each opening shall be correctly located and must be of ample size for the purpose for which it is intended. All inspection covers shall be provided with lifting handles.

The tank cover shall be fitted with thermometer pockets for oil and winding temperature indicators. 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.

The transformer tank shall be capable of withstanding an internal positive pressure of not less than 70 kPa without any permanent deflection of any parts. The tank shall also be capable of withstanding a vacuum of 50 mm of mercury absolute when emptied of oil.

3.3.2. CONSERVATOR TANK

The conservator tank shall have two separate oil containing compartments— one for the main transformer tank and another for the OLTC tank.

Each conservator oil compartment shall be equipped with its own oil level indicator, breather, drain and filter valves, air ventilation, removable end plates for inspection and maintenance and lifting
lugs. The conservator of the main tank shall be equipped with an airbag filled with dry air, which isolates the transformer oil space from the ambient air. Provision shall be made to monitor the integrity of the airbag and to give an electrical alarm if it is damaged.

The space inside the airbag shall be connected to ambient air through an oil seal type silica gel breather, designed for humid environmental conditions and mounted approximately 1,400 mm above ground. The weight of the dehydrating agent shall be not less than 0.5 kg per 1,500 litres of oil in the transformer and cooler. Facilities shall be provided for inspection of the colour and condition of the silica gel.

An oil level gauge shall be mounted on each compartment and positioned to be easily read from ground level. The normal level at an oil temperature of 20°C shall be indicated and the minimum and maximum levels shall also be correlated with oil temperature markings. The temperature markings shall be integral with the level-indicating device.

### 3.3.3. Oil Valves and Location

Each transformer shall be fitted with the following valves as a minimum requirement. All the valves shall be made of brass and have provision for padlocking. There shall be an arrow marking in the handhold to indicate the OPEN/CLOSE position.

**Main Tank**

- One 50 mm nominal bore gate valve for oil treatment (oil inlet) near to the top of the tank.
- One 50 mm nominal bore gate valve for oil treatment (oil outlet) near to the bottom of the tank, located diagonally opposite to the oil inlet valve.
- One residual oil drain gate valve on the bottom of tank, with such arrangements as may be necessary inside the tank to ensure that the tank can be drained of oil as far as practicable. This valve shall also be provided with an approved oil-sampling device.

**Conservator – Main-Tank**

- One gate valve between the conservator and Buchholz relay and Buchholz relay and main tank.
- One drain gate valve for the oil conservator so arranged that the tank can be completely drained of oil.
- One pressure equalising gate valve between main tank conservator and the OLTC conservator.
- One outlet valve with closure cap to drain the conservator.
- One gate valve on the by-pass pipe of the Buchholz relay.

**OLTC conservator- OLC COMPARTMENT**

- One gate valve between the OLTC conservator and protection relay and between the protection relay and OLTC compartment.
• One drain gate valve for the OLTC conservator so arranged that the tank can be completely drained of oil.
• One outlet valve with closure cap to drain the conservator.

**OLTC CHAMBER**

• One outlet valve with closure cap to drain the compartments.
• One 50 mm nominal bore gate valve for oil treatment (oil inlet) near the top of the compartments.
• One 50 mm nominal bore gate valve for oil treatment (oil outlet) near to the bottom of the compartments.

**3.3.4. RADIATORS**

Each radiator shall be connected to the main tank through flanged butterfly valves (on the top and bottom of radiator). Vent screws shall be fitted at the top of each radiator for air release and at the bottom for draining. Valves shall be provided on the tank at each point of connection to the detachable radiator. Blank flanges, plates or captive screw caps shall be fitted to all valves and pipe ends not normally connected in service.

**3.3.5. OIL AND GAS SAMPLING DEVICES**

Oil sampling devices shall be fitted for taking oil samples from the top and bottom of the main tank and from the OLTC oil compartment. Sampling points shall be accessible to a person standing at ground level (approximately 1,400 mm above ground). The following valves shall be provided:

1. One outlet valve with closure cap for oil from the middle of the tank.
2. One outlet valve with closure cap for oil from the bottom of the tank.
3. One outlet valve with closure cap for oil from the top of the OLTC compartments (tank).
4. One outlet valve with closure cap for gas from the Buchholz relay.
5. One outlet valve with closure cap for gas from the OLTC gas actuated protective relay.

**3.3.6. OIL FILTRATION AND VACUUM PROCESSING**

The transformer shall be fitted with gate oil valves and suitable removable flange adapters for the connection of oil filter and vacuum equipment.

**3.3.7. LIFTING LUGS, JACKING PADS AND HAULING EYES**

Lifting lugs shall be provided, suitable for the weight of the transformer, including core and windings, fittings, and with the tank filled with oil. The tank shall be provided with at least four lifting lugs. Lifting lugs shall be provided on all parts, which require lifting for erection, maintenance, inspection or repair.

The tank shall be provided with minimum of four jacking pads conveniently located to allow the raising or lowering of the completely mounted and oil filled transformer. The load carrying capacity of each jacking pad shall not be less than 50% of the total weight of the transformer.

Hauling eyes with suitable lugs shall be provided on all sides of the transformer for haulage in any direction.
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.

3.3.8. JOINTS AND GASKETS

Gaskets shall be of approved material impervious to and having no deleterious effect on transformer oil. Gaskets made from nitrile rubber and utilising compression control stops are preferred. Oil resistant synthetic rubber gaskets will not be accepted except where the synthetic rubber is used as a bonding medium for cork or similar material or where metal inserts are provided to limit compression. The Contractor shall submit the material proposed for gaskets and the method of application for approval.

All joints shall be made oil-tight and shall be so designed that no deterioration of the gaskets, which could give rise to oil leakage, will take place in service, and all such joints shall withstand without leakage the maximum vacuum which may be applied to the assembled transformer during commissioning or subsequent maintenance.

3.3.9. EARTHING TERMINALS

Earthing terminals shall be provided on the transformer, close to each of the four corners and bottom of the tank to connect the transformer to the earthing system. Earthing terminals shall be suitable for an M12 bolt.

3.3.10. SURFACE TREATMENT

The interior surfaces of transformers shall be sandblasted and finished with two coats of anti-corrosive and oil-resistant priming paint. Exterior surfaces shall be sand-blasted and have two rust inhibiting priming coats and one intermediate coat with paint on zinc chromate or urethane alkyd basis or equivalent; one final coat of weather and oil resistant paint of 0.20 mm minimum total thickness.

All interior and exterior surfaces subject to corrosion, that cannot readily be painted shall be hot-dip galvanised with an average thickness not less than 0.1 mm. Bolts and nuts associated with galvanised parts shall be hot-dip galvanised.

The radiator external surfaces shall be hot-dip galvanised with a zinc deposit on average not less than 400 g/m² and painted the same colour as the tank.

3.4. PROTECTION AND INDICATION EQUIPMENT

3.4.1. BUCHHOLZ RELAY

Each transformer shall be fitted with a double float Buchholz type relay with alarm contacts and tripping contacts. The relay shall be provided in the pipe connection between the main tank and associated conservator with two isolating valves and a by-pass pipe with valve.

The upper float of the Buchholz relay shall operate contacts on accumulation of gases caused by a gradual fault. The lower float shall operate contacts on occurrence of a sudden oil flow caused by an explosive development of gases.

Each Buchholz relay shall be equipped with a gas-sampling valve with outlet approximately 3 mm diameter for a flexible pipe connection to check the operation of the relay. A small bore pipe shall be connected to the gas release cock on the Buchholz relay to allow gas to be collected at ground level. The pipe shall be run to a point approximately 1,400 mm above ground level, where it shall be
terminated by an isolating valve and gas sampling valve with captive screwed cap. This shall have provision for locking to prevent unauthorised operation.

Each relay shall be fitted with a calibrated glass window to indicate gas volume; a testing mechanical push button with protective cover; oil drain valve at the bottom with blanking plug; cable glands etc. The pipe work shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay.

3.4.2. OLTC PROTECTIVE RELAY

A Buchholz relay, similar to the main tank relay, shall be mounted in the connection pipe from the OLTC compartment head to the associated oil conservator with two isolating valves. The relay shall be actuated by an oil flow caused by a tap-changer fault.

3.4.3. PRESSURE RELIEF DEVICES

Approved pressure relief devices shall be provided for the main oil tank and tap changer oil compartment (chamber). They shall be of sufficient size for the rapid release of over pressure that may be generated in the tank and designed to operate at a static pressure lower than the design hydraulic test pressure. Pressure relief devices shall not be electrically operated, and shall be provided with two sets of signalling contacts.

The relief devices are to be mounted on the tank covers. Where possible the oil discharge shall be directed away from the transformer top cover and clear of any manual operating position to minimise the overall effect.

3.4.4. TEMPERATURE INDICATING, CONTROL AND ALARM DEVICES

Temperature indicators shall be of the dial-type graded in °C, with a manually resettable pointer to register the highest temperature reached. The indicators shall be mounted on the transformer in a suitable weatherproof steel cabinet with a lockable door. The cabinet shall be so positioned as to allow easy access to and readability of the gauges.

Each transformer shall be provided with one winding temperature indicator of the "thermal image" type compensated for changes in ambient temperature for each winding type high voltage, low voltage and tertiary as appropriate. The indicator shall be provided in one phase only. The indicator shall have a load-temperature characteristic approximately the same as the hottest part of the windings. The primary current transformer for operating the indicator shall be built into the main transformer tank on the bushings. Information shall be included in the maintenance instructions in the form of either a graph or table showing the relationship between current injected into the heater coil and the corresponding temperature reading. Each indicator shall be fitted with two sets of adjustable contacts, one connected to give a high temperature stage 1 alarm and one to give a high temperature stage 2 trip. The high voltage winding indicator shall have two additional contacts for control of the cooling fans.

Each transformer shall be provided with a dial type thermometer connected by a capillary to a temperature-sensing element suitably located in a pocket in top oil. The indicator shall be fitted with two sets of adjustable contacts, one connected to give a high temperature stage 1 alarm and one to give a high temperature stage 2 trip.

Temperature indicator dials shall be approximately 150 mm diameter and shall have linear gradations to clearly read at least every 2°C.
The instrument and set points shall have an accuracy of ±1% of full scale deflection and the indicated winding temperature must reflect the hot spot temperature to within ±3°C under all operating conditions. A contact which has closed shall re-open when the temperature has fallen by approximately 10°C.

The transformer winding temperature current transformers shall be equipped with test windings. Checking the output and testing of the current transformer and thermal image characteristics shall be via terminals in terminal box. It shall be possible to remove the indicator bulbs without draining oil from the tank.

The colours of the pointer and dial plate shall be non-fading in intense sunlight conditions.

### 3.5. ON LOAD TAP CHANGER (OLTC)

#### 3.5.1. GENERAL

The transformer shall be provided with an on load tap changer mounted in the high-voltage winding. The tap-changer shall be in accordance with IEC 60214, shall operate based on the Jensen principles and shall feature low-maintenance characteristics, preferably with belt-type (oil-free) transmission gear. The OLTC manufacturer shall be an internationally recognised manufacturer with at least 5 years proven successful experience in manufacturing OLTC equipment.

Tap positions shall be numbered consecutively ranging from one upwards. All terminals shall be clearly and permanently marked with numbers corresponding to the cables connected thereto.

The tap changer diverter switch shall be in its own oil-tight compartment supplied from a separate compartment in the conservator tank. To facilitate inspection and maintenance of the OLTC switch, it shall be possible to drain the oil from around one without lowering the level of the oil in the transformer below the top of the windings. Adequate access for personnel shall be provided for inspection and maintenance.

#### 3.5.2. DRIVE MECHANISM

The tap changer shall be driven by a motor operated mechanism. The mechanism shall incorporate a stored energy device to ensure that once a change of tap begins it is completed and the mechanism cannot fail in an intermediate position on loss of the supply voltage to the motor or any other contingency.

The motor drive control shall ensure that a tap change operation, once initiated, is completed whether or not the control switch or push button is operated continuously during the operation. Another operation shall only be possible when the control switch or push-button has been released and the tap change sequence has been completed.

Phase failure relays shall be provided at the transformer to monitor the tap changer motor power supply.

Limit switches shall be provided to prevent over-travel 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-travel of the mechanism under any conditions. 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 OLTC control and drive mechanism box.
3.5.3. TAP CHANGER MECHANISM BOX

The transformer shall be provided with an outdoor tap-changer mechanism box fitted with all equipment necessary for manual and electrical - local and remote operation of the OLTC. The motor and control circuits shall be protected by miniature circuit breakers at the tap changer mechanism box.

The mechanism box shall have a hinged door and shall be mounted on the transformer tank using anti-vibration mountings. The degree of protection of the mechanism box shall be IP43. The mechanism box shall be ventilated and designed to minimise condensation. The door shall have padlock facilities.

The OLTC drive mechanism control box installed at the transformer shall contain all the electrical and mechanical parts for the Local Control. A REMOTE/LOCAL selector switch shall be provided at the mechanism box to select either remote or local operation. When this switch is turned to the "LOCAL" position, control shall be possible from drive mechanism control box only. Interlocking shall be provided to interrupt the electrical supply to the drive motor when the manual operation device is engaged.

The following controls shall be provided in the mechanism box:

- Facilities for manual mechanical operation of the tap changer
- Facilities for electrical “RAISE” and “LOWER” operation by control switch or push buttons.

The mechanism box shall include a voltage relay which shall prevent a RAISE operation if the transformer voltage exceeds a set value.

The mechanism box shall include a mechanical tap position indicator and an operation counter. It shall also contain a tap position transmitter with a 4-20 mA analogue and a digital (BCD) output.

The inside of the mechanism box shall be treated with anti-condensation or thermal barrier type paint to a light or white finish. The mechanism box shall be fitted with an anti-condensation space heater, which shall be controlled as follows:

- A manual switch with OFF/AUTO positions. A humidistat and/or thermostat shall automatically control the heater in the AUTO position.
- A humidistat with an adjustable operating range.
- A cut-out thermostat with an adjustable operating range, to prevent overheating.
- Test circuits with test push-button and associated lamp. The lamp shall indicate "HEATER IS WORKING" when the test push button is pressed.

The heater control circuits shall operate at 240 V, 50 Hz. An internal lamp controlled by a door switch shall be provided.

The Contractor shall state the maximum internal temperature at which the mechanism box is designed to operate under site conditions. This temperature shall take into account the effects of solar heat gain, transformer losses at full power and any heat released in operation of equipment in the box. The Contractor shall provide evidence that all the equipment in the mechanism box is designed to operate continuously at this temperature.
3.5.4. OLTC CONTROL PANEL

Each OLTC shall have an associated OLTC control panel located in the control building. The panel shall provide for remote manual and automatic control of the tap changer when the control selector switch in the tap changer mechanism box is selected to “REMOTE”.

The OLTC control panel shall include a MANUAL/AUTO selector switch, a LOCAL/REMOTE point of control selector switch and RAISE/LOWER pushbuttons.

When control is selected to “MANUAL”, tap changer raise and lower control shall be from the RAISE/LOWER pushbuttons if LOCAL control is selected or through the substation control or SCADA system if REMOTE control is selected.

When control is selected to “AUTO”, tap changer raise and lower control shall be automatic through a voltage control relay. The voltage control relay shall be responsive to variation in the measured voltage and cause the necessary tap change to be made to restore the voltage to the desired level within pre-determined limits. It shall include control selections INDEPENDENT/PARALLEL and MASTER/FOLLOWER. If INDEPENDENT control is selected, the OLTC shall be controlled from a set point within the voltage control relay. Two or more transformers operating in parallel may be selected for PARALLEL OLTC control, in which case one of them shall be selected as MASTER and the others as FOLLOWER. The voltage control relay of the transformer selected as MASTER shall control all transformers in the group from a set point within its voltage control relay.

During a master/follower tap change operation, tap changing shall be staggered to ensure that only one transformer is changing tap at any time.

All transformers operating in parallel shall be on the same tap and the maximum difference between transformers when tap changing shall be one tap. Operation with a tap difference greater than one shall be prevented and an ”out-of-step” alarm signal shall be given if the tap difference is one for an excessive time.

The voltage control relay shall include facilities for proportionate load sharing for transformers operating in PARALLEL control.

The voltage control relay shall include inverse or definite time operating characteristic, line drop compensation, under-voltage and over-voltage detectors, blocked tap change operation, over-current and circulating current supervision, load shedding/boosting capabilities, reverse reactance or circulating current tap position indication. The relays shall also have integral serial communication facilities through which it shall be possible to read, reset and change settings from a local or remote personal computer. Relay setting shall also be possible through a keypad on the relay.

- Tap position.
- “Tap change in progress” indication.
- “Tap changing incomplete” alarm.
- “Parallel operation – out of step” alarm.
- “Motor or control supply failed” alarm.

3.6. COOLING EQUIPMENT

3.6.1. GENERAL

A combination of two methods of cooling ONAN/ONAF shall be applied to the transformer. The transformer shall be capable of operating under the ONAN condition up to its ONAN rating, after
which the cooling equipment shall come into operation and the transformer shall operate as an ONAF unit. Failure of any one fan in each group shall not reduce the continuous maximum ONAF rating of the transformer. The transformer ONAN and ONAF ratings shall be guaranteed by the Contractor.

3.6.2. RADIATORS

The transformers shall be equipped with detachable flanged radiators, designed in such a manner that all painted surfaces can be easily cleaned and re-painted. The design shall also avoid pockets in which water can collect and shall be capable of withstanding the pressure test as defined in this specification.

Each radiator group shall be equipped with drain valve and air release plug.

Dismantling of one of the radiators shall be possible without causing the temperature to rise above the permissible values.

Suitable valves, with spare blanking plates shall be provided at the inlet and outlet of each radiator so that it may be removed without draining oil from the tank. Inlet and outlet valve "OPEN" and "CLOSED" positions shall be clearly marked. The valves shall be readily accessible and easy to operate. Lifting facilities, a drain cock and an air release vent shall be provided on each radiator.

3.6.3. FANS

The forced air-cooling shall be provided by electric motor driven fans. Fans shall be of low noise type and approved make and design and be suitable for continuous operation outdoors. Fan motors shall be suitable for direct-on-line starting, and motor enclosures shall have class IP54 protection.

To reduce noise to the practical minimum, motors shall be mounted independently from the coolers or alternatively over fixing springs. It shall be possible to remove the fan complete with motor without disturbing or dismantling the cooler structure framework.

Fan blades shall be of galvanised steel or cast aluminium alloy unless otherwise approved. The thickness of galvanising shall be at least 55 μm. Blower casings shall be made of galvanised steel of thickness not less than 2.0 mm or aluminium alloy and shall be suitably stiffened by angles or tees.

Galvanised wire guards with mesh not exceeding 12.5 mm shall be provided to prevent accidental contact with the blades. Guards shall also be provided over all moving parts. Guards shall be designed to provide a protection of IP2X to the fan blades. The direction of rotation shall be indicated.

3.6.4. FAN CONTROL

Fan operation shall be selectable TEST/NORMAL. In NORMAL operation the fans shall be automatically switched ON when the transformer winding temperature exceeds pre-set values and shall be switched OFF when the winding temperature falls below these values. Fans shall be separated in two groups and controlled by contacts of the winding temperature indicator, depending on transformer load (one or two groups together). In TEST operation fans (or fan groups) shall be started and stopped using local pushbuttons.

Motor contactors shall comply with IEC 60158 or equivalent International standard class of intermittent duty 0 3 with type IP52 enclosure protection and utilisation category AC4. The contactors and their associated apparatus shall be capable of switching the stalled current, and shall have a continuous current rating of at least 50% greater than the full load current of the motors they control.
The operating currents of overload trips fitted to motor contactors shall be substantially independent of ambient temperature conditions, including the effect of direct sunlight on the enclosure in which the contactors are installed.

Where small motors are connected in groups, the group protection shall be arranged so that it will operate satisfactorily in the event of a fault occurring on a single motor. The control and protection equipment shall be accommodated in the control cabinet or marshalling kiosk.

Each motor or group of motors shall be provided with control gear for starting and stopping by hand and automatically from the winding temperature indicator. Overload and single phase protection shall be provided.

Fan control shall include staggered start to prevent the starting of motors totalling more than 15 kW simultaneously.

3.6.5. FAN CONTROL CABINET

All the necessary automatic control, motor contactors, protective devices and switches for the forced-cooling plant shall be assembled in a dust-proof, weatherproof and vermin-proof fan control cabinet preferably mounted on the transformer tank using anti-vibration mountings.

A fan control box shall include a general purpose single-phase 13 A socket outlet.

3.7. TERMINALS AND CONNECTION ARRANGEMENT

3.7.1. BUSHINGS

Power transformers shall be equipped with bushings for the 132 kV and 33 kV connections.

Bushing insulators shall be of the condenser type made of high quality electrical porcelain and copper of high conductivity, filled by transformer oil and mounted on the transformer cover (inside the cable boxes). The design of the bushings shall be such that stresses and strains due to the differing thermal characteristics of the components shall not exceed the safe limit and shall not produce a cumulative reduction in mechanical and electrical strength. A vent screw shall be provided.

Insulators shall be made in one piece, with mounting flange manufactured of corrosion-resistant alloy. Each bushing shall be fitted with bolted brass clamps with internal thread, suitable for connecting cables or auxiliary disconnecting flat copper conductors. Dismantling or replacing of bushings shall not require opening of the transformer tank cover.

The rated current of bushing leads shall be 120% of the continuous rated capacity of the transformer. Other technical characteristics of bushings shall be in accordance with the relevant IEC and DIN Standards.

3.8. HANDLING EQUIPMENT

Specific handling equipment for the transformer shall be provided. The handling equipment to be provided shall be compatible with the fittings provided on the Transformers. The handling equipment shall include the following:

- A set of four jacks.
- A set of four skids.
• A set of pulling devices.
• Bushing handling slings.
• A set of slings for radiators, conservators, etc.

3.9. HIGH VOLTAGE AND MV NEUTRAL POINT

To facilitate the application of neutral earth fault protection arrangements, the neutral point of 132kV and 33 kV sides of all transformers shall be brought out by an outdoor air bushing mounted on the cover of the tank.

The neutral earthing connection shall be by copper conductors of adequate section but of at least 185 mm² secured by insulators to pads on the tank wall, with bolted connections descending to the earth grid. Bare conductors shall be shielded to prevent contact by personnel.

3.10. TERMINAL MARKING

The phase labels of terminals shall be in accordance with the relevant IEC standards. Terminal markings shall be cast-in or moulded-in lettering on the plates which shall be non-ferrous material and permanently fixed.

3.11. LABELS AND RATING PLATES

The following plates, or an approved combined plate, shall be fixed to the transformer tank at an average height of 1,500 mm above the ground level:

• A rating and diagram plate in accordance with the relevant IEC standard shall be provided. This shall include this specification number and full details of all CTs.

• A plate showing the location and function of all valves, oil sample devices and air vent or plugs. This plate shall also incorporate a warning to operators to refer to the Operation and Maintenance Manuals before applying vacuum.

Rating Plates are to be of stainless steel with clear and indelible markings in the English language, capable of withstanding the rigorous, continuous outdoor service at site.

Labels shall be attached to all valves and devices accordingly to the general technical requirements. Labels shall be attached to HV and control cable boxes and to all gas release, gas sampling and Buchholz test points stating the name of the associated compartment. The direction of rotation of operating handles, valves and fans shall be clearly labelled or marked.

3.12. TRANSFORMER OIL

The transformers shall be supplied complete with the first filling of ester oil.

Oil shall be compatible with the oil used in the manufacturer's works and with oil which is readily available commercially. The oil properties shall be not less than the best values for those for mineral insulating oil to IEC60296 to be used on this class of power transformer, other than those of viscosity at low temperature.
The Contractor shall submit a detailed specification of the insulating oil for approval.

At each substation an additional quantity of transformer oil comprising 10% of the total quantity for all transformers in that substation shall be provided. The complete quantity of insulating oil shall be supplied in 210 litre drums suitable for long term storage in facilities which shall be provided by the Contractor on the site for this purpose.

3.12.1. DRYING OUT, TRANSPORT AND FILLING

The transformers shall be dried out by an approved method at the manufacturer's factory and so arranged that they can be put into service without further drying out at the site.

Transformers shall be transported without bushings, conservator, pipes, cable boxes, wheels, radiators and protective devices. The oil tank shall be drained and filled with dried nitrogen or air. Before transport, transformers shall be fitted with a shock indicator (impactograph), humidity indicator and gas pressure gauge with an adequate gas cylinder to maintain internal pressure above atmospheric. The Contractor, in the presence of the Project Manager, shall check all these indicators and gauges after unloading and before commencement of erection. If there are any adverse indications, the Contractor shall undertake further investigations, tests and remedial treatment to ensure that the transformer will satisfy the technical requirements.

Clear instructions shall be included in the Operating and Maintenance Manuals regarding any special precautionary measures (e.g. strutting of tap changer barriers or tank cover) that must be taken before transformer vacuum treatment and filling can be carried out. Any special equipment necessary to enable the transformer to withstand the treatment shall be provided with each transformer.

As soon as possible after the transformer is off loaded on the transformer pad, it shall be filled with suitable oil as specified in Section S14. Transformer shall be filled under vacuum and the oil shall be circulated and treated until it has a breakdown voltage not less than 60 kV r.m.s and water content less than 15 ppm.

3.13. NOISE LEVEL

Noise under all operation conditions shall not exceed 70dB(A). During the factory tests transformers shall be tested at no-load and at rated load with all cooling running to confirm that the corrected average weighted sound pressure level is not greater than 70dB(A) when tested in accordance to IEC 60076-10.

Noise levels measured on site shall not be more than 80dB(A) at any location more than 2 m from a transformer under all loading conditions.

3.14. TESTS

3.14.1. INSPECTION AND TESTS

The Employer or Project Manager may inspect the transformer at any stage of manufacture or be present at any tests. Such inspection shall not relieve the manufacturer of his responsibility for meeting all requirements of the specification. Similarly any such inspection will not prevent subsequent rejection where any materials or component of a power transformer are subsequently found defective.

The Contractor will meet all costs for three representatives of the Employer to witness the factory tests.
Timing of tests shall generally be in accordance with the agreed work programme. The Contractor shall provide at least two weeks notice of the intention to conduct factory tests and their location. Associated inspection and test plans and procedures shall be submitted for approval not later than the time that the notice is given.

No transformer shall be prepared for transportation or dispatched from the manufacturer’s works without the prior approval of the Project Manager.

3.14.2. TYPE TESTS

Transformers shall be deemed to have satisfied all type test requirements set out in relevant IEC standards. The Contractor shall submit type test reports of tests conducted by a third party testing agency which have been undertaken in the last 5 years and which cover all type tests required in IEC standards. If the Contractor has not submitted acceptable type test reports prior to the factory tests, the outstanding type tests shall be included in the factory tests and shall be performed on one transformer of each voltage and output. Where a type test might impair the performance or service life of a transformer, it shall be conducted on a transformer equal to but not part of the transformers being provided under the Contract.

The Employer may accept type test reports on a transformer of the same design and a similar rating as satisfying this requirement.

3.14.3. FACTORY TESTS

All routine tests included in relevant IEC standards shall be performed on all transformers as part of the factory tests.

The Contractor shall coordinate with the Project Manager to determine if any routine tests which are identified in the IEC standards as optional are required to be performed.

3.14.4. TESTS AT SITE

Before commissioning and energising of transformer, the site tests shall include but are not limited to:

- Insulation resistance test at 2.0 kV between core and core clamping structure.
- After treatment breakdown voltage tests not less than 60 kV on insulating oil.
- Check of calibration of oil/winding temperature devices.
- Tap selector and diverter switch alignment.
- Calibration of automatic voltage control equipment.
- Proving tests as necessary on control schemes.
- HV and LV winding resistance.
- Test on protection devices, test and calibration of temperature meter.
- Tan delta and capacitance of winding.
- Test of alarms operation of OLTC
- Dissolved gas analysis test according to the relevant IEC standard.

The dissolved gas analysis test shall be repeated one month after energisation and at the end of the Defects Liability Period.
3.15. **GUARANTEES**

Transformer ratings and losses shall be guaranteed by the Contractor.

If a transformer fails to meet the guaranteed values during factory tests, the Employer may reject the transformer or may apply liquidated damages.

3.15.1. **RATED OUTPUT**

If the rated output is less than the guaranteed output, the liquidated damages shall be:

FOB price for transformer x (guaranteed output – measured output) ÷ (guaranteed output).

3.15.2. **LOSSES**

For every one kW exceeding the guaranteed value the liquidated damages shall be:

- No-load losses $7,040 per kW
- Load losses $3,520 per kW

Where $ represents one United States dollar. These values are based on 25 years period of evaluation and $0.08/kWh. The load factor assumed for no-load losses is 100% and that of load-losses is 50%.
4. HIGH VOLTAGE SWITCHGEAR AND SWITCHYARD EQUIPMENT

4.1. GENERAL

This Chapter covers the technical requirements of the 132kV equipment to be installed at the outdoor switchyards.

The supply shall comprise all apparatus and requisite accessories, conductors, insulators, clamps and connections, earth wires, operating cubicles, cable marshalling kiosks, fixing materials, apparatus supports and towers for the complete plants.

4.2. DESIGN

132 kV switchgear shall comply with the latest versions of IEC 62271 standards and the requirements of this specification. Basic equipment parameters are given in Section 0.9.

The high voltage switchgear shall be of the outdoor type and capable of continuous operation under the climatic conditions existing at the Site.

The control of high voltage switchgear shall be local at the equipment or from a remote location.

The switchgear shall be designed to minimise corona or other electrical discharges and radio interference. Tests for corona and radio interference shall be carried out by the Contractor at its works for all equipment, as applicable, and if necessary at Site if required by the Employer.

Single line diagrams and typical layouts are included in the Drawings

4.3. 132 KV CIRCUIT BREAKERS

4.3.1. GENERAL

132 kV circuit breakers shall conform to IEC62271 and shall be three-pole outdoor and of the single-pressure, sulphur hexafluoride (SF6) type mounted on steel structures with motor-charged spring operating mechanism. Each interrupter shall be capable of interrupting rated fault current at least 15 times without any reconditioning.

The circuit breaker shall be complete with terminal connectors, operating mechanism, control cabinets, piping, interpole cable, cable accessories like glands, terminal blocks, marking ferrules, lugs, pressure gauges, density monitors (with graduated scale), galvanised support structure for CB and control cabinets, their foundation bolts and all other circuit breaker accessories required for carrying out all the functions the CB is required to perform.

The total breaking time (opening time plus duration of the arc) of the breakers shall be as short as possible, but in no case is it to be longer than 50 ms.

132 kV circuit breakers shall be suitable for both three-phase rapid auto-reclosing and three-pole low speed single-shot automatic reclose and shall have operating sequence O – 0.3 s – CO – 3 min - CO.

The circuit breakers shall be suitable for clearing any fault at any location in the electricity network shown on the Drawings.
They shall be capable of breaking any current from zero to their rated breaking current at any voltage up to the rated voltage in a predominantly resistive or inductive circuit; the use of opening resistors shall not be permitted. No re-strikes at the main contacts shall be permitted under any operating duty.

The breaker shall be capable of interrupting the steady state and transient magnetizing currents corresponding to power transformers and shall be able to satisfactorily withstand the high stresses imposed on it during fault clearing, load rejection and re-energisation of lines with trapped charges.

If a circuit breaker uses multi-break interrupters, these shall be designed to have uniform voltage distribution across them.

The maximum sound pressure level when the circuit breaker is opened or closed shall be less than 140 dB(A) at the local control cabinet.

At least 5 normally open and 5 normally closed auxiliary contacts in addition to those required for operation and indication shall be provided on each circuit breaker pole.

### 4.3.2. CIRCUIT BREAKER OPERATING MECHANISM

Circuit breakers shall be operated by a motor-operated, spring-charged mechanism. 132 kV circuit breakers may have one mechanism for the complete circuit breaker.

Circuit breaker operating mechanisms shall be “trip free”.

Circuit breaker opening and closing shall be independent of the operating mechanism motor, which shall be solely used for charging the mechanism. After circuit breaker closing, the motor shall fully recharge the mechanism within 15 s. An alarm shall be given if the operating mechanism is not fully recharged within 15 s. The energy stored in a charged operating mechanism shall be sufficient for one open-close-open operation.

It shall not be possible to close a circuit breaker if the operating mechanism is not fully charged; neither shall it be possible to have a closing operation when the circuit breaker is already closed.

The circuit breakers shall be provided with means to prevent contact pumping while the closing circuit remains energised should the circuit breaker either fail to latch or be tripped during closing due to the operation of the protective relays.

It shall be possible to hand-charge an operating mechanism when the circuit breaker is in the open or the closed position. It shall be possible to manually operate the operating mechanism.

An operating mechanism shall include a mechanical indicator to show the charged/discharged state.

Every operating mechanism shall have an open-closed indicator which is visible from outside the mechanism cabinet. Every operating mechanism shall have an operation counter.

Circuit breaker opening shall be initiated by two fully independent trip coils which operate from the station d.c. supply. The coils shall be connected to separate terminal blocks in the terminal cubicle, allowing for the connection of two independent opening command circuits.

Facilities shall be provided to permit manual slow closing and slow opening of the circuit breaker for maintenance purposes. It shall not be possible to operate the slow closing and slow opening facility when the circuit breaker is in the normal service condition. An interlock shall be provided between
the slow and normal fast operation to prevent both modes of operation being available simultaneously.

Facilities for continuously monitoring the gas density shall be provided. At a certain low density, signal shall be given to indicate that refilling should take place. At the extreme low density, the circuit breaker shall automatically be blocked against operation.

SF6 gas refilling equipment shall be provided.

4.3.3. CIRCUIT BREAKER LOCAL CONTROL CABINET

Each circuit breaker shall have a local control cabinet which provides local control facilities and serves as a marshalling point for all electrical connections to the circuit breaker. The local control cabinet shall be water-tight and dust-proof (min. IP 54 protection according to IEC-60529). All parts shall be easily accessible without dismantling other parts. Openings, covered with dust filters, shall allow a good ventilation of these cubicles. In order to avoid any moisture condensation, thermostat controlled heaters for 240 V AC shall be built-in. Push buttons for operating the breaker shall be located not more than 1.7 m above ground.

The circuit breaker local control cabinet shall include a lockable LOCAL/REMOTE control selector switch. Opening the circuit breaker through electrical protection operation shall be possible irrespective of the position of this control selector switch. If the switch is in the “local” position automatic reclose shall be inhibited.

The circuit breaker local control cabinet shall include pole discrepancy detection and anti-pumping devices.

4.3.4. SULPHUR HEXACHLORIDE

Each circuit breaker pole shall have an SF6 enclosure independent of the other poles. The SF6 gas shall comply with IEC-60376, 60376A and 60376B and shall be suitable in all respects for use in the switchgear under the operating conditions. The SF6 gas shall be tested for purity, dew point, air, hydrolysable fluorides and water content as per IEC 60376, 60376A and 60376B.

The SF6 density of each pole shall be monitored by a temperature-compensated instrument which provides local indication of SF6 density and which includes contacts for a 2-stage alarm and trip system for each circuit breaker.

Each circuit breaker interrupter shall include facilities to absorb moisture and SF6 decomposition products. It shall be adequate for not less than 10 years service without requiring replacement of the absorbent medium.

It is preferred that there be no leakage of gas under the specified operating conditions and that entry of moisture or other gases should be prevented. SF6 gas leakage shall not exceed 1% per year.

The Contractor shall provide the first fill of SF6 plus 20% of the total SF6 at each station as spare for future use. An additional amount of spare SF6 equal to 10 times the leakage measured one year after commissioning shall be provided. Spare SF6 shall be in 45 kg cylinders and stored in facilities which shall be provided by the Contractor on the site for this purpose.

The Contractor shall provide two sets of gas leakage detection equipment at each substation.
The Contractor shall provide at each substation one set of mobile gas handling plant for filling, evacuating and processing switchgear SF6. The plant shall be capable of reducing the gas pressure in a circuit breaker to below 8 millibars within 2 hours. This plant shall include cylinders for temporary storage of evacuated SF6 gas and all accessories, hoses and fittings necessary to connect the plant to the switchgear. The Contractor shall provide detailed instructions on safe use of the gas handling plant and sufficient personal safety and first aid equipment for the service life of the switchgear.

4.4. 132 KV DISCONNECTORS AND EARTHING SWITCHES

4.4.1. GENERAL

Disconnectors and earthing switches shall be mounted on steel structures and shall be suitable for outdoor installation. They shall conform to IEC 62271-102.

The contact surfaces shall be heavily silver-plated with the contact pressure ensured by means of springs.

Disconnectors shall be suitable for off-load, live operation and shall be capable of switching the charging current of open busbars and connections. They shall also be capable of withstanding the dynamic and thermal effects of the maximum possible short circuit current of the systems in their closed position and shall be constructed in such a way that they do not open under influence of short circuit current.

At double busbar substations the bus select disconnectors shall be suitable for transfer of current between balanced synchronised busbars on a make-before-break basis.

Earthing switches shall be capable of discharging trapped charges of associated transmission lines.

Disconnectors with earth switches shall include mechanical interlocks which prevent the disconnector from closing if the earth switch is in a closed position, and prevent the earth switch from closing if the disconnector is in a closed position.

Disconnectors and earthing switches shall not need lubrication of any part more frequently than after every 1,000 operations or after 5 years, whichever is the earlier.

4.4.2. CONSTRUCTION AND OPERATION

Three pole disconnectors and earthing switches shall be gang operated with all three poles interconnected and synchronised through a robust mechanical linkage.

Disconnectors and earthing switches shall be motor-operated. They shall also have a facility for manual operation. The manual operation devices shall be in a readily accessible position and shall include a switch which disengages the electrical drive when the manual control is put into its operating position.

The maximum operating torque of manual mechanisms shall be less than the maximum set out in IEC 62271-102.

It shall be possible to lock disconnectors and earthing switches in the open and in the closed positions.
Disconnectors and earthing switches shall be provided with a local control cabinet which includes a LOCAL/REMOTE control selector switch for the disconnector and open/close pushbuttons for the disconnector and the earthing switch. Remote operation of earthing switches is not required.

Disconnectors and earthing switches shall have a mechanical operation indicator which is clearly visible from the local control facilities. The indicator and the switch auxiliary contacts shall not indicate that the switch is closed unless it has reached a position at which it can safely carry its rated current, and shall not show the switch as open unless there is contact clearance greater than 80% of the isolating distance. Special additional auxiliary contacts may be provided where intermediate positions are necessary within the supplier’s standard control arrangement. There shall be at least 5 normally open and 5 normally closed auxiliary contacts in addition to those required for operation and indication.

Earth switch local control facilities shall include a “safe to close” indicator which shows that all main conductor phases are de-energised and any other applicable interlocks are satisfied.

The complete operating mechanism, including the controls, shall be housed in a water-tight and dust-proof cubicle (min. IP54 protection according to IEC- 60529). All parts shall be easily accessible without major dismantling of other parts. The necessary openings for a good ventilation of the cubicles, which shall be covered with dust filters, shall be provided. Thermostat controlled heaters for 220 V AC shall be provided for each cabinet in order to prevent any moisture by condensation.

All current carrying parts shall be made from high conductivity electrolytic copper/ aluminium shall be designed to eliminate sharp joints, edges and other corona producing surfaces; where this is impracticable adequate corona shield shall be provided. Corona shields/rings etc. shall be made up of aluminium/ aluminium alloy.

Isolators and earthing switches including their operating parts shall be such that they cannot be dislodged from their open or closed positions by short circuit forces, gravity, wind pressure, vibrations, shocks, or accidental touching of the connecting rods of the operating mechanism.

Motors and motor control circuits shall be designed in accordance with IEC 60072-3 and, and shall be effectively protected by miniature circuit breakers, with alarm contact in accordance with IEC 60947.

4.5. VOLTAGE TRANSFORMERS

Voltage transformers for 132kV and above shall conform to IEC: 60186, IEC 60358 and IEC 60044-1, and shall be of capacitor voltage divider (CVT) type with electromagnetic units.

The Voltage transformers shall be single-phase, oil filled, self-cooled and shall be hermetically sealed against the ambient air. The sealing methods as well as the method of compensation for changes in the oil volume due to temperature changes shall be described in the documentation of the CVT. The single-phase voltage transformers shall be mounted in one insulator and shall be mounted on steel structures.

The Contractor shall indicate what measures are provided for relieving dangerous pressure rises that may develop due to an internal electrical fault.

Each voltage transformer shall be equipped with an oil level gauge to be easily visible from ground level.
Voltage transformer secondaries shall be protected by miniature circuit breakers (MCB) for all windings. The secondary terminals of the CVTs shall be terminated to the stud type non-disconnecting terminal blocks in the individual phase secondary boxes via the MCB.

The electromagnetic unit comprising compensating reactor, intermediate transformer and protective and damping devices shall have a separate terminal box with all the secondary terminals brought out.

The damping device that shall be permanently connected to one of the secondary windings and shall be capable of suppressing the ferro-resonance oscillations.

All secondary connections shall be connected to a terminal block that shall be located in a dust-proof and watertight terminal box and shall be clearly labelled. It should be ensured that access to secondary terminals is without any danger of access to high voltage circuits.

The primary connections shall be silver-plated.

A protective surge arrester shall be provided to prevent breakdown of insulation by incoming surges and to limit abnormal rise of terminal voltage of shunt capacitor/primary winding, tuning reactor/RF choke etc. due to short circuit in transformer secondaries. If an alternate arrangement is proposed, the Contractor shall submit the details for review and approval.

The wiring diagram for the interconnection of the three single phase CVTs shall be provided inside the marshalling box in such a manner that it does not deteriorate with time.

An earth connection to the housing shall be provided.

Secondary winding rating and accuracy shall be appropriate for the connected equipment. However, under no circumstances shall the rating be less than 300VA. The Contractor shall submit for approval calculations which confirm this and that ferro-resonance will not be an issue.

The accuracy of 0.5 on secondary windings should be maintained throughout the entire burden range of all the windings without any adjustments during operation. However, the voltage transformers shall have two of its secondary windings designed for an accuracy of 3P for the protective relaying purposes.

4.6 CURRENT TRANSFORMERS

The current transformers shall conform to IEC: 60185 and IEC 60044-1, shall be single-phase, oil-immersed mounted in one insulator. They shall be mounted on lattice steel support structures.

Current transformers shall have single primary either ring type, or hair pin type and suitably designed for bringing out the secondary terminals in a weather proof (IP 55) terminal box at the bottom. These secondary terminals shall be terminated to stud type non-disconnecting terminal blocks inside the terminal box. In case ”Bar Primary” inverted type current transformers are offered, the following additional requirements shall be met by the Contractor:

- The secondaries shall be totally encased in metallic shielding providing a uniform equipotential surface for even electric field distribution.
- The lowest part of the insulation assembly shall be properly secured to avoid any risk of damage due to transportation stresses.
• The upper part of insulation assembly resting on primary bar shall be properly secured to avoid any damage during transportation, due to relative movement between insulation assembly & top dome.

• Nitrogen if used for hermetic sealing (in case of live tank design) should not come in direct contact with oil.

• The Contractor shall recommend whether any special storage facility is required for spare CTs.

Each current transformer shall be equipped with an oil level gauge to be easily visible from the ground.

The oil of the current transformer shall be hermetically sealed against the ambient air. The sealing method as well as the method of compensation for changes in the oil volume due to temperature changes shall be described in the documentation of the CT.

The CT shall be designed as to achieve the minimum risks of explosion in service. The Contractor shall clearly indicate what measures are provided for relieving dangerous pressure rises that may develop due to an internal electrical fault.

The expansion chamber at the top of the porcelain insulators should be suitable for expansion of oil.

The primary connections shall be silver plated.

Facilities shall be provided at terminal blocks in the marshalling box for star delta formation, short circuiting and grounding of CT secondary terminals. An earth connection to the housing shall also be provided.

Core laminations shall be of cold rolled grain oriented silicon steel or other equivalent alloys. The cores used for protection shall produce undistorted secondary current under transient conditions at all ratios with specified CT parameters.

Where multiple ratio CTs are used, this shall be achieved by secondary taps only and primary reconnection shall not be accepted.

The current transformers shall be designed to carry continuously a current of 120% of the rated current, unless specified otherwise. The rated current of the secondary windings shall be 1A.

The ratings and classes of the Current transformers shall be as follows:

i. Measuring core(s):
   Accuracy class 0.5
   Instrument security factor equal to or less than 5

ii. Protection core(s):
   Accuracy class 5 P
   Accuracy limit factor equal to or greater than 10

iii. busbar protection core(s):
   Accuracy class X
   Knee point voltage As required by protection scheme.
The Contractor shall submit for approval calculations which confirm this.

The wiring diagram plate for the interconnections of the three single phase CTs shall be provided inside the marshalling box. The markings on the plate shall be such that they do not deteriorate with time.

Current transformers shall be suitable for high speed auto reclosing. Proof shall be provided to show that the current transformer shall be able to withstand Fast Transients and high frequency over voltages generated by high speed auto reclosing as well as the closing & opening operation of isolators; the test carried out shall be as per method specified in IEC: 60044-1. The Contractor shall also demonstrate that the current transformers selected will ensure correct functioning of the associated protective equipment in all instances.

4.7. SURGE ARRESTERS

4.7.1. GENERAL

The surge arresters shall be metal oxide gapless type conforming to IEC 60099-4 and shall be mounted on steel structures.

Arresters shall be of hermetically sealed units, self-supporting construction, suitable for mounting on tubular or steel angle supports.

The arresters shall be capable of withstanding the combination of stresses arising in service without causing damage or thermal runaway.

The surge arresters shall be capable of discharging over-voltages occurring during switching of unloaded transformers, reactors and long lines.

The surge arresters shall be capable for discharging energy equivalent to line discharge Class 3 on two successive operations.

4.7.2. CONSTRUCTIONAL FEATURES

The features and constructional details of surge arresters shall be in accordance with requirement stipulated hereunder:

- The non-linear blocks shall be of sintered metal oxide material. These shall be provided in such a way as to obtain robust construction, with excellent mechanical and electrical properties even after repeated operations.
- The surge arresters shall be fitted with pressure relief devices suitable for preventing shattering of porcelain housing and providing a path for flow of rated fault currents in the event of arrester failure. Details shall be furnished in the bid along with quality certificates.
- The arresters shall not fail due to arrester insulator contamination.
- Seals shall be provided in such a way that these are always effectively maintained even when discharging rated lightning current.
- The arrester housing shall be so coordinated that external flashover will not occur due to application of any impulse or switching surge voltage up to the maximum design value for arrester.
• The end fittings shall be made of corrosion proof material and preferably be non-magnetic.

• The heat treatment cycle details along with necessary quality checks used for individual blocks along with insulation layer formed across each block are to be furnished. Metalising coating thickness for reduced resistance between adjacent discs is to be furnished with additional information in the data sheets along with procedure for checking the same. Details of thermal stability test for uniform distribution of current on individual disc is to be furnished.

4.7.3. FITTINGS AND ACCESSORIES

All lightning arresters shall be complete with insulating base having provision for bolting to a flat surface of a structure.

The lightning arresters shall be fitted with a pressure relief device.

A surge monitor consisting of discharge counter and leakage current meter shall be provided for each surge arrestor. It shall be suitable to be mounted on support structures of the arresters and shall have IP55 degree of protection. The reading of the meter and counter shall be visible through a glass inspection panel.

The earth conductor from the arrester to the counter as well as the in-terminal of the counter shall be suitably insulated or screen protected against accidental touching.

The terminals shall be robust and of adequate size and shall be so located that incoming and outgoing connections are made with minimum possible bends. The design of the surge monitor shall be such that it is possible to tilt the surge monitor downwards by an angle of up to 45 degrees from the horizontal plane.

Grading resistors and/or grading capacitors and grading rings shall be provided for uniform voltage distribution between the units making up the arrester as dictated by the voltage class of arrester.

4.8. BUSBARS AND CONNECTIONS

4.8.1. BUSBAR CONDUCTOR AND LIVE CONNECTIONS

The conductors used for the busbars, overhead line gantries and other connections within the switchyard shall be concentric-lay stranded, flexible conductors made of round aluminium, aluminium alloy or copper wires. The alloy shall be aluminium alloy 6201-T81 in accordance with ASTM Standard B 398-67 or aluminium alloys of similar approved composition, as known under the trade name "ALDREY", or equivalent.

Alternatively, ACSR conductors conforming to the requirements of IEC 62219 or tubular aluminium pipes conforming to BS 2898:1970 or other internationally accepted Standards may be used. The conductor to be used shall be to the approval of the Project Manager.

The same type of conductor may be used for the overhead earth wires, the cross-section being at least the equivalent of 95 mm² copper. Other earth wires shall always be of copper.

The cross-section area of the conductors shall be chosen according to the electrical and mechanical requirements. The minimum factor of safety for busbars or other connections based on elastic limit shall be 2.5.
The number of different cross-section areas to be used for the current carrying conductors shall be strictly limited. For overhead earth wires, the same cross-section area shall be used for the entire substation.

The busbar shall have mechanical strength to withstand stresses arising from the specified symmetrical short circuit currents: Continuous current carrying rating at a temperature rise of 30°C above ambient temperature shall not be less than 2000 A. Suitable connection materials to the switchyard equipment shall also be supplied.

All wires comprising the conductor shall be free from dirt, splints, scratches and all imperfections not consistent with the best commercial practice.

The conductor shall be tightly and uniformly stranded with no loose strands and when subjected to 50% of ultimate strength, it shall show no displaced wires but shall maintain a true cylindrical form.

4.8.2. BUSBARS AND CONNECTIONS

Any Cu-Al connections outdoor shall be made using special bimetallic copper-to-aluminium connectors. The bimetallic connectors shall be to the approval of the Project Manager.

All hardware such as connectors, joints and clamps shall be designed for the specified 6201-T81 aluminium alloy, ACSR conductor or tubular aluminium pipes. All connectors shall be of aluminium alloy and shall have a current carrying capacity and strength equal to or greater than the busbars for which they are used. The connector material for the aluminium conductors must be free from copper.

For the main busbar, busbar connections and for other busbar plant, aluminium steel-reinforced ACSR conductors of 435/5 mm² shall be used.

4.8.3. INSULATORS

4.8.3.1. GENERAL

The insulators shall be of high impact strength, glazed, wet process porcelain type conforming to IEC – 60273 for post insulators and IEC – 60433, IEC – 60305 for string insulators and shall comply with the provisions of IEC - 60120 and IEC - 60372. The insulators shall be made of wet process homogenous porcelain. Alternatively, hydrophobic composite insulators conforming to IEC –61109 may be used. Glass insulators shall not be accepted.

Post insulators comprise fully interchangeable units of either the pedestal or solid core cylindrical type and shall be designed so that they can be used either upright or inverted.

For string insulator units, the type of insulator and the characteristics of the discs and the number of discs per string shall be chosen according to the electrical and mechanical requirements. The ball and socket connections shall be provided with cotter pins, which are able to effectively lock the connection against accidental uncoupling without detracting from its flexibility. The cotter pin shall be of stainless steel or bronze.

Each insulator shall be marked with the initials or trademark of the manufacturer and with the guaranteed electromechanical strength of each insulator. All markings shall be plainly legible and durable.

Porcelain insulators shall be glazed in a uniform shade of brown, free of such imperfections as blisters and burns.
The insulators shall be free of laminations, cavities or other flaws affecting the mechanical and electrical strength, and shall be well vitrified, tough and impervious to moisture.

In general the contours of the metal and porcelain parts shall be such as to eliminate areas or points of high electrical flux concentration. All surfaces of metal parts shall be smooth with no projecting points or irregularities so as to minimise the influence of corona.

All ferrous material that is not made of stainless steel shall be hot dip galvanised in accordance with BS 729 or equivalent.

The required leakage distance shall be chosen carefully to avoid designs in which skirts are mechanically fragile.

Minimum factors of safety shall be 2.5 for complete insulators based on electro-mechanical failing load test (IEC 60383) as well as for insulator metal fittings based on elastic limit.

### 4.8.3.2. *DEAD-END AND SUSPENSION TYPE INSULATORS*

The entire exposed surface shall be glazed and free from imperfections. The insulators shall have clevis and tongue fittings, securely connected to insulators.

The design of the insulators shall be such that breakage of the porcelain cannot materially affect the mechanical strength of the insulators.

Dead-end/tension and suspension-type insulators for insulator assemblies shall comply with relevant IEC- 60305. The creepage distance of the assembly shall be minimum 25 mm/kV line to ground.

The insulator shall be of modern fog-type design, embodying deeper outer skirts and shallow inner grooves. The Contractor shall demonstrate, to the satisfaction of the Project Manager, that the contamination collection properties of the insulator unit are 50-60% of the standard 254 x 146 mm disc.

The insulator assembly shall be of single string. The type of insulator and the characteristics of the discs and the number of discs per string shall be chosen according to the electrical and mechanical requirements.

The insulator socket shall be of galvanised malleable cast iron or ductile cast iron and the pin of galvanised steel.

Ball and socket connections shall be provided with cotter pins, which effectively lock the connection against accidental uncoupling without detracting from its flexibility. The cotter pin shall be of stainless steel or bronze.

Socket and pin shall be of such design that they will not yield or distort under the specified mechanical loading in such a manner as to add undue stresses to the porcelain shells.

### 4.8.3.3. *POST-TYPE INSULATORS*

The insulators shall be of outdoor, solid core, station-post type. They shall comprise fully interchangeable units of either the pedestal or solid core cylindrical type and shall be designed so that they can be used either upright or inverted.
The maximum force encountered during a full short circuit, plus own weight of insulators and connected plant (such as clamps and conductors) shall not exceed the maximum cantilever for the insulator.

The radius of the conductor' grooves must bear such a ratio to the conductor radius that an abrasive contact be produced on the current-carrying connector components.

The bearing of the conductor in the support clamps should be thermally stable friction bearings of low friction coefficient. A permanent and reliable transmission of charging current to the support must be ensured.

The deflection angle in the suspension clamps must be 8 degrees in all directions. Expansion in the expansion clamps must not be impeded. In case the provided expansion is exceeded, the locking device must prevent the conductor from falling out of the suspension clamp.

The maximum force encountered during normal service (own weight + wind load + switching load of insulator and connected plant) shall not exceed 40% of the maximum cantilever strength.

Porcelain shall be manufactured in wet process and shall be one piece, non-porous, homogenous and free from cavities or other flaws. The glazing shall be uniform in brown colour and free from blisters, burns and other defects, and shall meet all applicable requirements of IEC 60273.

The metal parts shall be designed to transmit the mechanical stresses to the porcelain by compression and to develop maximum and uniform mechanical strength of the insulator.

4.8.3.4. STRING INSULATORS

String insulator assemblies shall be of cap&pin type porcelain insulator type. The total specific creepage distance shall be at least 25 mm/kV (related to the maximum phase to earth voltage, as per IEC 60071/2). The insulators shall be assembled with all necessary bolts and fittings. The electrical and mechanical design of the complete set shall comply with IEC- 60120, IEC 60372 and IEC 60471 or with IEC- 60433 for long rod insulators as relevant.

4.8.3.5. ACCESSORIES

For all accessories as clamps, connections, care shall be taken to fulfil all conditions required concerning current carrying capacity, mechanical strength, glow discharge characteristics, corrosion resistivity and easy mounting.

4.9. TESTS

4.9.1. INSPECTION AND TESTS

The Employer or Project Manager may inspect the high voltage equipment at any stage of manufacture or be present at any tests. Such inspection shall not relieve the manufacturer of his responsibility for meeting all requirements of the specification. Similarly any such inspection will not prevent subsequent rejection where any materials or component of a power transformer are subsequently found defective.

The Contractor will meet all costs for three representatives of the Employer to witness the factory tests.
Timing of tests shall generally be in accordance with the agreed work programme. The Contractor shall provide at least two weeks’ notice of the intention to conduct factory tests and their location. Associated inspection and test plans and procedures shall be submitted for approval not later than the time that the notice is given.

No high voltage equipment shall be prepared for transportation or dispatched from the manufacturer’s works without the prior approval of the Project Manager.

4.9.2. TYPE TESTS

All high voltage equipment shall be deemed to have satisfied all type test requirements set out in IEC 60060, IEC 60233, IEC 60270 and IEC 61000 as well as ANSI-C29.1 where it applies. The Contractor shall submit type test reports of tests conducted by a third party testing agency which have been undertaken in the last 5 years and which cover all type tests required in the above stated IEC standards. If the Contractor has not submitted acceptable type test reports prior to the factory tests, the outstanding type tests shall be included in the factory tests and shall be performed on one equipment item of each type. Where a type test might impair the performance or service life of the equipment, it shall be conducted on equipment equal to but not part of the equipment being provided under the Contract.

The Employer may accept type test reports on equipment of the same design and a similar rating as satisfying this requirement.

4.9.3. FACTORY TESTS

All routine tests included in relevant IEC standards shall be performed on all high voltage equipment as part of the factory tests.

The Contractor shall coordinate with the Project Manager to determine if any routine tests which are identified in the IEC standards as optional are required to be performed.

Ten insulator units shall be selected at random from each lot, and shall be tested for thermal mechanical performance in accordance with IEC 60575.

4.9.4. TESTS AT SITE

Site tests shall confirm correct interconnection of equipment and shall repeat relevant routine tests. They shall also include any site tests recommended in the relevant IEC standards.
5. 33 KV OUTDOOR SWITCHGEAR AND SWITCHYARD EQUIPMENT

5.1. 33 KV CIRCUIT BREAKERS

5.1.1. GENERAL

Circuit breakers for 33 kV shall be of the SF6 or vacuum type with three-pole motor-spring charged operating mechanisms.

The poles of the CB shall be porcelain-clad construction. Each porcelain insulator of the CB shall have marked on it the manufacturer’s name or trademark, the year and month of manufacture and the manufacturer’s reference mark. Marks shall be visible after assembly of fittings shall be imprinted and not impressed. The marks shall be imprinted before firing and shall be clearly legible after firing and glazing.

Adequate phase spacing and height should be provided to meet standards and safety requirements.

Outdoor insulator fittings shall remain unaffected by atmospheric conditions producing weathering, acids, alkalis, dust and rapid changes in temperature that may be experienced under working conditions.

33 kV circuit breakers shall be suitable for 3-phase auto reclose.

5.1.2. VACUUM TYPE CIRCUIT BREAKERS

Particular requirements for design and construction of vacuum circuit breakers are:

- Vacuum circuit breakers shall be rated for not less than one hundred breaking operations at rated short-circuit breaking current.
- Vacuum circuit breakers shall not produce excessive over voltages as a result of current chopping during switching and the contacts shall be of suitable material and shall not show any tendency of welding together during severe arcing.

5.1.3. SF6 CIRCUIT BREAKERS

Particular requirements for design and construction of SF6 circuit breakers are:

- SF6 circuit breakers shall be puffer type or self-extinguishing type with rotating arc dead tank and single pressure design.
- SF6 circuit breakers shall be provided with two-stage pressure/density monitoring with a first stage alarm and second stage trip and lock off.
- One set of SF6 filling equipment (reducer valve and hose of 5 m with coupling plug) and one extra bottle of 20 kg of SF6 gas shall be provided as part of the tools and equipment for each substation with 33 kV SF6 circuit breakers.

5.1.4. OPERATING MECHANISMS

Circuit breaker operating mechanisms, auxiliary switches and associated relays, control switches, control cable terminations, and other auxiliary equipment shall be accommodated in sheet steel vermin-proof and weatherproof cabinet.
Cabinet shall be of rigid construction, preferably folded but alternatively formed on a framework of hot dip-galvanised standard rolled steel or aluminium and shall include any supporting steelworks necessary for mounting on the circuit breaker supports or on concrete foundations. Access to all compartments shall be provided by doors with lift-off hinges. Doors shall include a locking facility, shall be fitted with appropriate weatherproof sealing material and if necessary shall be glazed to permit viewing of instruments without needing to open the cabinet.

The arrangement of equipment within the cabinet shall be such that access for maintenance or removal of any part of the equipment shall be possible with the minimum disturbance of associated apparatus. Cabinets shall be well ventilated through vermin-proof louvres comprising a brass gauze screen attached to a frame and secured to the inside of the cabinet.

Requirements for circuit breaker operating mechanisms shall include:

- Operating mechanisms shall be of the trip free type incorporating anti-pumping features.
- Operating mechanisms shall have stored energy spring mechanisms with motor and manual charging facility. DC motors shall be used for automatic charging of the spring mechanism. A hand crank will be provided for each CB and stored in the mechanism cabinet.
- It shall be possible to charge the spring mechanism with the circuit breaker in either “OPEN” or “CLOSED” positions.
- Operating mechanisms shall include mechanical indication of the circuit breaker state (CLOSED/OPEN).
- It shall not be possible for the circuit breaker to close unless the spring is fully charged. A visual indicating device, 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, the circuit breaker shall not open and neither shall such operation result in damage to the circuit breaker.
- Operating mechanisms shall be fitted with a local manual spring release, preferably a mechanical pushbutton, shrouded to prevent inadvertent operation and provided with means for padlocking.
- Operating mechanisms shall be equipped with an operation counter.
- Operating mechanisms shall have one tripping coil.

The circuit breakers shall be provided with suitably rated auxiliary switches. Sufficient auxiliary switches shall be provided to meet all control, indication and protection requirements. In addition, two normally open and two normally closed contacts shall be provided as spares.

5.2. 33 KV DISCONNECTORS

5.2.1. GENERAL

Three-pole 33 kV disconnectors for outdoor installation shall have the phases in parallel and equipped with earthing switches. Disconnectors and earthing switches shall be manually operated for all three poles. Post insulators shall be made of high quality porcelain, brown coloured and one unit.
The static effort to operate manually operated mechanisms on the disconnectors and earthing switches shall not exceed 150 N. Disconnectors shall be fitted with mechanical interlock that prevents closing of the earthing switches when the disconnector is in the closed position and vice versa.

The contacts of disconnectors shall be fitted with springs or similar to provide adequate contact pressure.

Each disconnector mechanism shall be fitted with an auxiliary switch with sufficient contacts to provide indication and interlocking functions for a fully developed substation and 2 normally open and 2 normally closed additional contacts. The enclosure class of motor operating mechanism shall be IP43. All auxiliary contacts shall be wired in separate block mounted into IP54 enclosure.

All operating mechanisms shall be mounted 1,200 mm above ground level. All operating handles and linkages for the disconnectors and earth switches shall be connected to the earth mat with a copper flexible braid of sufficient cross section for mechanical strength and for the fault level specified. Disconnector switch mechanism shall be protected against damage in case of wedging of disconnecting switches.

All operating mechanisms shall be capable of being padlocked in both the open and closed positions for both disconnector and earth switch.

Disconnectors shall be supplied and delivered as a three phase unit with the associated steel base as an integral part. The disconnectors shall be mounted on hot-dip galvanised steel supports in the substation. All exposed ferrous parts of disconnectors shall be hot-dip galvanised with stainless steel bolts, nuts and washers.

Holes for lifting and erection shall be provided on the supporting base and structure of disconnectors, point for earthing connecting and rating plate as well.

Disconnectors shall be electrically interlocked so that they cannot operate (open or close) unless the associated circuit breaker is open.

5.3. 33 KV CURRENT TRANSFORMERS

The current transformers for outdoor installation shall be oil insulated. Measuring cores shall have accuracy class 1.0 and protection cores shall be class 5P10. Each core shall have a rating suitable for the connected equipment and not less than 15 VA.

5.4. 33 KV VOLTAGE TRANSFORMERS

Voltage transformers for outdoor installation shall be oil insulated and of the inductive type.

The voltage transformer shall be connected between earth and phase conductor, designed with a low flux density in the core and flat magnetisation curve and dimensioned for an over voltage factor of 1.9 for eight (8) hours.

The tank shall be hot-dipped galvanised. The expansion vessel and upper part of the voltage transformer shall be supported by a brown porcelain insulator. The oil tank and expansion cap shall be fitted with an oil level indicator. The oil tank shall be fitted with means for lifting and erection.
Primary terminals shall be made of nickel-plated brass or stainless steel. The terminal box for secondary windings shall be made of corrosion resistant material (metal alloy) and equipped with cable glands. The protection class of secondary terminal box shall be IP54. The units shall be fitted with earthing terminals made of the same material as the primary terminals. Earthing of the secondary terminals should be provided in the terminal box.

5.5. 33 KV SURGE ARRESTERS

33 kV surge arresters shall be gapless, zinc oxide type for A.C. systems and suitable for outdoor installation. The housing shall be brown porcelain. The surge arresters shall be rated at 10 kA for standard rated discharge current and shall conform to Line Discharge, class 3.

One surge counter shall be provided for each set of three surge arresters.

5.6. TESTS

5.6.1. INSPECTION AND TESTS

The Employer or Project Manager may inspect the 33 kV equipment at any stage of manufacture or be present at any tests. Such inspection shall not relieve the manufacturer of his responsibility for meeting all requirements of the specification. Similarly any such inspection will not prevent subsequent rejection where any materials or component are subsequently found defective.

The Contractor will meet all costs for three representatives of the Employer to witness the factory tests.

Timing of tests shall generally be in accordance with the agreed work programme. The Contractor shall provide at least two weeks notice of the intention to conduct factory tests and their location. Associated inspection and test plans and procedures shall be submitted for approval not later than the time that the notice is given.

33 kV equipment shall be prepared for transportation or dispatched from the manufacturer’s works without the prior approval of the Project Manager.

5.6.2. TYPE TESTS

All 33 kV equipment shall be deemed to have satisfied all type test requirements set out in relevant IEC standards. The Contractor shall submit type test reports of tests conducted by a third party testing agency which have been undertaken in the last 5 years and which cover all type tests required in IEC standards. If the Contractor has not submitted acceptable type test reports prior to the factory tests, the outstanding type tests shall be included in the factory tests and shall be performed on one equipment item of each type. Where a type test might impair the performance or service life of the equipment, it shall be conducted on equipment equal to but not part of the equipment being provided under the Contract.

The Employer may accept type test reports on equipment of the same design and a similar rating as satisfying this requirement.

5.6.3. FACTORY TESTS

All routine tests included in relevant IEC standards shall be performed on all 33 kV equipment as part of the factory tests.
The Contractor shall coordinate with the Project Manager to determine if any routine tests which are identified in the IEC standards as optional are required to be performed.

5.6.4. TESTS AT SITE

Site tests shall confirm correct interconnection of equipment and shall repeat relevant routine tests. They shall also include any site tests recommended in the relevant IEC standards.
6. SUBSTATION EARTHING

6.1. GENERAL

The Contractor shall provide an earthing system designed to protect persons and plant and to allow for the correct service, operation and maintenance of the installation. The earth system shall consist of the earth electrode system in the ground under the switchyard, and of the earth conductors above ground and in the buildings.

The earthing for all plant and the provision of earth systems, electrodes and connections shall be in accordance with the recommendations in the “Guide for Safety in Substation Grounding” ANSI/IEEE No. 80–2000 and the requirements of British Standards BS 6651 and BS 7430.

6.2. DESIGN

The earthing system shall be provided by an earth grid of buried conductors designed for the specified earth fault current. The preliminary design shall be such that the potential rise shall not exceed 5 kV.

The earth system shall be constructed and installed to comply with the requirements of local regulations and of the applicable standards.

The earthing system shall provide:

- Adequate protection for personnel against dangerous voltages, currents and arcs;
- Safe touch voltages and step voltages;
- A low earthing impedance for the lightning arresters;
- An earth resistance which does not exceed 1 ohm at any location in the substation under all pertinent climatic conditions.
- A low earth impedance for the transformer neutrals and a sufficiently low neutral conductor impedance;
- Limitation of the induced, or capacitively transformed, voltages on low voltage, current and electronic cables, circuits, panels and other plant;
- That short circuit, earth fault and double earth faults currents will flow through the earth systems and not through other conducting parts or building constructions to a hazardous extent.

The conductors shall be reliably protected against mechanical damage and corrosion.

Buried connections shall be made by compression clamps or by approved exothermic welding process. No bolted clamps may be used underground except where accessible by link chamber (covered inspection/test pit). Connections above ground shall be bolted and shall be easily accessible for test purposes. All connections shall be protected against corrosion.

The Contractor shall submit his preliminary design for the earth systems for approval by the Project Manager. This shall include measurement of soil resistivity, calculations of resistance, potentials and current ratings for current flowing into or out of the ground and physical design of the system.
6.3. **EARTH ELECTRODE SYSTEM UNDER BUILDINGS**

Earth conductors shall be of galvanised steel or electrolytic copper with dimensions at least 30 x 3 mm for strap or at least 95 mm² for stranded wires.

Risers shall be galvanised steel strap or copper stranded wire at least 95 mm².

The conductors shall be placed on or in the ground after the excavation is completed and just before the concreting commences. Care must be taken that the earth wire is in good contact with the soil and embedded into it.

Under the building the grid of conductors shall be placed with an average distance between conductors of not more than 10 m. At all crossings the conductors shall be interconnected by exothermic welding or equivalent, acceptable to the Project Manager. The grid shall also be connected to the concrete reinforcement at several places as well as to the earthing grid of the switchyard area. Vertical risers shall be exothermically welded to the conductors where not accessible for inspection/testing.

The risers shall be placed in the concrete shuttering and led out of the shuttering at appropriate places approximately 300 mm above the floors. Care shall be taken to protect the risers against damage during shuttering and concreting.

Connecting terminals for the screwed connections between the risers and the above-floor main earthing conductors shall be placed at easily accessible places and protected against mechanical damage.

The above information describes the minimum requirements. The final design and construction for the achievement of the total requirements of the earthing systems shall be made by the Contractor.

6.4. **EARTH ELECTRODE SYSTEM OF THE SWITCHYARD**

The Contractor’s design shall comply with the following requirements as a minimum.

The conductors shall be of galvanised steel strap with dimensions at least 30 x 3 mm for the strap or at least 95 mm² for stranded wire.

The risers shall be of at least 95 mm² stranded galvanised wire or equivalent.

The conductors shall be placed forming a grid covering the whole switchyard area. The average distance between the conductors shall not be more than 20 m.

Earth mats connected to the main earthing grid shall be installed at the position of operating cubicles/handles of isolating switches and other plant in the switchyard and substations.

A conductor shall also be placed outside the fence along the whole length of the fence at a distance and at a depth suitable for the potential gradation needed to avoid dangerous touch voltages between the fence and the ground.

Trenches 900 mm deep, for the earthing grid shall be excavated in the ground, backfilled with soil of good conductivity with and a layer of at least 250 mm of the conductive material placed over the conductor. The conductor shall at no place be less than 800 mm below the ground level.

Where advantageous for achieving low resistance to ground, vertical galvanised steel earthing rods may be used, in addition to the horizontal grid.
Connecting terminals for the bolted connections between the risers and the above ground earth conductors shall be placed in easily accessible locations for testing and visual inspection.

The fence of the switchyard shall be earthed at intervals of not more than 20 m.

Earth switches and lightning arresters shall have a riser directly connected to the current carrying part in addition to a riser connected to the structure.

### 6.5. EARTH CONDUCTORS IN BUILDINGS

In buildings a main earthing bus shall be installed on each floor in the cable trenches.

The conductors for these main earthing buses shall be of electrolytic copper with flat bar or stranded conductor.

All the risers from the earth electrode systems shall be connected to these main buses by disconnecting bolted connections. At appropriate places at the end of the buses they shall be interconnected, thus to the greatest extent forming interconnected grids or loops.

Branch offs to switchgear, panels and other parts which must be earthed, shall be of electrolytic copper with adequate dimensions for each item to be earthed.

Each item shall be directly connected to an earth conductor and not through a series connection of other metallic parts.

Where rows of switchgear cubicles, boards and panels occur, each cubicle, board or panel shall be earthed individually.

Earth conductors for low current and electronic systems shall be insulated and shall be run from the systems, panels, directly to a main earthing bus close to a connection to the earth electrode system. These earth conductors shall not be mixed with the earth conductors of the high power systems.

### 6.6. EARTH POINTS

Where the minimum earth resistance may not be achieved by the installation of the earth grid, additional earth rods shall be used as appropriate.

The number of earth points necessary for installation of additional earth rods shall be verified by site earth resistivity tests during construction works.

Each earth point shall consist of not less than four and not more than eight 15 mm diameter galvanised steel electrodes, each approximately 3.5 m in length and driven or drilled into undisturbed ground, at spacing of not less than the length of the rods. Each electrode shall be complete with approved clamps for the connection of earth conductors and with a hardened steel tip and cap for driving by means of a power hammer.

Test link chambers and covers for each point shall be provided and a drawing showing the proposed arrangement shall be submitted by the Contractor for approval. Locations for the electrode chambers and the interconnection arrangement shall be approved by the Employer when the results of the site earth resistivity tests are known.
6.6.1. **CONNECTION OF EARTH POINTS AND SYSTEM NEUTRALS**

The electrodes of an earth point shall be arranged in two groups with a conductor from each group to the test link and there shall be duplicate conductors from each test link to the earth grid. Each connection to the earth grid shall be at a link chamber adjacent to the grid with two conductors from the grid connected to one terminal. Where the electrode groups are close to the grid, the group connection can be made directly to a link chamber at the grid.

Any neutral points for high voltage systems within a substation shall have duplicate connections to the closest link chamber(s) of an earthing point(s).

Conductors interconnecting the electrodes to a test link and between the tests links and the earth grid shall have a cross-sectional area or not less than 95 mm\(^2\) steel. There shall be at least two such connections from each link to the electrodes and to the earth grid. Duplicate connection may be in the form of rings.

Earthing conductors shall be of annealed high conductivity copper stranded in accordance with Table 4 in BS.6346 and protected with an extruded PVC sheath of 1000 V grade.

Earth conductors shall normally be buried directly in the ground but where necessary they may be attached to walls, fixed to cable racks or laid in the cable trenches as convenient.

6.6.2. **PLANT EARTHS**

The frames of all electrical plant and the bases of all structural steelwork shall be connected by branches of the same cross section area to the earth grid or to subsidiary branches running to a group of plant. All disconnector bases, earth terminals and earthing switches, neutral current transformers, power transformers, surge arrester bases and towers and gantries on which overhead earth wires are terminated shall be connected to the earth grid.

Surge arresters installed for the protection of transformers shall be connected by direct low reactance paths both to the transformer tank and to the earth grid. Particular care shall be taken to avoid any sharp bends, with lengths of such leads minimised, to avoid additional high impedance at lightning frequency levels.

Capacitor voltage transformers used in connection with line traps shall be connected by direct low reactance paths to a single earth rod in addition to the earth grid.

Disconnector and earth switch operating mechanisms and circuit breaker control kiosks not integral with the circuit breaker shall be connected to the earth system by a branch entirely separate from that employed for earthing the disconnector, earthing-switch or circuit breaker structure. Such branches shall be connected to a ground mat which shall be provided beneath the position where an operator will stand.

Galvanised steel structures with sufficient area and current carrying capacity may be used as part of the earth connection to post and strain insulators and to overhead earth conductors which shall be terminated directly on the steel works.

Buildings containing electrical plant shall be provided, at each level, with a ring of earth conductors which shall have duplicate connections to the earth grid outside the building. The frames of all switchgear control and relay panels and other electrical plant and exposed structural metal work shall be connected by branches to a ring. The ring and branch conductors shall be of the same material as the earth grid.
Earthing strip run within buildings, inside cable trenches or above ground level apparatus shall be neatly supported in clamps.

6.6.3. **JOINTING AND BONDING**

Where a strip has to be drilled to fit an earth terminal the diameter of the hole shall not be greater than a quarter the width of the strip.

Stranded earth conductors shall be terminated with sweated or crimped cable lugs

6.6.4. **ATTACHMENT POINTS FOR PORTABLE EARTHING DEVICES**

Facilities designed to permit the application of fully rated portable earthing devices for the safe maintenance of substation equipment shall be provided. Sufficient quantities shall be provided for each substation for the safe earthing of one complete substation bay (or each set of switchgear for two circuits at 1½ circuit breaker substations).

The application of portable earthing equipment shall be considered and where a conductor configuration, angle of approach or size prevents the direct application of a portable earth clamp, a supplementary connection facility shall be provided. Provision shall also be made for the connection of the earth end of the portable earth at each location noting that several leads may be required to achieve a fully rated connection.

The portable earthing equipment shall be designed for ease of application and removal, and when it has been applied shall be firmly locked in position such that it will not be dislodged for any electrical fault.

6.7. **LIGHTNING PROTECTION**

Lightning protection shall be provided for each substation. This protection shall be carried out by a combination of Faraday rods, lightning masts and stranded overhead conductor with cross-section area not less than of 35 mm$^2$ forming a lightning screen. The rods and masts shall be made of hot-dip galvanised steel, of suitable height and number. All necessary clamps and accessories shall be provided for connecting the overhead conductor.

The Contractor shall determine the layout of the earthing screen required using the rolling sphere or a similar graphical method.

The lightning protection system shall be inter-connected with the earthing system. The connections shall form the most direct path for lightning currents from the air terminals to the earth electrodes. Additional conductors and earth electrodes shall be installed as necessary to ensure a direct path.

The down leads shall be brought in such a manner that they pose minimum risk to personnel and do not disturb the visual appearance of the building.

The earth screens shall be suitable for extension to protect the substation plant to be installed in future stages of development.

Overhead earthing wires supported from switchgear structures or overhead line towers within the area of the installation shall be bonded to the earthing system at each structure or tower. The metalwork of the structure, including steel reinforcement in concrete, may form part of the bonding conductor.
Earth wires shall be held in clamps with free, pin type joints between clamps and supports. Connections shall be provided for the terminations of the earth wire of the overhead lines including bimetal connectors where necessary.
7. STEEL STRUCTURES

7.1. GENERAL

The gantries and HV equipment support structures shall be lattice type using galvanised steel angles.

Steel structures shall be erected on reinforced concrete foundation using anchor bolts. The number, size of these bolts shall be determined by the Contractor and the associated calculation submitted for approval. The protruding portion of the galvanised bolts shall be greased and fitted with nuts and washers.

Design calculations shall include the computation of stresses in all structural components and shall show how all loads are transferred to the foundations. Stress diagrams and calculations, and drawings showing the dispositions and sections of all members and the design of joints and fittings shall be submitted for approval. The factor of safety for each complete structure shall not be less than 2.5 based upon the maximum working loading for normal conditions and 2.0 for abnormal cases. Consideration shall be given in sizing members to eliminate excessive deflection or vibration during service.

The maximum allowable stresses in tensile members shall be such as to give a factor of safety of not less than 2.5 on the elastic limit strength.

The ultimate stress in compression members shall not exceed a value based on the elastic limit strength. The Contractor shall submit details of the calculation.

The maximum allowable slenderness ratio for various classes of members shall be supported by calculation sheets. It shall not exceed the following:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Main members</td>
<td>150</td>
</tr>
<tr>
<td>Braces and all other members</td>
<td>200</td>
</tr>
<tr>
<td>carrying calculated stress</td>
<td></td>
</tr>
<tr>
<td>Tension and redundant members</td>
<td>250</td>
</tr>
</tbody>
</table>

The rolled steel sections, tubes, flats, plates, bolts, nuts and bars and angles used shall employ weldable structural steel of an approved quality to the relevant ISO and BS standards. The steel shall be free from blisters, scale and other defects.

The design shall be such as to minimise the number of different parts and to facilitate transport, erection and inspection.

Main members and bracing of structures shall not be less than 6 mm and 5 mm thick respectively. Shop connections shall generally be electric arc welded or bolted. Welding is provided only for top plates of column's peaks and for bearing plates of column's corner legs. All welds shall be continuous seal welds. Site connections shall be bolted as shown in the drawings unless specifically approved by the Project Manager. At Site, drifting of holes will not be permitted. Step bolt or ladder bars shall be provided on one leg of the column, the position of which shall be shown in the layout arrangement drawings. Steps shall be spaced approximately 380 mm apart, with maximum spacing of 430 mm. Holes for step bolts shall be located on the inner gauge of the leg.
angle. Pockets and depressions likely to hold water shall be avoided and all parts of the structures shall be properly drained.

All steelwork shall be hot dip galvanised. Bolts and nuts shall be galvanised and fitted with spring washers. Taper washers shall be added where necessary. Threads of bolts shall be spun galvanised and the threads of nuts shall be oiled.

Before leaving the Contractor’s works, all steelwork components shall be painted or stamped in at least two places with a marking number and/or letter corresponding to the marking number and/or letter on an approved drawing and material list. The erection marks on galvanised parts shall be stamped before galvanising and shall be clearly legible after galvanising.

The Contractor shall provide templates for each typical steel structure support or gantry column to enable installation of the anchor bolts in concrete foundation.

7.2. **LOAD COMBINATIONS**

Steel structures shall be designed to withstand all dead and dynamic loads imposed by equipment including loads arising during assembly and erection or in service simultaneously with wind loads.

Wind loads shall be determined based on the whole projected area of all conductors, insulators and apparatus carried on the structures. For lattice steel structures the loadings shall be assumed working on 1.5 times the projected area of members on one face.

Substation structures onto which slack spans are terminated shall be suitably designed for this additional loading.

7.3. **BOLTED JOINTS**

Bolted joints shall be calculated as bearing type connections, and no allowance for frictional resistance shall be made. The minimum bolt size shall be 12 mm.

All bolts and nuts shall comply with BS 4190 or other equivalent standard and screw threads shall be to the metrical standards. Bolts and nuts shall be of steel with hexagonal heads. Bolts of any given diameter shall be of one grade of steel and marked for identification. Screw threads shall not form part of the shearing plane between members.

Bolt holes shall not be more than 1.5 mm larger in diameter than the corresponding bolt diameter. When in position all bolts or screwed rods shall project through the corresponding nuts with a minimum of 2.5 mm and a maximum of 10 mm.

The total thickness of the washers shall not be more than 0.6 times the bolt diameter.

Minimum distances for bolted joints shall be as follows. Distances in parenthesis apply to tension members:

<table>
<thead>
<tr>
<th>Bolt (mm)</th>
<th>Minimum width of section (mm)</th>
<th>Minimum distance from hole centre to edge (mm)</th>
<th>Minimum distance between holes (mm)</th>
</tr>
</thead>
</table>
7.4. **GALVANISING**

All structure parts and components shall be hot dip galvanised in accordance with BS 729.

- The minimum coating mass on any individual component shall be 610 g/m².
- Bolts, nuts and washers shall have a zinc coating not less than 305 g/m². (equal to 43 mm thickness) when galvanized according to BS 729.

The nut threads shall be cut after hot tip galvanising and thinly oiled in order to protect the threads during storage.

The zinc coating on bolt threads shall be smooth and free from blisters, drops and projections that nuts can be screwed on with fingers. Bolt threads shall not be opened by cutting after hot dip galvanising.

Galvanising of steel counterpoise cable and other rods not exceeding 7 mm diameter shall be in accordance with BS 443 or other approved standard.

Galvanising defects shall be repaired as directed by the Project Manager. Minor galvanising defects may, however, be patched by painting over with zinc powder paint.

After galvanising, parts of a structure must not be welded, machined or bent.

7.5. **INSPECTION AND TESTING**

All materials used in and components of steel structures may be inspected by the Project Manager at any time.

All manufacturer’s quality records that demonstrate that material meets specified and design requirements shall be submitted for approval.

All materials and components shall be subjected to all routine tests required in applicable standards.

The Contractor shall, on request, provide samples of any applicable material to the Project Manager for independent testing.

Welded joints shall be subject to non-destructive testing.

Tests shall be made on a representative sample of steel structure components to confirm dimensions and thickness of galvanising.

All structures shall have a trial assembly in the manufacturer’s workshop. The Contractor will meet all costs for three representatives of the Employer to witness trial assemblies. If the Project Manager waives witness of a trial assembly, the Contractor shall make photographic records of the
assembly and submit these to the Project Manager for approval. Steel structures shall not be dispatched from the manufacturer’s works prior to the trial assembly being approved.
8. CIVIL WORKS

8.1. SCOPE

8.1.1. GENERAL

The civil works for substations include the following:

- Earthworks to formation level for substation platforms;
- Subsoil drains and storm water drains;
- Bitumen surfaced internal roads;
- Gravel surfaced access roads;
- Subsoil drains and stormwater drains;
- 100 mm thick layer of crushed stone on platform surfaces;
- Fencing;
- Concrete bases and stub columns;
- Cable trenches;
- Transformer cells;
- Control buildings;
- A guardhouse located at the main gate;
- Any other works necessary for construction of a fully functional substation.

8.1.2. SUBSTATION CONTROL BUILDING

Substation control buildings shall include as appropriate rooms for:

- 132 and 33 kV switchboards;
- Control and protection equipment;
- Communications equipment;
- Batteries;
- AC and DC power supply;
- Diesel generator;
- Control room;
- Storage;
- Staff amenities.

Substation control buildings may be provided as a conventional building or as a set of prefabricated modules. The Contractor shall submit the arrangement and design of the substation control buildings for approval.

The control room and staff amenities room shall have air conditioning. Other rooms shall have air conditioning if reliable operation of the equipment in them would be impaired if they did not.
33 kV switchboard rooms shall be large enough for the future expansion of the switchboard by up to 2 bays at each end while retaining the supplier’s requirements for access for maintenance. They shall be designed to withstand and release rapid pressure increases associated with arc faults within the switchboard.

The control room shall include, in addition to the operator workstation and associated desk and chair, two additional chairs which match the operator’s chair, a stand for the control system printer and storage facilities for printer consumables and one full set of operation and maintenance instruction manuals for the substation.

The storage facilities shall be suitable for storage of spare parts, tools and equipment, and shall include an area which may be used as a workshop for minor tasks. Separate storage facilities shall be provided for potentially hazardous substances such as transformer oil and SF₆ gas.

The staff amenities room shall be partitioned into a washroom and a restroom. The washroom shall include a water closet (WC), shower, wash basin, towel rails, mirror and soap dispenser. The restroom shall include a table and four chairs, a microwave oven, kitchen sink, storage for crockery and cutlery, a drinking water dispenser, a 200 l refrigerator and a wall-mounted first aid kit.

8.1.3. WATER SUPPLY

The Contractor shall supply a water tank not less than 1000 l for each substation control building. The Contractor shall determine the most practical way to provide water at each site. This may be by rain water harvesting, deep well, and pumped from watercourses or from an external reticulated water supply. If rain water harvesting is used, a larger tank shall be provided to ensure that 1000 l of water is available under normal conditions.

The water supply shall be filtered to remove sand and debris, but shall not otherwise be treated.

The Contractor shall submit the design of the water supply systems for approval.

8.1.4. SEWERAGE

The Contractor shall provide a permanent sewerage installation at substations comprising sewer mains, septic tanks and absorption trenches. The sewerage system for a substation shall have 10 user capacity, and that for the central control building shall have 20 user capacity.

The Contractor shall submit the design of the sewerage systems for approval.

8.1.5. CLEARANCE

The areas of the platforms, access roads, and borrow pits shall be cleared of all trees, vegetation and roots. These shall be neatly stockpiled within 300 m of the site at locations agreed with the Project Manager and shall remain the property of the Employer.

The top soil within the areas of platforms and access roads shall be stripped to an approximate depth of 200 mm and stockpiled at locations agreed with the Project Manager for later use on embankment slopes.

Overburden in the borrow pit shall also be stripped to a depth specified by the Project Manager and stockpiled for later use in rehabilitation.
8.2. EARTHWORKS

8.2.1. ROAD BED PREPARATION

The "road bed" is that part of the ground uncovered by clearing the site, completion of cuts, excavation and removal of unsuitable material as required, on which the platform and road structure shall rest. The "road bed" must be scarified to a depth of 150 mm; water added as considered necessary, and compacted with a minimum of four passes of a 50 tonne single axle pneumatic super compactor. If the roadbed is rock no preparation is necessary.

8.2.2. CLASSIFICATION OF MATERIALS

Materials excavated and either placed in the works for the formation of the platforms and roads, or carted to spoil will be paid for in the following three classes of materials:

- “Rock” shall include all material which requires blasting for its removal or cannot be extracted by ripping with a single tine heavy duty ripper of at least 5 tonne mass towed by a crawler tractor in good condition with a net available flywheel power rating of not less than 135 kW continuous according to BS 649 and with a minimum bare tractor mass of 15 tonne. The use of explosives by the Contractor to excavate does not in itself imply that a material is rock in terms of this Contract. Individual boulders greater than 0.2 m³ in volume shall be included in this class when their nature and size are such, that they cannot be removed without recourse to blasting.

- “Hard Material” or “Decomposed Rock” shall include all material such as consolidated gravels, decomposed or stratified rock, stones or boulders less than 0.2 m³ in volume which cannot be classified as “Rock” but which in the opinion of the Project Manager requires additional processing, such as ripping or breaking down by compressor tools before normal loading processes may be employed. For the purpose of this clause normal loading processes will include the use of graders or dozers to stockpile material.

- “Common Material” shall be all material not defined as rock or hard rock material. All materials shall be classified as “Common” unless otherwise certified by the Project Manager. Should the Contractor during excavation encounter any material which in his opinion should be classified as rock or hard material, then he shall request the Project Manager to certify the material before excavation of that material commences.

8.2.3. ORDER OF WORK

The construction of side cuttings, side drains and embankments shall proceed in methodical and orderly manner. It shall be solely the Contractor’s responsibility to arrange his methods and program of work, to ensure that the earthworks are carried out by the most efficient and economical methods possible with the type of plant employed at the works.

All trimming of cuttings, and embankments, drains and shoulders to the specified slopes and shapes, shall be carried out concurrently with the earthworks, which are being carried out at that particular site and level.

8.2.4. FILL MATERIAL

“Fill Material” shall mean material deposited to build up an earthworks construction to formation level. The CBR of fill for the platforms shall not be less than 5% at 91% MOD AASHTO density (4 day soaked test) and for road sub-grade, 9%. The Contractor shall obtain the fill material from a source approved by the Project Manager.
8.2.5. SPOIL MATERIAL

“Spoil Material” shall mean excavated material which is unsuitable for the requirements of the works. Spoil material shall be removed from the site to a spoil tip which should be within 300 m of the boundary of the site in a neat and tidy manner and shall be approved by the Project Manager.

8.2.6. EXPANSIVE MATERIAL

When expansive material (black cotton, clay) is encountered, it shall be removed to a depth of 600 mm below the formation or the existing ground level, whichever is greater. Material removed shall be stockpiled for later use in slope protection or spoiled to a tip as instructed by the Project Manager.

8.2.7. SURPLUS MATERIAL

“Surplus Material” shall mean excavated material which is temporarily surplus to the fill requirements and shall be carted to a designated stockpile for re-use later elsewhere in the works, or to an approved spoil tip.

8.2.8. FORMATION, SUB-GRADE AND PAVEMENTS

The “Formation” shall be the top surface of the earthworks in its final shape after completion. “Sub-Grade” of the roads and platforms shall be the top 150 mm of the fill in embankments, or of the existing ground in cut, lying immediately below the “Formation”. The “Pavement” shall be the whole construction in the road or paved areas made to support the traffic above the subgrade, comprising surfacing and base layers.

8.2.9. SIDE DRAINS

Where side drains are required, they will be considered as earthworks and measured and paid for as such, and shall be shaped by excavating the lines, slopes and widths shown on the Contractor’s design and finished off so that the formation levels and camber or super-elevation of the formation, level and crossfall of the shoulders and shape and invert levels of the side drains are everywhere in accordance with the Contractor’s design.

Any excess depth or width excavated from the side drains shall be backfilled and made good to the satisfaction of the Project Manager at the Contractor’s expense.

All other types of drains are specified separately in this specification.

8.2.10. EXCAVATION IN “ROCK”

Unless otherwise directed, the formation of the platform can be founded on rock. However, for roads, rock shall be excavated to an average level 150 mm below the formation and in no place less than 100 mm below the formation.

Any excess excavation in rock below the formation shall be backfilled and compacted.

Excess excavation in the invert of drains shall not be backfilled, but the rock surfaces shall be trimmed, and all loose particles removed, to allow free drainage of water.

Where side slopes are over-excavated, the slopes shall be trimmed to a neat shape and safe angle acceptable to the Project Manager. The sloping sides of all cuttings shall be cleared of all rock fragments which move when prised with a crowbar. Such excess excavation and additional work will not be paid for under the Contract.
The provisions of this clause do not apply to hard and common material, which materials shall be excavated to the lines and levels shown on the Contractor’s design or as instructed, within the permitted tolerances.

8.2.11. **SETTING OUT AND PREPARATION FOR EARTHWORKS**

The Contractor shall set out the earthworks and the tips of cuttings and toes of embankments at intervals of 10 m. Reference pegs shall be provided, clear of the earthworks and at right angles to the centre lines, from which the centre lines and levels can be re-established at any time.

Before the construction of any earthworks in the fills, the levels of the existing ground shall be agreed between the Contractor and the Project Manager. If the Contractor fails to take the requisite levels, then the ground levels determined by the Project Manager shall be taken as correct.

8.2.12. **CONSTRUCTION OF EARTHWORKS TO FORMATION**

All earthworks up to formation shall be formed and completed to the correct lines, slopes, widths and levels shown on the drawings and with the sub-grade parallel to and at the correct depth below the profile, camber, crossfall or super-elevation shown for the finished level, unless otherwise directed by the Project Manager.

Embankments and fills shall be constructed only of suitable material obtained from the excavation of cuttings. If the Contractor encounters material, which he considers unsuitable for earthworks, then he shall forthwith inform the Project Manager, who shall instruct the method of use or disposal of such material. If insufficient material can be obtained from the cuttings, additional material may be taken from approved borrow pits.

The Project Manager may direct that certain soils be excluded from certain layers and other soils set apart or obtained from borrow pits and used only for these layers, in which case the Contractor shall comply with the Project Manager’s directions and shall allow in his rates for such selection of materials.

8.2.13. **UNSUITEABLE MATERIAL INFORMATION**

Where, in the opinion of the Project Manager, unsuitable material occurs in cuttings, the Contractor shall excavate it to the depths and widths directed and replace it with selected fill material to form an improved formation.

8.2.14. **SPREADING AND COMPACTION OF EMBANKMENT AND FILLS**

Embankment and fills shall be compacted in layers not exceeding a compacted thickness of 150 mm, provided that the minimum relative density specified is achieved throughout the layer when compacted. The Contractor shall obtain the Project Manager’s approval of the previous layer before the next layer is spread. If the Contractor wishes to continue placing fill before density test results are available, he may do so entirely at his own risk and, should tests fail, then the Contractor must remove both the layer being tested and those placed above it, all at his own expense.

Unless otherwise specified, embankments and fills shall be compacted to a minimum relative dry density or 91% Mod AASHTO.

Embankments shall be constructed as far as is reasonable in layers parallel to the formation and to the full width corresponding to the height at which the work is being carried out from time to time. In no circumstances may a narrow portion of the embankment be constructed first and material “side tipped” to make up the specified width. Density tests must be taken on every layer at a frequency of
one for every 1000 m² of area. The specified density is a minimum so the Contractor must aim to achieve a higher density than the minimum specified to achieve a stable platform with sufficient bearing capacity and stability.

8.2.15. **ANT, TERMITE AND OTHER INSECT HILLS OR NESTS**

Where an ant, termite or other insect hill or nest occurs within the limits of earthworks, all that portion of the hill or nest which is up to 2 m below formation level shall be removed. The cavity formed by the excavation of the hill or nest shall be poisoned with an approved pesticide and be backfilled with approved material in layers not exceeding 150 mm and compacted.

8.2.16. **DRAINING OF WORKS**

All cuttings, embankments and borrow pits shall be kept free of standing water and drained during the whole of the construction.

Should water accumulate on any part of the earthworks, either during construction or after construction, until the end of the maintenance period, giving rise to soaking or eroding conditions in the earthworks, the Project Manager may direct the Contractor to remove and replace at the Contractor’s expense any material which has been so affected.

All drains shall be maintained throughout the Contract in proper working order.

The Contractor must allow in his rates for draining the earthworks satisfactorily at all stages during the construction and arrange his methods and order of working accordingly.

8.2.17. **SUB-GRADE LAYERS**

The sub-grades of roads, in both cuttings and embankments shall be compacted to 93% Mod AASTHO dry density or as otherwise specified. The sub-grades of the platforms shall be compacted to 91% Mod AASHTO dry density. The maximum compacted thickness which shall be laid, processed and compacted at one time shall be 150 mm. The maximum dimension of any particle in the layer shall not exceed 100 mm.

The layer shall be scarified and water shall be mixed in, or the material allowed to dry to the correct moisture content, and the layer shall then be compacted to the specified dry density, or as otherwise directed. The most suitable moisture content for compaction will be usually in the range of +½% to -2% Optimum Moisture Content.

During the process the final surface of the sub-grade layer shall be graded to level, parallel to the crossfall or camber and profile shown upon the drawings or directed by the Project Manager. Density tests must be taken at frequency of one for every 250 m² of area.

An item is provided in the Bill of Quantities for the additional compaction of sub-grade in roads which shall include the cost of complying with the final tolerances. No separate item is provided for the platforms where the cost of achieving the final tolerances must be included in general earthworks rates.

8.2.18. **TOLERANCES**

The following tolerances will be permitted in the finish of the formation roads and platform:

- The level of the formation should be within ± 50 mm of that specified.
On the final trimmed slope of earthworks a variation of ± one fifth of the specified slope will be allowed.

The tolerances permitted in the overall width of the bottom of cuttings shall be ±150 mm in the distance between centre lines and the toe cuttings slopes and plus 150 mm in the case of embankments.

8.2.19. PROTECTION OF EMBANKMENT SLOPES

The topsoil and expansive material removed from the works shall be placed on embankment slopes as directed by the Project Manager. The slopes shall be trimmed to form a gradient not less than 1 on 5 unless otherwise directed.

8.2.20. GRASSING OF SLOPES

The surface of embankment slopes, after placing of topsoil, shall be planted with grass sprigs at approximately 250mm centres. Unless instructed otherwise by the Project Manager, the type of grass shall be indigenous, low growing or runner grass. While planting, the area shall be irrigated for as long as necessary to ensure that the grass is properly established and has completely covered the ground. Grass should be planted only in the rainy season.

8.2.21. BORROW PITS

Where it is necessary to borrow material for construction, suitable pits shall be provided by the Contractor to the approval of the Project Manager.

All borrow pits must be carefully cross-sectioned before and after excavation on order to determine the quality of earth excavated.

After removal of material for use, the area must be rehabilitated by the Contractor so that it will not prove a hazard to person or animal or be a source of erosion. The sides of the excavation must first be sloped and then any previously stockpiled topsoil spread as far as possible.

At some borrow pit locations, further cleaning and fencing may be required.

8.2.22. SOIL STERILISATION

In order to stop the growth of vegetation and incidence of ants, the Contractor shall apply an approved herbicide before any spreading of crushed stone over the platform area.

Insecticide shall be used around the Control Buildings.

8.2.23. EARTH ELECTRODES

The Contractor shall install an earth grid and/or earthing electrodes in trenches as determined by his earthing system design.

8.3. MATERIALS FOR THE WORKS

8.3.1. GENERAL

Before placing any order for materials or manufactured articles for incorporation in the civil works, the Contractor shall submit for the approval of the Project Manager the names of the firms from whom he proposes to obtain such materials, together with a list of the materials and manufactured articles giving the origin, quality, weight, strength, description, which he proposes that the firms
should supply. No materials or manufactured articles shall be ordered or obtained from any firm of which the Project Manager shall not have previously approved.

All materials shall be delivered to the site in a sufficient period of time before they are required for use in the works, to enable the Project Manager to take samples for testing and approval. Any materials rejected as unsuitable for works shall be removed from the site at the Contractor’s expense.

The Contractor may propose for the Project Manager’s approval alternative materials of equivalent quality to those specified.

8.3.2. CONCRETE PIPES

Concrete pipes, porous concrete pipes, cast iron manhole covers and gratings, bricks, concrete kerbs, bituminous surfacing, cement, steel and aggregates shall comply with local or regional standards (to be approved by Project Manager) as follows:

- Precast concrete non-pressure pipes for the culverts and storm water drainage shall comply with CAS A17. The pipes shall have ogee joints.
- If required, porous concrete pipes for use in sub-soil drains shall comply with CAS A17.
- Cast iron manhole covers and frames and gratings shall comply with SABS 558 1973 or BS 497 and the duty shall be medium weight 100 kg.

8.3.3. FILTER BACKFILL FOR SUB-SOIL DRAINS

Filter backfill for sub-soil drains shall be graded crushed stone.

8.3.4. STONE FOR PITCHING

Stone for pitching to drains, inlets and outlets of culverts, to embankments and around structures shall consist of sound un-decomposed rock. Precast concrete tiles may also be used.

The stone as dressed shall be roughly cubical in shape with minimum dimensions of 150 x 150 x 150 mm for a nominal thickness of 150 mm pitching or 225 x 225 x 150 mm for a nominal thickness of 225 mm pitching.

Hard stone boulders may be used for grouted pitching only but in this case the size shall be 225 mm minimum diameter for a nominal thickness of 150 mm pitching and 300 mm diameter for a nominal thickness of 225 mm pitching.

8.3.5. CLAY AND CONCRETE BRICKS

Clay bricks shall comply with CAS 211 and concrete bricks shall comply with CAS A 41.

8.3.6. STONE FOR PLATFORM SURFACING

The stone shall be hard and durable crushed rock with a maximum particle size of 62 mm and not more than 15% shall pass a 9.5 mm sieve.

The stone layer to be spread uniformly over the finished surface of the platform shall have a thickness of 100 mm.
8.3.7. **GRAVEL SUB-BASE MATERIAL**

Gravel for the road sub-base layer shall be natural gravel obtained from a proven source and shall comply with the following requirements:

- CBR at 95% Mod AASHTO density and after 4 day soak \( \text{Min 30} \)
- Plasticity index \( \text{Max 12} \)
- Plasticity product \((I_f \times I_p)\) \( \text{Max 200} \)
- Maximum particle size (mm) \( \text{Max 80} \)

8.3.8. **CRUSHED STONE BASE COURSE**

Material for road base to support the bituminous surfacing shall be crushed rock complying with the following requirements:

- CBR at 97% Mod AASHTO density and after 4 day soak \( \text{Min 80} \)
- Plasticity Index \( \text{Max 6} \)
- Liquid limit \( \text{Max 25} \)
- Coarseness Index \( 50 – 70 \)
- Fineness Index \( 5 – 15 \)

In addition the grading shall be within and approximately parallel to the following envelope:

<table>
<thead>
<tr>
<th>British Standard Sieve size (mm)</th>
<th>Percent Passing by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5</td>
<td>100</td>
</tr>
<tr>
<td>19.0</td>
<td>80-100</td>
</tr>
<tr>
<td>9.5</td>
<td>55-80</td>
</tr>
<tr>
<td>4.75</td>
<td>40-64</td>
</tr>
<tr>
<td>2.36</td>
<td>30-50</td>
</tr>
<tr>
<td>1.18</td>
<td>22-40</td>
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<tr>
<td>0.6</td>
<td>15-30</td>
</tr>
<tr>
<td>0.3</td>
<td>10-23</td>
</tr>
<tr>
<td>0.15</td>
<td>8-19</td>
</tr>
<tr>
<td>0.075</td>
<td>5-15</td>
</tr>
</tbody>
</table>

Equivalent road gravel, produced by a recognised quarry which has been successfully used as Base 1 elsewhere, may be utilised with the approval of the Project Manager.

8.3.9. **PRECAST CONCRETE KERBS**

Precast concrete kerbs shall be in accordance with CAS 104 and the dimensions shall be 1000 x 300 x 100 mm at the base with a chamfer to 60 mm, over the top 150 mm.
22.2.10 Surface Dressing Chipping for Roads

All chippings shall consist of tough durable crushed stone cubical in shape and free from visible dust and harmful materials such as loam, clay, salt, lime, organic matter and other deleterious constituents.

The rock from which the chippings are to be produced shall comply with the following:

- Aggregate crushing value: not greater than 22%
- Los Angeles Abrasion value: not greater than 28%
- Sodium sulphate soundness test: Loss on 20 cycles to be no more than 20%

b) Gradings

Chippings for surface treatment work shall be “Single sized crusher stone for roads” in accordance with CAS 232. The following nominal sizes of chippings shall be used:

- First seal 13.2 mm + 6.7mm
- Second seal 6.7 mm + 1.18 mm

8.3.10. BITUMEN AND TARS

Before any bitumen, bitumen emulsion or tar is delivered to the site the Contractor shall provide the Project Manager with a certificate from the manufacturer that the material to be supplied complies in all respects with the specification.

The types of bitumen required will be as follows:

- Prime Coat - MC 30 or 70 or RC 30 or 70 cut back bitumen conforming to CAS 145 or TP 7 Tar conforming to CAS 105
- Surface dressing - 150/200 penetration straight run bitumen conforming to CAS 144
- With special approval - 60% cationic rapid setting bitumen diluted 1:1 with water.

8.4. DRAINAGE AND STORM WATER

8.4.1. SETTING OUT OF SUB-SOIL AND STORM TRENCHES

The Contractor shall be responsible for setting-out from information provided by the Project Manager and shall include for such work in his rates.

Prior to excavating a section of pipeline, sight rails shall be erected at each end and at each change in grade and direction with a maximum distance between profiles of 50 m.

Site rails and boning rods shall be of substantial construction and shall be painted black and white in such manner as to indicate clearly the lines and levels to be worked to.
8.4.2. EXCAVATION AND BACKFILLING OF SUB-SOIL DRAINS

The drains shall be formed by cutting a trench, lining it with double thickness of black shade cloth and backfilling with a suitable filter material surrounding a porous concrete pipe. The drains shall have a minimum of 600 mm depth from platform formation and a gradient of 1 in 100. The internal diameter of the porous pipes shall be 225 mm and the backfill filter material shall consist of crushed stone.

The stone backfilling should be placed around the pipe in the trench and compacted thoroughly in layers so as to ensure that no settlement will occur later in the section of finished platform directly above the trench. The discharge ends of all subsoil drains must be carefully protected to avoid blockage and they should be suitably marked.

8.4.3. EXCAVATION AND BACKFILLING OF PIPED STORM WATER DRAINS

The piped drains are to be formed by cutting a trench, laying a minimum 300 mm internal diameter pipe and backfilling with a suitable material. The drains shall have a minimum of 650 mm depth from platform formation and a gradient of 1 in 100. The backfill material shall have the following grading:

<table>
<thead>
<tr>
<th>British Standard Sieve size (mm)</th>
<th>Percent Passing by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>≥85</td>
</tr>
<tr>
<td>5</td>
<td>≤20</td>
</tr>
<tr>
<td>2.36</td>
<td>≤5</td>
</tr>
</tbody>
</table>

A 150 mm thick layer of backfill material shall be laid and compacted thoroughly before placing the pipe in the trench. The material shall also be placed and compacted around the pipe for the full width of the trench and shall extend to a level 150 mm above the top of the pipe and compacted to a density not less than 91% of Mod AASHTO density. The rest of the trench shall be backfilled to the same standard with approved material from excavation or other works.

8.5. OTHER SERVICES

Where trenches pass near or across other services, the Contractor shall take every precaution against damaging such services. These services shall be properly supported in the trench until backfilling is complete and the backfilling shall be thoroughly compacted under and around such services.

8.6. EXPLOSIVES AND BLASTING

Blasting shall only be carried out on sections of the works for which permission in writing shall have been given by the Project Manager and shall be restricted to such hours and conditions as he may prescribe. Such permission shall not be withheld nor such hours and conditions imposed unreasonably.
8.7. CLASSIFICATION OF EXCAVATION

For the purpose of measurement of excavation in pipe trenches the excavation will be classified as follows:

- “Rock” which for this purpose is undecomposed rock occurring in bulk or banks or ledges, the practicable excavation of which requires explosives or drilling, wedging and splitting, or undecomposed boulders each exceeding 0.2 m³ in volume.

- “Hard” which for this purpose is material other than rock, the economically practicable excavation of which necessitates the use of mechanical breakers, or which will reduce the rate of excavation of a back-acting excavator having a power of at least 0.1 kW/mm width of bucket to one third or less of that achieved by the same excavator in soft excavation at a similar depth. Laterite, iron pan and cemented gravels will generally fall into this category.

- “Common” which for this purpose is all other material not falling into the categories of “Rock” or “Hard” and will include all loose, decomposed boulders less than 0.2 m³ in volume.

For purpose of payment, items are included in the Bill of Quantities for excavation in the foregoing three classes. The classification of material into these classes shall be agreed by the Project Manager, or on his behalf. For the Contractor as the work proceeds, material shall be classified only as “Rock” or “Hard” when the Project Manager has given its agreement prior to its removal.

8.8. PIPE CULVERTS

8.8.1. PREPARATION OF FOUNDATION

The construction of pipe culverts shall be carried out to the lines and levels shown on the drawings. In order that the foundation material shall be undisturbed, the last 100 mm depth of excavation shall be carried out by hand. The excavated surface shall be kept clean and free from standing water. Before placing the concrete, the surface shall be lightly compacted.

Excavation in rock shall be carried out to the specified levels and dimensions unless otherwise directed by the Project Manager.

8.8.2. FORMS

The Contractor will be required to form vertical surfaces to the concrete by means of timber forms. Smooth formwork shall be used for the exposed faces and shall be adequately supported to prevent movement during concreting. Unsmooth butt-jointed timber may be used for the unexposed faces. The top surface of the forms shall be set accurately to the required levels or slopes.

8.8.3. STONE PITCHING

Where shown on the drawings or where directed by the Project Manager, stone pitching shall be used to form apron slabs and banks at culvert inlets and outlets, as lining to drains and slopes.

All areas to be pitched shall first be thoroughly cleaned and compacted to a sufficient extent to ensure that no subsequent settlement shall occur. At culvert inlets and outlets the level of the pitching shall be the same as the culvert or apron inverts.
The pitching stones shall be laid with their longest dimensions perpendicular to the slope and shall be rammed into the under-surface until firmly bedded and uniform surface true to line and grade is obtained. Pitching stones shall be firmly butted up against the adjacent pitching stones.

Where grouted stone pitching is called for, the stone shall be laid as prescribed, the surface thoroughly wetted and the spaces between the stones filled with cement mortar or composed of one part of cement to three parts of approved river sand. The mortar shall be worked into the pitching so as to ensure that all spaces or voids between the stones are completely filled with mortar. The grouted pitching shall then be cured by keeping it continuously covered with wet sacking, or other approved wet cover. For the period of not less than four days from the time the mortar was applied.

8.8.4. OUTLET AND OTHER DRAINAGE WORKS

Where directed by the Project Manager, channels shall be excavated as outlets from culverts, to straighten or extend water courses, improve entries to culvers, form cut-off drains, divert water and the like. These channels shall be excavated to the sizes, shapes, levels and dimensions shown on the drawings or directed by the Project Manager.

Material from such excavation shall be carted to spoil or stockpile or used elsewhere in the Works as instructed by the Project Manager. In some cases the material shall be deposited adjacent to the sides of the excavation in which case the material shall be deposited in such a manner and location that it will not obstruct the flow of water along the channel or subsequently be washed back into the channel and it shall be trimmed to a neat and tidy shape as shown on the drawings or directed by the Project Manager.

8.9. ROAD PAVEMENTS AND SURFACING

8.9.1. PREPARATION

Prior to the construction of each pavement layer, the previous shall be thoroughly cleaned of all foreign substances. Any ruts or soft spots which occur or any deviation from the specified tolerances or degree of compaction shall be corrected by scarifying, removing and/or adding approved material, relaying and re-compacting the unsatisfactory areas to the required density and to the required lines and levels. Should any damage occur to a pavement layer prior to the construction of the next layer, it shall be rectified to the satisfaction of the Project Manager at the expense of the Contractor.

8.9.2. ALIGNMENT AND LEVEL CONTROL

Stakes, boards and boning rods of substantial construction shall be furnished, set and maintained by the Contractor, in order that the works will conform to the lines and levels shown on the drawings. The stakes shall be set at intervals not exceeding 20 m in lines parallel with the centre lines and not more than 15 m apart. Stakes, boards and boning rods shall be painted black and white in such a manner as to indicate clearly the lines and levels to be worked to for each layer or pavement.

8.9.3. THICKNESS AND SURFACE TOLERANCES

The thickness of each pavement layer shall be such that the depths from the required finished surface levels of the pavement to the surface of each pavement layer shall nowhere be less than the depths shown on the drawings. The surfaces of each layer other than the final layer may be lower than the required surface within the tolerances stated below, provided that any such deficiency shall be made good at the Contractor’s expense by increasing the thickness of the course above the surface in question.

Each layer of pavement shall be finished to a surface profile parallel to the finished surface of the pavement shown on the Contractor’s design within the following level tolerances:
- Sub-base layer +5 to -20 mm
- Base course +5 to -10 mm

The finished surface of the base course shall be such that when tested with a straight edge 3 m long placed in any position and direction, there shall not be any gap greater than 10 mm between the bottom of the straight edge and the surface. In addition to this requirement there shall not be any deflection exceeding 20 mm from a straight line between any two points 30 m apart. Neither of these requirements shall apply across road crowns. These smoothness tolerances apply to straight profiles and equivalent smoothness tolerances shall be applied to vertical curves and profiles.

8.9.3.1. SUB-BASE AND WEARING COURSE

Natural gravel sub-base and wearing course materials for internal and access roads respectively shall comply with the requirements for earthworks, and shall be compacted to achieve, as a minimum, density of 95% of the modified AASHTO density. The frequency of density tests shall be one for every 250 m² of layer area.

After the completion of second stage works, the gravel-wearing course of the access road shall be re-shaped, replaced of any gravel loss and re-compacted as directed by the Project Manager.

8.9.3.2. BASE COURSE

Graded crushed stone for base in internal roads shall comply with the requirements for earthworks and shall be compacted to achieve, as a minimum, the density of 97% of the Modified AASHTO density. The frequency of density tests shall be one for every 250 m² of layer area.

The Contractor shall supply and stockpile at site, the required quantity of crushed stone for later use, as soon as possible after the commencement of the Contractor. The quantity to be paid to the Contractor for supply and stockpile shall be the compacted volume incorporated in the Works. The Contractor shall include in his rates, the transport costs of crushed stone to site and an allowance for bulking and wastage.

8.9.4. LAYING AND COMPACTING PAVEMENT LAYERS

The pavement material shall be deposited in such quantity and spread in a uniform layer across the full width of the area, so that the final compacted thickness is everywhere not less than shown upon the drawings or ordered by the Project Manager.

The uncompacted thickness of the layer shall be such that the thickness after compaction shall not exceed the specified thickness. The material shall be thoroughly mixed to a uniform consistency and large material shall be broken down so that the grading complies with the specification. Large stones or boulders, which cannot be broken down to the required size, shall be removed to an approved tip.

The spread material shall be brought uniformly to within a range of 90% to 110% of the optimum moisture content, as previously determined for the material, by sprinkling with water and/or mixing as required.

Compaction shall be carried out by such method and using such plant as the Project Manager may approve until the specified minimum dry density is achieved. The Project Manager may disapprove any methods of compaction or items of compaction plant, which in his opinion are detrimental to the work.

Additional water shall be applied to the materials during compaction in amounts such as are required to maintain the moisture content within the specified limits. Any base course finished with a surface level above the required surface level shall be planed down to the correct level scarified re-compacted and finished as specified.
If at any time after compaction the base course dries out sufficiently to lose apparent cohesion, or is damaged by rain, it shall be scarified, aerated and/or watered, re-compacted and finished as specified above.

The surface of the material shall, on completion of compaction, be well closed, free from movement under the compaction plant and free from compaction planes, ridges, cracks or loose material. All loose, segregated or otherwise defective areas shall be dug out and made good with new material to the full thickness of the layer and re-compacted all at the Contractor’s expense.

8.9.4.1. JOINTS BETWEEN NEW AND PREVIOUS WORK

The forming of construction joints and the protection of previously completed works shall be carried out so as to produce a uniformly compacted and homogenous layer free from ridges or other surface irregularities.

Full width working without longitudinal joints is required. When forming a transverse joint at least 5m length of the previously laid work shall be incorporated into the new layer.

8.9.4.2. HEATING OF BITUMEN

Bitumen shall be heated in approved boilers or bulk storage containers equipped with adequate pumps and accurate thermometers such that the temperatures at the time of spraying are within the limits given in the table below.

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straight run bitumen grade 150-200 penetration</td>
<td>165   200</td>
</tr>
<tr>
<td>M.C.30, R.C.30</td>
<td>35   60</td>
</tr>
<tr>
<td>M.C.70, R.C.70</td>
<td>60   85</td>
</tr>
<tr>
<td>Bitumen emulsion</td>
<td>15   70</td>
</tr>
</tbody>
</table>

No bitumen shall be heated above the maximum temperature recommended by the supplier and any that is accidentally over-heated shall be removed from the site and disposed of by the Contractor at his own expense.

No bitumen shall be heated in a boiler for which the thermometer is broken or inaccurate.

8.9.4.3. CONSTRUCTION LIMITATION

No bituminisation will be permitted when the road is wet or when the surfacemoor moisture is such as to prevent even coverage by the binder. Work may not proceed when the temperature is less than 15°C unless specifically approved by the Project Manager.

The surface of the layer shall be thoroughly swept and all loose and foreign material removed. All loose material shall be swept well clear of the layer to expose the full width of the layer.

The surface of the layer shall be checked for line, camber and level and the surface corrected made good as necessary and approved by the Project Manager before any bitumen prime is added.

Where required by the Project Manager immediately prior to the application of prime the surface of the layer shall be lightly sprayed with water but not saturated.

8.9.4.4. SPRAYING OF PRIME COAT

General
Immediately after the area to be primed has been prepared and approved by the Project Manager the prime shall be sprayed onto it.

**The amount and type of prime**

The amount and type of prime shall be as directed by the Project Manager. The rate of spray will depend upon the texture and density of the surface but will usually be in the range of 0.75 l/m² to 1.0 l/m². The quantities used must give complete coverage of the surface. Should the Contractor find that when using the rate of spray directed by the Project Manager the coverage is inadequate or if there is run-off he shall immediately inform the Project Manager and amend the spray rates as directed by the Project Manager.

**Curing of Prime Coat**

The prime coat shall be allowed to dry out before anything is allowed to pass over the surface. Where the prime puddles on the surface, it shall be blinded with sand or quarry dust until the free bitumen is absorbed. Pneumatic-tyred vehicles shall not run over primed surfaces for at least 7 days.

**Binders for Surface Dressing**

The type of binder and the rate of spray shall be as directed by the Project Manager. The quantity of binder required will depend upon the shape and size of chippings and the nature and absorbency of the surface.

The rate of spray will generally be between 0.8 l/m² and 1.4 l/m² for each seal coat to give a total application of 2 l/m². The Project Manager may from time to time direct the Contractor to vary the rates of application and the Contractor shall be deemed to have allowed for this in his prices.

8.9.4.5. **Surfacing of Platforms:**

The stone for surfacing of platform must be uniformly spread to a thickness 100 mm over the full-uncovered formation of the platform.

The Contractor shall supply and stockpile at site, the required quantity of stone for later use, as soon as possible after the commencement of the Contract. The Contractor shall trim the stockpile to have a flat surface and rectangular shape with uniform and stable slopes. The Contractor will be paid for the measured volume of the stockpile and the rate shall include for the supply and transport to site and forming the stockpile.

If instructed at a later date to lay and spread the 100 mm layer of stone on the platform, the Contractor shall remove any growth of vegetation, re-compact, trim and sterilise the platform surface before laying the stone, so that the formation shall comply with the requirements of this Section. Payment for this work will be negotiated.

8.10. **FENCING**

8.10.1. **GENERAL**

The Contractor shall construct fencing both along the perimeter of substations and round the boundary of the property including gates where necessary.
8.10.1.1. DIMENSIONS

<table>
<thead>
<tr>
<th>Description</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of fence</td>
<td>2300 mm</td>
</tr>
<tr>
<td>Height of chain link fabric</td>
<td>2000 mm</td>
</tr>
<tr>
<td>Barbed wire</td>
<td>3 wires above fabric, height of 300 mm, on supporting arms facing outwards from site at 45° angle</td>
</tr>
<tr>
<td>Maximum distance between posts</td>
<td>3000 mm, except where interrupted by gate</td>
</tr>
<tr>
<td>Terminal posts (including end, corner and straining posts)</td>
<td>89 mm outside diameter; 114 mm outside diameter at gates</td>
</tr>
</tbody>
</table>

Embedment lengths of terminal posts

| Corner and straining posts                                      | 100 mm                      |
| End posts                                                       | 200 mm                      |
| Gate posts                                                      | 400 mm                      |

Tension bars and bands

Locate at terminal posts to fix fabric, bottom wire and barbed wire

Top rail

“extra-strong” pipe, 43 mm outside diameter

Braces (use two braces at corner and restraining posts)

“extra-strong” pipe, 43 mm outside diameter for attaching end and gateposts to adjoining posts

Gate width (free distance between 2 gate posts)

| single gate                                              | 1500 mm                     |
| double gates                                             | 5000 mm                     |

Double gates

One leaf for normal traffic. Other leaf to remain closed by means of drop bolt locking into centre rest, inoperable from exterior

Gate opening

Able to open in either direction to 90°

Gate hardware

Three hinges, latch with padlock accessible from either side of gate, latch catch

Top of posts and uprights

Weatherproof tops

8.10.1.2. MATERIALS:

Fabric: ASTM A 392, 2000 mm high, 3.8 mm diameter (No. 9 gauge) steel wire, 50 mm diamond pattern, twisted and barbed finish at top, knuckled wires at bottom, zinc coated.

Pipes: ASTM A 120, steel pile, hot-dipped zinc coated after welding, diameter and weight size as shown on drawings, unthreaded ends, free from burrs.

Fence fittings: ASTM F 626, hot-dipped zinc coated according to ASTM A 123
Barbed wire: ASTM A 121, 2.51 mm diameter wire in strand (No.12-1/2 gauge), 2 strands with 4-point barbs spaced at 125 mm, Class 3 zinc coating.

Bottom wires: 5mm (No.6 gauge) steel wire, 500 g/m² zinc coating. This shall be surrounded by a concrete beam (C20) as shown on the drawings.

Fence fittings: ASTM F 626, steel tension bars and bands, nuts and bolts, weatherproof tops of commercial aluminium alloy, malleable cast iron, or rolled or pressed steel, cast iron and steel fittings hot-dipped galvanised with 500 g/m² according to ASTM A 123.

Concrete: 20 MPa at 28 days

8.10.1.3. INSTALLATION

Installation of fencing and gates shall be according to ASTM F 567, unless otherwise indicated and to drawings and this specification.

Level ground surface so that space between finished ground surface elevation and bottom of fabric does not exceed 50 mm.

Plumb and align posts to within 10 mm.

Install posts of a gate at same elevation regardless of difference in ground level.

Set posts in concrete footings in form of truncated cone, according to ASTM F 567, and as follows:

<table>
<thead>
<tr>
<th>Foundations</th>
<th>Ordinary Soil</th>
<th>Solid Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Line Posts &amp; Centre Rests</td>
<td>Terminal Posts</td>
</tr>
<tr>
<td>Depth</td>
<td>1000 mm</td>
<td>1600 mm</td>
</tr>
<tr>
<td>Diameter at top</td>
<td>250 mm</td>
<td>300 mm</td>
</tr>
<tr>
<td>Diameter at bottom</td>
<td>350 mm</td>
<td>400 mm</td>
</tr>
</tbody>
</table>

Make joints in fabric at terminal posts.

Fasten every 450 mm along top rail, braces and bottom wire and every 300 mm on line posts.

Secure barbed wire to terminal and gateposts with tension bands, and to gate uprights with hooks.

Install bottom wire in middle of last line of mesh.

8.11. CONCRETE AND BUILDING WORKS

8.11.1. EARTHWORKS

Soil Parameters
For preliminary design and calculation of concrete foundations in the substation the Contractor shall use the following soil parameters:

- Soil submerged \( \gamma_1 = 10.00 \text{kN/m}^3 \)
- Soil dry \( \gamma_2 \text{= 19.00 kN/m}^3 \)
- Cone angle \( \varphi = 300 \)°
- Factors bearing capacity \( N_g \) and \( N_q \) from handbooks
- Safety factor \( F\approx 1.5 \)

These parameter values shall be replaced by measured values after soil testing has been completed.

The Contractor shall be required to perform sub-soil tests within the area if the switchyard to the depth and by the method of test specified by the Project Manager. The details of performing the test, tools and plant to be used for, shall be submitted to the Project Manager for approval.

The sub-soil tests shall be carried out by any method as stated hereafter under the supervision of a qualified person, who shall be subject to approval of the Project Manager.

8.11.2. EXCAVATION

Excavation for concrete foundations shall be carried out in strict accordance with the requirements of the Project Manager and to fit in with the programme of construction.

8.11.3. SHORING AND TIMBERING OF EXCAVATION

The Contractor shall be entirely responsible for the safety of all excavations, for the prevention of injury to workmen and for the stability of the faces of the excavation.

The adjacent road surfaces shall remain trafficable, and cracking or cave-ins shall be avoided. All shoring and timbering shall be done to the approval of the Project Manager, who may direct such shoring or timbering to be strengthened or altered if he considers this necessary in the interest of the work or to safeguard against accidents to workmen or cave-ins. For the purpose of measurement the following categories of shoring shall apply:

- Open timber shoring - This shall consist of vertical boards of not less than 225 mm width and not greater centres than 1.6 m on both sides of the trench and held in place by shoring which shall be strutted apart. Intermediate boards may be used and must be firmly wedged in position against the shoring.
- Close timber shoring - When directed by the Project Manager or dictated by the ground condition close timber shoring shall be timber boards in contact to give a complete support to the sides of the trench. The boards shall be supported by walls and strutted as required.

8.11.4. DEWATERING

The whole Works shall be constructed in the dry and the Contractor shall keep all excavations free from water, whatever the source or cause may be, and shall properly deal with and dispose of water by use of sufficient temporary works, plant and appliances so as to ensure that the whole Works is executed in a satisfactory dry and safe manner. Prices for the excavation shall be deemed to include for all dewatering operations.
8.11.5. **EXCAVATION TO BE APPROVED**

In no case shall broken stone for under drainage or concrete be placed in an excavation until the surface on which such materials are to be placed has been approved by the Project Manager.

The Contractor shall advise the Project Manager whenever the bottom of any excavation is ready for inspection or whenever it is necessary to cover up the work. In default of such notice the foundation shall, on the order of the Project Manager, be uncovered by the Contractor and reinstated without extra charge.

8.11.6. **DISPOSAL OF EXCAVATED MATERIAL**

All material excavated under this Contract shall be disposed of in accordance with the instructions issued by the Project Manager. Selected material required for back-filling shall be removed to a tip found by the Contractor and the Contractor shall ensure that the required amount of spoil is set aside.

8.11.7. **OTHER SERVICES**

Where trenches pass near or across other services, the Contractor shall take every precaution against damaging such services. These services shall be properly supported in the trench until backfilling is complete and the backfilling shall be thoroughly compacted under and around such services.

8.11.8. **BACKFILLING**

Backfilling shall be carried out either with selected spoil as set aside, or with imported selected spoil, or with crusher run, or where specified, with gravel of 38 mm nominal size to B.S.C.P. 2006 Table 4.

No backfilling shall be done until all the formwork has been removed together with pieces of timber, cement bags, vegetation and/or other rubbish.

All backfilling shall be compacted in layers not exceeding 150 mm thick and shall be sprayed with water to bring the moisture content to the optimum for dense compaction.

Compaction shall be such as to achieve a minimum of 91% H.C.E. density up to 300 mm below pavement level, and a minimum of 98% above this level up to the underside of the pavement. Compaction shall be tested by a Testing Laboratory.

8.11.9. **MEASUREMENT OF EXCAVATION**

All excavation are measured to the net sizes of the foundations, no allowance is made of battering sides, or for workroom unless otherwise described. No allowance is made for increase in bulk after digging. Prices shall be deemed to provide for well watering and ramming bottoms to the satisfaction of the Project Manager.

Except where essential, casing shall be measured to the sides of the column foundation bases below ground level. Should the Contractor excavate the foundations wider than the concrete base sides, the additional excavation, filling and any necessary consequent casing shall be to his cost.

The final depth of all column foundation bases will be decided on site by the Project Manager. The Contractor shall give notice to the Project Manager when the bases have been excavated to the decided level.

No concrete shall be laid until the Project Manager has given his written opinion that a proper foundation had been obtained and the quantity surveyors have been notified in writing in order for them to take the necessary records for adjusting their original measurements contained in the Bill.

Where vertical faces of excavation are to be cut neat to take the face of a concrete wall, they shall be
protected immediately after cutting with 500 gauge polythene fixed with 50 mm x 50 mm vertical timber battens at 800 mm centres. Hollow or uneven surfaces caused by inaccurate excavations are to be completely filled with 1 : 3 : 6 concrete at the Contractor’s expense.

For the purpose of measurement all excavations shall be divided into the following classes:

- **Rock** - undecomposed boulders each exceeding a 0.3 m³ volume and solid rock occurring in bulk or in banks or ledges, the practicable excavation of which would normally necessitate the use of explosives.

- **Hard material** - material other than rock, the excavation of which would be economically impracticable if executed by pick and shovel.

- **Soft material** - material more easily excavated than, and not falling into the categories of “rock” or “hard material”, such as gravel, earth, sand, silt and clay.

### 8.11.10. MEASUREMENT OF BACKFILLING

Backfilling shall be measured as the difference between the nominal volume of excavations as specified and the external volume of the concrete works as specified on the drawings. Thus no payment will be made for backfilling of over-break of subsidence. The bill of rates for filling shall be deemed to cover the cost of all operations described in this specification, including selection of spoil, excavation from temporary spoil dumps or transporting from excavation, loading and transporting to site of fill, off-loading, spreading, watering and compacting.

Where the fill material is crusher run or gravel the schedule rates shall include the cost of supply of the materials as well as the off-loading, spreading, watering and compacting as specified. No payment will be made for overhaul and the rates entered by the Contractor will be deemed to cover the complete backfilling operation specified in this document up to the underside of the pavement.

### 8.12. CONCRETE, FORMWORK AND REINFORCEMENT

#### 8.12.1. MATERIALS

**Aggregates**

- Shall conform to CAS 233.
- Shall be heaped separately on hard, self-draining surfaces.
- Normal size of coarse aggregate shall be 20 mm.

**Water**

- Shall be fit to drink.

**Reinforcement**

- Shall conform to the following standards: BS 4449, BS 4461, BS 4482, BS 4483, SABS CKS 158.

**Cement**

- Shall conform to CAS A46.
- Shall be either normal Portland or P.C. 15.
- Shall be used within 6 weeks of manufacture.
- Shall be stored in a manner to exclude any moisture
- Shall be stored in a manner to ensure use of the earliest consignment
- Different types of cement from different manufacturers shall not be mixed for a single cast or structural element.
  Additives shall not be used.

8.12.2. BEFORE CONCRETING

Design Mixes

- Not less than 2 weeks before the start of concrete work, the Contractor shall submit to the Project Manager for his approval a statement of proposed mix proportions for the various grades required in the project. Note: the grade is the characteristic strength or the cube strength below which not more than 5% of the result may be expected to fall when tested at 28 days.
- The statement shall include proportions of cement, fine and coarse aggregate, and water, the maximum and minimum slump and the target strength for each grade.
- A certificate by a recognised laboratory that the proposed mix will meet the requirements must accompany the statement.
- The proportions stated shall not later be altered without the written approval of the Project Manager.
- Cost of mix designs to be borne by the Contractor.

Formwork

- Formwork shall be sufficient to leave the concrete finishes specified on drawings and to be within the tolerances specified in the following table and to provide an acceptable surface for applied finishes, where required.
  - Line and level: 1 mm per metre not exceeding 5 mm
  - Pockets, sleeves etc.: ± 5 mm
  - Bases: ±50 mm

- Where specified as smooth or the concrete as off good shutter, the surface shall be formboard or smooth timber of not less than 200 mm width, to impart a smooth finish free of projections, voids, and tender prices are to include for any necessary rubbing down. The type of ties to be used shall be such that the required finish is achieved and does not become marred by subsequent corrosion. Ties are to be set out to definite pattern to the Project Manager’s approval. Rubbing down is allowed only after the Project Manager’s approval of the surface to be treated.

Reinforcement

- Shall not be heated or re-bent without the Project Manager’s permission.
- Shall be free from any material likely to impair bond or initiate corrosion.
• Shall be bent and fixed according to the Project Manager bending schedules.
• Shall be tied with soft iron wire.
• Shall be supported to maintain the following minimum cover during concreting.
  • The greater of the diameter of the bar or 40 mm for external un-plastered face.
  • The greater diameter of the bar or 15 mm for internal face.
• Shall be inspected by the Project Manager.

**Construction Joints**

• Shall be avoided if possible, but if unavoidable shall be pre-planned in consultation with the Project Manager and temporary stop ends inserted. Before placing of concrete against a construction joint, the formed face shall be hacked down to expose the coarse aggregate, kept continuously wet for 24 hours. Vertical faces should be covered with cement/water slurry and horizontal faces should be covered with 15 mm layer of cement/sand grout. New concrete should then be placed immediately.

**Camber**

• To formwork as noted on drawing shall not be at the expense of the overall depth of the concrete.

**Weather**

• Concrete shall not be placed if temperatures above 30°C or below 0°C are expected.

8.12.3. **DURING CONCRETING**

**Batching**

• Shall be by mass in accurately calibrated scales.
• Soundly constructed gauge boxes making due allowance for bulking of the fine aggregate.
• Shall be in proportion to whole sacks of cement.

**Mixing**

• Shall be in a machine in good condition, large enough to carry the whole mix, controlled by a competent experienced operator

**Placing**

• Shall be under the control of a competent, experienced overseer
• Shall be in a manner to prevent separation of the ingredients
• Shall be a continuous process until the pour is complete

**Compaction**

• Shall be by immersion (poker) vibrator in the hands of experienced operators
• Concrete shall not be moved by vibrator
• Shall be sufficient to remove all air pockets and honey-combing and to ensure complete dense concrete cover to all reinforcement
Testing

- Shall be performed on of concrete cubes made by the Contractor under the supervision of the Project Manager. Contractor shall transport the cubes to approved testing laboratories and have them tested. Cubes to be in sets of 3.

Curing

- Shall commence early on the morning following the placing of the concrete
- Shall be effected by keeping the concrete in a permanently wet state
- Membranes shall not be used
- Shall continue for a minimum of 7 days or such longer time as may be required by the Project Manager.

8.12.4. STRIPPING OF FORMWORK

Formwork shall not be stripped until directed by the Project Manager.

Soffits shall not be struck less than 7 days after placing of concrete.

Vertical faces shall not be struck less than 14 days after placing concrete

Props to soffits shall not be struck less than 14 days after placing concrete

8.12.5. PATCHING

The Project Manager may reject the complete element if an unreasonable amount of patching has to be done, or if patching will spoil the appearance of the finished concrete.

Patching of defective work shall not be undertaken without the prior permission from the Project Manager.

Records

The Contractor shall keep records showing date and time of each concrete pour, the weather conditions, the temperature, the number of the cubes which represent the concrete, the slump and any other items which the Contractor and/or the Project Manager consider relevant. These records are to be made available for the Project Manager’s inspection when required.

8.12.6. BUILDER'S WORK

8.12.6.1. SETTING OUT WALLING

The Contractor shall provide proper setting out rods and set out all work on the same for courses, openings, heights, etc. and shall build the walls and piers, etc. to the widths, depths and heights indicated on the drawings and as directed and approved by the Project Manager.

8.12.6.2. CONCRETE BLOCKS

Concrete blocks for walling shall be provided by the Contractor complying with B.S. 6073, and made in approved block manufacturing machines.
Minimum thickness of blocks in external walls shall be 150mm, and in internal walls the thickness shall be minimum 100 mm.

Samples of the proposed block types shall be approved by the Project Manager before any walling work is commenced.

Blocks shall be cast under sheds in suitable block manufacturing machines either power driven or hand operated. The form shall be of steel, and accurately made to size to give the required shape and squareness of block. The concrete shall be vibrated during casting to achieve a dense and uniform concrete. The material shall contain only sufficient water to obtain full chemical reaction of the cement and to give proper workability of the constituents.

The ratio of combined aggregate to cement shall not exceed 3:1. The Contractor shall present his proposal for mix recipe supported by test results for the Project Manager's approval.

Concrete shall have a minimum of 28 days strength of 20 N/mm² in accordance with B.S. 1881. Mixing shall take place in mechanical mixers so as to thoroughly mix the constituents to a uniform consistency before casting.

On removal from the machine the blocks shall be carefully deposited on edge on boarding or a clean concrete floor under sheds so as to prevent drying out by the sun for 3 days. During this time blocks shall be kept constantly damp. The blocks may then be stacked if required, but not more than one metre high, and in such a way as to prevent damage to the edges and corners.

No blocks shall be used in building or be transported to site before having reached required 28 days strength criterion. All concrete blocks shall be of even texture and properly mixed ingredients and all portions of the block shall be properly set and hardened concrete.

Blocks shall be free from cracks or blemishes and shall be true to shape and size with clean sharp edges and corners and with corners truly square. Damaged blocks shall immediately be removed from the site. No dimension of a block shall deviate individually by more than 3 mm from the correct size. The average length, width and height of a sample of 15 blocks should neither be longer nor less than 2 mm than the correct size.

8.12.6.3. CEMENT MORTAR

The cement mortar is to be mixed in the proportions of 1-cement to 4-sand, and thoroughly incorporated with a sufficiency of water. Any cement mortar which has been left for more than one hour shall not be used in the works. Dressed natural stone blocks of at least 200 mm in width may be used as alternative to concrete blocks. Approved gauge boxes are to be used for measuring all ingredients. The ingredients are to be mixed dry on an approved mixing platform until they are thoroughly incorporated, and then water may be added slowly afterwards. Care must be taken that no foreign matter is mixed in with the mortar.

8.12.6.4. BUILDING WALLS

All block-work shall be laid in raking stretcher bond solidly bedded, jointed and flushed up in mortar. Where wall faces are to be plastered the joints shall be raked out to form a key. The blocks shall be thoroughly wetted for at least 24 hour before laying. Walls shall be carried up evenly course by course.

During laying an open joint not less than 15 mm wide shall be left between the ends of all concrete lintels, whether pre-cast or cast in-situ and the blocks adjacent to these ends. These open joints shall
be left as long as possible during construction and not filled until plastering or other works render such filling necessary. All such joints shall be properly filled in before the completion of the work.

External walls shall be reinforced with two 8mm high yield steel bars in every third horizontal mortar joint. Block-work which is not to be rendered or plastered shall be finished with a fair face and the blocks shall be selected for even texture and unmarked faces, regular shape and square unbroken arises. The block-work shall be pointed as the work proceeds with a neat joint. Where block-work is to be rendered or plastered the joint shall be raked out 10 mm deep as the work proceeds to form an adequate key.

Galvanised steel ties shall have a fishtailed end cast into the concrete spaced at alternate courses and extending not less than 150 mm into the block joints. All mortar joints shall not to exceed 15 mm or less than 12 mm.

8.12.6.5. DAMP PROOFING

Damp proof course is to be three-ply Malthoid, or other equal and approved material, laid under all superstructure walls. It is to extend the full width of the walls, overlapping at all ends and angles, and stepped if necessary. Damp proof course is to be laid under all window sills, and tucked up under window section and under the eaves beam.

8.12.6.6. LINTELS

Concrete lintels shall be used for all openings and shall be reinforced with two 12mm high yield steel bars. Lintels shall have a minimum bearing of 500 mm at the ends.

8.12.6.7. STRUCTURAL STEELWORKS FOR BUILDINGS

Structural steelwork shall be shop-fabricated from structural shapes of medium grade carbon steel in suitable lengths for easy transport and erection. The structural members shall be jointed or fixed on site by bolting or welding. Site welds should be minimised. All workmanship and fabrication shall be in accordance with the best practice and shall generally comply with the requirements of B.S. 449. The greatest accuracy shall be observed to ensure that all parts fit together correctly on erection within the tolerances stated in this section.

Loading and factors of safety shall comply with relevant codes and regulations. Shopdrawings shall be prepared using welding symbols to B.S. 499 where appropriate. Design calculations and shop drawings must be submitted to the Project Manager for his approval prior to fabrication of members. The approval of shop drawings and calculations by the Project Manager shall not relieve the Contractor of the full responsibility for any discrepancies, errors, omissions or failure arising there from.

All steelwork shall be transported, handled, stored on site and erected so that members are not damaged or subjected to excessive stresses. Fabrication and erection shall comply with B.S. 5950 Part 2.

8.12.6.8. ROOFING

Roof sheeting shall be hot dip galvanised troughed mild steel sheeting and shall be of minimum thickness 0.6 mm. The sheeting shall have approved plastic coating on face side. Type and brand of such sheeting shall be subject to the approval of the Project Manager.

The sheets shall be laid with 200 mm end laps and double corrugation side laps away from the prevailing wind. The sheets shall be fixed to light gauge steel purlins with galvanised coach screws and seating washers.
Holes for screws shall be carefully drilled in the ridges of the corrugations. Great care shall be exercised to avoid damage and disfiguration to the surface coating of the sheets. At eaves and exposed edges the corrugations shall be closed with purpose made corrugation closers.

Maximum load acting on the building shall be in accordance with local or regional standards.

8.12.6.9. **CEILINGS**

All rooms shall have ceilings consisting of form manufactured sheets, mounted on steel or tree grids jointed to roof structures unless otherwise approved by the Project Manager.

8.12.6.10. **ROOF DRAINAGE**

Gutters and down pipes shall be plastic coated steel of diameters 200 mm and 150 mm respectively. One down pipe shall be provided for approximately every 50 m² roof area.

Joints shall be lapped 150 mm in the direction of the flow and soldered. Slip joints shall be provided to allow for expansion. All hangers, brackets, and fastenings should be of the same metal as the gutter or of compatible materials. Gutters and down pipes including supports shall be designed for a concentrated load of 100 kg. Screens or strainers shall be provided to prevent debris from clogging the down pipes.

8.12.7. **METALWORK**

Unless otherwise specified, metalwork shall be carried out in accordance with the provision of B.S. 5950 and other relevant BSI standards.

All steel shall unless otherwise specified, be hot dip galvanised.

Prior to fabrication the Contractor shall submit shop drawings to the Project Manager for approval.

8.12.7.1. **DOORS**

Doors shall in general be metal and comply with the following:

- Door frames shall be pressed steel frames made from minimum 2 mm thick steel sheeting and reinforced where door closers are fixed. Thresholds shall be made from rolled steel sheeting approximately 100 mm wide and 12 mm high.
- Door shall be filled with mineral wool acoustic insulation and lined both sides with steel sheeting minimum 1.25 mm thick. Total thickness of door shall be 45-55 mm.
- All doors shall have fire rating Class A 30.
- Location of doors shall be in accordance with switchgear building drawing.
- Door frames are to be built in to brickwork truly vertical and square with ties per frame. Cement mortar is to be packed around brickwork built into back of frames. Temporary props shall be provided.
- Internal door frames are to be built with six ties per frame while external door frames are to be built with eight/t en ties per frame.
- All door frames are to be from an approved manufacturer and illustrated in the Manufacturer's Catalogue.
- Door frames are to be complete with 100mm, loose pin steel hinges welded in position and adjustable striking plate. Frames shall generally be built-in during construction of the walls.
and securely fixed. A gap shall be left between the top of the frame and the soffit of the lintel during construction.

- Frames shall be adequately strutted to prevent distortion and shall be protected from damage during other work.
- Door frames and similar components shall be fixed with countersunk screws or bolts with heads set into the frames.
- Walls shall be built as close as possible to the frames and the gap filled solid with mortar at each course. Render shall be neatly brought up to the frame and well tamped into any remaining cavities. The junctions between window frames or external door frames and external finish or block work shall be caulked tight with approved mastic or mortar wherever required, and neatly pointed. Mastic so used shall have long-term resistance against weather, insects and ultra-violet light.
- Doors wider than 800 mm shall have three 100 mm hinges. Other doors may have two hinges except where specified or detailed otherwise.
- Door stops shall be fitted by screwed fixings where necessary.

The Project Manager may approve the use of timber doors for some internal doors. Timber doors shall be 47 mm thick hollow core doors consisting of skeleton frames covered with 4 mm plywood for painting.

8.12.7.2. WINDOWS

Windows shall consist of aluminium sub-frame with clear glass and provided with corrosion resistant metal insect screens.

Frames shall generally be built-in during construction of the walls and securely fixed. They shall be built in to brickwork truly vertical square with six ties per frame. Windows over 1,070 mm wide shall be provided with additional head and sill ties.

All windows shall have approved burglar bars, and approved means of opening/locking.

8.12.7.3. DOOR AND WINDOW FURNITURE

- Door and window furniture shall be strongly made, well finished, good quality "stock pattern" articles and where appropriate shall be designed for external use. All door and window furniture shall be cleaned, oiled, adjusted and left in perfect working order.
- All doors shall be lockable. Doors and gates shall have security locks and a master key system. The Contractor shall provide three keys for each lock, clearly labelled, and three master keys for each substation.

8.12.8. ROOMS HOUSING INDOOR SWITCHGEAR

The Rooms housing indoor switchgear shall be designed to withstand and release pressure increases associated with arc faults in the switchgear. The associated design shall be submitted for approval.

8.12.9. PLASTER AND FINISHING

8.12.9.1. PLASTER

Mixing
• All materials for mixing are to be used in proper gauge boxes and they are to be strike measured and not tramped down in boxes. Proper non-absorbent stages are to be used for mixing and storing mortar. No foreign matter shall be mixed with the mortar.

• The materials are to be mixed dry before adding water through a fine hose spray. Cement mortar which has taken its initial set shall not be used.

**Plaster Thickness**

• Unless otherwise specified all wall plasters should not be less than 13 mm thick and not more than 19 mm thick.

  *Cement Plaster*

• Cement plaster for external use to be composed of one part cement to four parts sand and for internal use to be one part cement to five parts sand.

**Form Key**

• Rake out joints and roughen if necessary to form key for pilaster.

• For concrete surfaces, hack and apply 1:1 cement sand slush to form key. Continuously wet for 7 days and the apply plaster.

• All brickwork and concrete works should be brushed down to remove dust and loose material.

**Wetting**

• All internal and external brick or concrete surfaces are to be wetted well before plastering.

• All cement plaster must be kept wet for at least 7 days.

**Repairing Defects**

• All defective plaster, cracks, hollows, etc., are to be cut out to a rectangular shape, the edges undercut to form a dovetail key and to be made good to finish flush with the edge of the surrounding plasterwork.

• All patches will be to the approval of the Project Manager and if the defects cannot be made good satisfactorily then the whole surface is to be removed and re-plastered at the Contractor’s expense.

### 8.12.9.2. GRANOLITHIC FLOOR

**Preparation of bases**

• Clean all bases thoroughly to remove all dirt, dust, rust and oil. Hack and expose as much coarse aggregate as possible. Wet base for 24 hours before laying finish and remove surplus water. Brush neat cement slurry onto surface 20 minutes before laying finish.

**Materials**

• Use approved, clean, washed granite chippings or other approved stone graded in size from 7 mm down with not more than 20% fine material passing 200 micron mesh sieve. Mix to comprise 1 part Portland Cement, 2 parts coarse aggregate and 1 part river sand by volume. Use smallest quantity of mixing water needed to give adequate mouldability. Lay to a finished smooth surface of 40 mm and finish off with a steel trowel. Continuously wet finished surface for 7 days.
8.12.9.3. WALL TILING

Ensure that the base to receive tiles is level, dry and clean with no loose and friable areas or surface dusting. Prepare and use adhesive to manufacturer’s recommendations to form a bed not more than 3 mm thick. Lay tiles dry and tamp well down to ensure a proper bond with base and a level surface. Grout up joint with approved white cement.

8.12.10. CARPENTRY AND JOINERY

8.12.10.1. TIMBER

Timber and timber products shall be best quality procurable, free from sap, white wood, shakes, large, loose or dead knots, waney edges and other defects.

Timber and timber products shall be free from borer and beetle infestation of any kind. Any defects traceable to such infestation shall be rectified by the Contractor at his own expense, including any timber adjacent to the affected parts. This guarantee shall be valid for a period of two years from date of handing over the works.

Timber to be well seasoned and kiln dried to moisture content not less than 10% or more than 12%.

All timber, including laminated timber, shall comply with relevant national or regional standards.

8.12.10.2. WORKMANSHIP

All timber for carpentry work to be in as long lengths as possible and all laps and joints to be placed over points of support. All timber to be finished clean, smooth and free from tool marks.

8.12.10.3. NAILING

All nails are to be of the best quality and of gauge, length and strength suitable for work. They will be long enough to enter the second timber at least one half their entire length before punching. Skew nailing will only be permitted in the framing.

8.12.10.4. SIZES

All sizes specified are nominal before dressing or shaping. 2.5 mm will be allowed off nominal (sawn) sizes for each face.

8.12.10.5. PRICES

Timber described as “sawn” shall include all workmanship and labour in preparation and connecting together by lapping, notching, splay or bird’s smooth cutting, halving, scarfing and for all nails and spikes.

Timbers unless otherwise stated, shall include for fixing with nails of the approved size and type.

Timber described as “plugged” shall include for fixing to concrete, brickwork or similar material with suitable plugs. Suitable patented expanding sockets may be used if approved.
8.12.11. GLAZING

8.12.11.1. GLASS

All glass is to be of approved manufacture, free from bubbles, waveness, scratches or other imperfections and is to be well bedded, putted and back putted and secured with glazing pins or clips in steel sashes or with sprigs in wood sashes.

All glass shall be carefully cut to the required sizes so that all panes of figured or textured glass are uniform in appearance with the pattern parallel to the edges and wired glass shall be so cut that the wires are parallel to the edges.

8.12.11.2. PUTTY

Putty for glazing to steel sashes is to be of approved proprietary brand specially made for use with steel sashes and shall conform to the relevant National or regional Standards. Best quality linseed oil putty conforming to the relevant National or regional Standards to be used for wood sashes tinted as necessary when used for glazing to hardwood. Rebates are to be thoroughly back putted before glazing and all putty is to be carefully trimmed and cleaned off so that back putty finishes level with the top of sections internally, external putty covers sight lines exactly and finished straight and true. Rough surfaces to putty will not be allowed and any defective putty will be cut out and replaced at the Contractor’s expense.

Rebates of wood sashes are to be given one coat of priming immediately before glazing.

8.12.11.3. MIRRORS

Glass mirrors are to be of the thickness specified, of selected quality glass, silvered on back, with protective sealing coat and arose edges, unless otherwise described.

General

The Contractor shall replace all cracked, broken or defective glass and shall properly dispose of the broken glass. All glass shall be left thoroughly clean and free of blemishes at completion.

8.12.12. PAINTING

8.12.12.1. MATERIALS FOR DECORATION

All paints, primers, varnishes, emulsions, stopping, etc., to be of approved manufacture.

The Contractor is to use proprietary ready mixed paints obtained from an approved supplier.

When a coat of proprietary paint is applied, the manufacturer’s priming and previous coats suitable for the particular type are to be used.

All materials shall be brought on to the site in unopened tins, and no dilution or adulteration shall be permitted.
8.12.12.2.  EMULSION PAINT

Emulsion paint shall be PVA (Polyvinyl Acetate) alkali-resisting formulated with high washability and capable of resisting a 8000 scrub test. The first coat to be specifically formulated base coat for direct application to the specified surface.

8.12.12.3.  FILLERS

Higher grade cellulose fillers are to be used internally and premixed filler to be used externally.

8.12.12.4.  HIGH GLOSS PAINTS

Primers

- Primers for application to bare metal to be red oxide primer for iron and steel; for galvanised metal to be an approved zinc chromate or galvanised iron primer; for application on wood or plaster to be an approved alkali primer.

Finish Enamels

- Finish enamels to be synthetic enamel high capacity paint with high coverage and high gloss finish unless otherwise described.

8.12.12.5.  WORKMANSIP

All surfaces shall be free from moisture, dust, grease and dirt and rubbed down smooth.

All plaster shall be free from efflorescence and treated with one coat of petrifying liquid, approved sealer or alkali primer if required. Hardwall plaster shall be glass papered before decorating.

The Contractor shall repair any defects to decorated surfaces.

Metalwork shall be scraped free of rust before priming and painting.

Galvanised iron and steel shall be cleaned down to remove manufacturer’s ammoniated dichromate protective covering before priming and painting.

Coated pipes are to be cleaned down, stopped and primed with one coat of aluminium primer before painting.

All knots in woodwork to be treated to prevent bleeding. Large or loose knots to be cut out and be replaced with sound wood, or cut back and filled. Small knots to be treated with two thin coats of Shellac in methylated spirits. Woodwork to be glass papered to a smooth surface with all sharp arises removed, all cracks, crevices, holes, etc., to be scraped out, primed as described and stopped with hard stopping, faced up and rubbed down to an even surface and finished as later specified.

Every coat of paint must be a good covering coat and must dry hard and be well rubbed down to a smooth surface before the next coat is applied.
8.12.13. **PLUMBING**

8.12.13.1. **REGULATIONS**

All plumbing and drainage work shall be executed strictly in accordance with the local laws and regulations. Plumbing works shall be carried out by appropriately licensed personnel.

8.12.13.2. **SHEET IRON**

All sheet iron to be approved brand, galvanised and of the thickness specified and shall conform to BS 2989. Galvanised iron nails shall be used for galvanised sheet iron where required.

8.12.13.3. **FLASHING**

Flashing shall be properly lapped at angles and passings. Flashing shall be dressed 38 mm into grooves and 6 mm up at back and wedge with rolled wedges. No screws or nails shall to penetrate gutters or flashings. Provision shall be made for expansion and contraction under changes of temperature.

8.12.13.4. **EAVES GUTTERS AND RAINWATER PIPES IN SHEET IRON**

Eaves gutters and rainwater pipes shall be formed to sizes and shaped as according to the Contractor’s design. The rainwater pipes shall have close welted and soldered seams, and all joints shall be riveted and soldered.

The eaves gutters shall be fixed to falls to outlets on 6 x 25 mm mild steel gutter brackets bent to suit the profile of gutter and twice holed for and screwed to woodwork or bolted to steel at not exceeding 1.00 m centres. Alternatively, approved fascia brackets may be used.

8.12.13.5. **PLASTIC PIPES**

Plastic pipes and fittings shall conform to the relevant national or regional standards and shall be fixed including brackets in strict accordance with the manufacturer’s printed instructions.

8.12.13.6. **CAST IRON PIPES**

Cast iron pipes and fittings shall conform to BS 416. Heavy-duty cast iron pipes and fittings shall conform to BS 1130. All pipes and fittings are to be coated with an approved preservative. Pipes are to be jointed with gaskin and caulked with molten lead.

8.12.13.7. **STEEL PIPES**

Steel pipes and fittings shall conform to BS 143 and the relevant national or regional standards and shall be galvanised. Pipes are to be jointed with hemp and red lead. Medium quality pipes shall be used. Pipes shall be fixed to roof timbers with stout galvanised clips and to walls with galvanised hinged holder bats with brass pins at not exceeding one metre centres, built into walls with cement mortar. Pipes shall be fastened to soffits on 6 x 32 mm mild steel strip fixed around pipes with 6 mm galvanised bolts with ends split and flanged and cut pinned to concrete soffits.

8.12.13.8. **COPPER PIPES AND FITTINGS**

Copper pipes shall conform to BS 659; BS 1306 and BS 1386 shall be solid drawn seamless supplied in straight random lengths, round clean, smooth, free from internal or external grooving, other defects and deleterious film.
All copper pipes carrying hot water are to be supported so as to allow free movement for expansion and contraction, particularly at the end of long runs where a change of direction takes place. Fix tubing to walls with brass hinged holder bats with pins at not exceeding one metre centres built into wall with cement mortar. Fix to soffits as described for steel pipes.

Fittings and couplings etc., for use with copper pipes shall be of the manipulative compression joint type or other approved type. All fittings, etc., are to be made from suitable corrosion resistant copper alloy, sound and clean, without flaws or laminations and full bore throughout. All fittings and their component parts shall be capable of withstanding an internal hydraulic pressure of 2.20 MPa without showing signs of leakage or other defects.

8.12.13.9. TRAPS

Traps shall be brass, copper, polythene or cast iron. Generally traps to shower trays, baths, lavatory basins, drinking water foundations and domestic sinks shall be tubular copper to BS 1184 of the same size as the waste outlet of the fitment, and shall have tails to suit the waste pipe to which they connect.

8.12.13.10. STAINLESS STEEL

Stainless steel to be of the austenitic type and shall comply with BS 970 EN58 series and unless otherwise described, to 0.9 mm thick in 18/8 quantity and shall be entirely non-magnetic.

8.12.13.11. BRASSWARE

Brassware is to be of the best quality and equal to the samples approved. All stop valves, bib taps, hose union bib taps and pillar taps shall comply with BS 1010 or SABS 226 and shall have washer plates so secured as to lift with the spindle.

Cold-water taps shall in every case be fixed at the right hand side of sanitary fittings.

All ball valves shall comply with BS 1212 and shall be of sizes and for the pressure indicated or specified. The loose orifice seats shall be of nylon for sizes 15 and 20 mm and bronze for sizes 25, 40 and 50 mm. Ball valves shall be supplied and fixed complete with copper floats to BS 1968 or with plastic floats not less robust and having a lifting effect not less than a BS 1968 copper float for the same duty.

8.12.13.12. EXCAVATION

The bottom of drain trenches shall be excavated to an even fall. A 75 mm cement concrete (Grade 10-20 mm stone) bed shall be laid under the pipe and each length of drainpipe shall be supported with cement concrete stools (Grade 10-20 mm stone) behind each collar and haunch up half way around external diameter of the pipe.

8.12.13.13. PENETRATIONS

No holes shall be cut through reinforced concrete unless approved by the Project Manager. Where possible, sleeves shall be cast into concrete. Where drainpipes pass through walls, etc., they shall be arched over to prevent any loads being transmitted from the structure.


All sheet metalwork shall be carefully and efficiently inspected and tested on completion and left perfectly watertight.
All defective work shall be taken out and replaced.

At completion of plumbing and draining installations, clean down and flush pipes, traps, etc., wash sanitary fittings and test the whole to the satisfaction of the Local Authority and the Project Manager including making good and re-testing until found perfect. The Contractor shall provide all necessary equipment to carry out any tests required.

8.12.14.  FIRE DETECTION AND PROTECTION

8.12.14.1.  FIRE DETECTION

The Contractor shall provide a fire alarm panel, with full mimic indication in all control rooms.

The system shall comply with local Codes, the National Fire Protection Association (NFPA) Codes and BS 5306 Fire Extinguishing Installations. The Contractor shall be fully responsible for all requirements and costs associated with obtaining approval of the fire fighting and fire alarm system from the local statutory authorities

Each room shall include at least one ionisation detector and one thermal detector.

Outdoor transformer cells shall be provided with thermal detectors.

The ionisation detector shall detect products of combustion using an ionisation chamber principle and shall include radioactive coils and cathode tube. The detector head shall have no moving parts. It shall be possible to change the sensitivity of detectors in individual steps to adjust the detector to the local conditions. If radioactive coils and cathode tube detectors are not allowed by applicable codes, optical detectors may be used. It shall include a pilot light which indicates that it has operated.

Thermal detectors shall initiate an alarm either on a rapid rise in temperature or at fixed temperature settings. If thermal detectors include fusible elements which mean that the detector has to be replaced after it has operated, they shall include a clear visual indication of their operation.

All fire detection system alarms shall be input to the substation control system and/or central control system as appropriate.

The Contractor shall design the fire detection systems and submit his design, with supporting calculations, for approval.

8.12.14.2.  FIRE PROTECTION

Fire protection shall be provided by portable fire extinguishers which comply with NFPA 10 and shall be suitable for the classes of hazards expected in each area.

Portable fire extinguishers having a gross weight in excess of 18 kg shall be wheeled types.

The Contractor shall install portable fire extinguishers in clearly visible locations, at heights recommended by NFPA 10 and with clearly visible labelling.

The Contractor shall install portable extinguishers within building and outside transformer cells, diesel generator enclosures and hazardous materials stores.

The Contractor shall design the fire protection systems and submit his design, with supporting calculations, for approval.
9. AC AND DC AUXILIARY POWER SUPPLY EQUIPMENT

9.1. GENERAL

Generally, auxiliary supplies shall be obtained from station transformers connected to two different 33kV feeders and an external supply from the distribution feeder of the neighbouring network. The station transformers shall be either 33/0.415 kV or 11/0.415kV Dyn11, 100 kVA depending on the existing distribution voltage in the neighbourhood.

They shall connect into a main 415 V switchboard which has two busbar sections and a bus section circuit breaker.

Normally the bus section circuit breaker shall be open and each busbar section shall be supplied from one of the station transformers. An automatic transfer arrangement shall be provided such that if the supply from one station transformer should fail, the associated 415 V incomer circuit breaker shall open and then the bus section circuit breaker shall close. If both station transformer supplies should fail, both incomer and if applicable the bus section circuit breakers will open and the external supply from the neighbouring network shall connect to the 415 V switchboard. Once this is connected, the operator may close the bus section circuit breaker. When a supply from a station transformer is restored, the operator may initiate a restoration sequence in which the external supply synchronises to the healthy station transformer supply, unloads, and is disconnected.

The substation shall be provided with a 110 V d.c. supply.

9.2. AUXILIARY STATION TRANSFORMER

9.2.1. GENERAL

The auxiliary station transformers shall be of the oil immersed core type suitable for outdoor use with ONAN cooling. It shall be three-phase, 415 V secondary, 100 kVA and vector group Dyn11.

All transformers shall have a life span of at least 25 years operating continuously under full rated power at the specified ambient temperature.

At rated output the top oil temperature rise shall not exceed 55°C and the winding temperature rise shall not exceed 60°C.

The LV neutral shall be brought out of the tank to a readily accessible terminal and shall not be earthed inside the tank.

9.2.2. WINDINGS

Taps shall be provided in the HV windings, preferably in the electrical centre of the windings, to permit variation of the number of HV turns without any variation in the VA rating. The variations shall be effected by means of a manually operated tapping switch.

Designs shall be such that electrical stresses are as uniform as possible throughout the windings under impulse conditions.

Windings shall be vacuum impregnated and insulating materials shall not be liable to soften, shrink, become brittle, carbonise, deteriorate, or collapse in any way during service.
LV windings of aluminium sheet shall not be accepted.

9.2.3. **CORES**

The magnetic circuit shall be earthed to the core clamping structure, at one point only, and the core assembly to the tank cover. Where transformers are not sealed, readily accessible removable bolted links shall be employed for the earthing connections.

The general construction of the cores, framework and the clamping arrangements shall be robust and such that they will be capable of withstanding completely any stresses which may occur due to handling, transport or service. All cores and yokes shall be terminated and clamped by means of a suitable framework. Suitable means shall be provided for lifting the cores from the tanks.

It shall not be possible for the core to move relative to the tank during handling or transport.

9.2.4. **TAP CHANGING**

Transformers shall be provided with approved off-circuit type tap changer. A fully insulated off-circuit externally manually operated ganged tapping switch shall be separately capable of withstanding the specified impulse voltage when connected to the transformer windings.

Clearly visible tap position indication shall be provided. The tapping switch shall be operated by means of an external handle, which can be positively located and locked in each operating position.

The switch shall be mechanically robust and provided with a device between the handle and the switch to permit operation without strain in the event of imperfect alignment between switch and handle. The switch-operating shaft shall be fully insulated as between tank and switch and shall be provided with a suitable oil and vacuum tight gland where it passes through the tank.

The use of wood shall be avoided wherever possible and all the supports and terminal boards shall be completely unaffected by hot oil and shall be non-moisture absorbent.

High grade insulating materials shall be used in the construction of tapping switches, which shall be designed with special attention to the elimination of points where tracking is likely to occur.

Tap switches shall be mounted on supports made of suitable high strength insulating material and shall be provided with self-aligning spring loaded wiping contacts, capable of maintaining good electrical contact without the need for periodic maintenance.

All clearances between tapping switch contacts and leads shall be indicated on drawings submitted at the time of tendering and such clearances shall be sufficient to prevent tracking or flashover in the event of carbon or sludge deposits forming on leakage paths.

Five tap positions shall be provided on the H.V winding at -5%, -2.5%, 0%, +2.5% and +5%.

9.2.5. **BUSHINGS**

All line terminals and neutral connections where specified, shall be brought out to porcelain outdoor type terminal bushings. The bushings shall be the outdoor type.

Arcing horns with equal double gaps shall be fitted on all transformer bushings above 660 V.
9.2.6. **TANKS AND CONSERVATORS**

9.2.6.1. **GENERAL**

Drain valves may be either screwed or flanged whilst conservator isolator valves shall be flanged. Drain valves shall be complete with captive plugs which shall be either of non-ferrous metal or galvanised.

All internal steel surfaces or tanks and conservators shall be shot blasted and cleaned, and a coat of protecting compound, unaffected by hot oil, should be applied.

All external surfaces and parts made of steel are to be thoroughly shot blasted and cleaned, after which two coats of priming paint, preferably of zinc chromate, one intermediate coat, and one coat of finishing paint are to be applied. The colour of the finishing coat shall be medium sea grey, colour No. 637 to BS 381C or near equivalent as may be approved by the Project Manager.

9.2.6.2. **TANKS**

Each transformer shall be housed in a tank of welded steel plate construction suitably stiffened where necessary but with a flat base.

The lifting lugs shall be suitable for lifting the transformer bodily by means of a hoist or crane when it is completely assembled and ready for service.

9.2.6.3. **CONSERVATORS**

Conservators, shall be dimensioned such that oil expansion may occur over the working range of temperature from no load with the transformer cold to full load at specified ambient air temperature ranges while the sump pipe remains covered and the oil level is visible or indicated.

Drain plugs shall preferably incorporate approved sampling facilities, and shall be mounted at the lowest part of the conservator tank and so designed that the sampling device can be readily cleared in the event of its being blocked by an accumulation of sludge etc., without the necessity of having to dismantle the device completely.

Oil level gauges on conservator tanks shall be of the refracting plate glass or other approved type, marked with the level at 20°C at no-load and capable of indicating the level of oil over the specified working range.

Where dehydrating breathers are specified they shall be of the silica gel type which give indication of moisture absorption by change in colour of the charge.

An inspection window shall be provided and mounted in a position convenient for inspection. The breather is to incorporate an oil seal to prevent contact with the external air when breathing is not taking place. The breather is to be fitted on the LV end of the transformer.

9.2.7. **NOISE LEVEL**

The noise levels at 1m of the station transformer shall not exceed 55 dB(A).
9.3. **110 V DC**

9.3.1. **GENERAL**

The Contractor shall provide 110 V DC systems in each substation. The DC system shall be rated for the total substation load, and on loss of supply to the battery charger each battery shall be capable of supporting the total substation load for 10 hours without the battery cell voltages falling below 1.85 V/cell.

The 110 V DC system shall be unearthed, and with provision to detect earth faults. The battery shall be complete with stands, inter-cell connections, and battery switchgear, and maintenance equipment. All cells, connections, switchgear and boards shall be designed with resilient, yet restrained, supports to withstand earthquake without spillages, breakages, or disruption of function.

For equipment requiring a different non-fail supply voltage level, the Contractor shall provide individual converters located within the equipment enclosure. If there is a large load at 48 V DC, the Contractor may provide a dual redundant positive earthed 48 V DC system which otherwise complies with the requirements for 110 V DC.

The Contractor shall provide one battery discharge test set which may be used for initial battery discharge testing and which shall then be handed over to the Employer.

9.3.2. **BATTERY TYPE AND ACCESSORIES**

Batteries shall be pasted plate, lead acid type. The number of cells in each battery shall be determined by the Contractor. The Contractor shall submit for approval calculations to

The cells shall be in transparent containers. Each cell shall be identified by a clearly marked cell number with the terminal cells marked to indicate polarity, and provided with an explosion preventing breather. The batteries shall be arranged in multiple tier staggered arrangements. The rated life of the battery under the specified site conditions shall not be less than 15 years.

The Contractor shall supply the following accessories at each substation:

- One – Cell voltmeter, 0-3 V, portable type, accuracy Class 1.0 complete with leads and probes;
- Two – Hydrometers;
- Two – Mercury -in-glass thermometers, 8°C to 55°C;
- One – First-aid kit;
- One – Battery record log books for each battery;
- One – Cabinet, wall mounted, to contain the accessories.

9.3.3. **BATTERY STANDS**

The battery stands shall be arranged to give maximum segregation between different batteries located in the same room. Stands shall withstand the specified earthquake conditions. The stand structures shall be designed to be without interference with the operational and maintenance inspection requirements of the cells and may incorporate members that get removed when a cell is removed from the bank.
The battery stands shall be of timber throughout, of robust construction, cross-braced, with fixed mortice and tenon joints and pinned with hardwood dowels, and have other stable mortice and tenon joints, as required, for removable members. The bottom of the lower tier (for two-tiered stands) shall be not less than 300 mm from the floor. The completed stands shall be coated with not less than two heavy coats of acid-resistant enamel after erection.

The Contractor may propose an alternative construction which provides the same performance.

9.3.4. BATTERY CONNECTIONS AND SWITCHGEAR

The continuous current rating of the battery connections shall be not less than the maximum service duty current. Battery connections shall be rigidly supported and insulated with porcelain insulators of the required rating. The connections between the tiers and to the battery circuit-breakers shall be cable, single core, insulated and sheathed, copper conductor, arranged to present a clear and functional arrangement of connections.

The Contractor shall supply and install for each battery, one wall mounted enclosure in the same room as the battery charger containing circuit-breakers and links. These shall be arranged to disconnect the battery and/or charger from the load in the event of a short circuit, and to allow the battery to be connected directly to the charger with the d.c. distribution board isolated, when required. The circuit-breaker enclosures, and the equipment inside them, shall be provided with appropriate identification labels.

9.3.5. BATTERY CHARGERS

9.3.5.1. GENERAL

One full-capacity battery charger shall be provided for each battery. Battery chargers shall be three-phase solid state rectifier type suitable for providing a DC supply source and automatic float and freshening battery charging facilities.

All battery chargers shall be suitable for initially charging the batteries and for re-charging a completely discharged battery under automatic control. The rated current of the battery chargers shall be selected to allow for recharging a fully discharged battery in 5 hours, in addition to simultaneously supplying the DC load.

The normal float voltage setting shall be 2.25 V/cell.

Each charger shall be complete with the following:

- Control and indication facilities as necessary, mounted on the front panel of the charger;
- Alarm initiating devices as necessary;
- Alarm indication lamps;
- Alarm lamp test pushbutton;
- Thermal overload relay and contactor on the AC input side arranged to open on AC supply failure of any phase;
- 415V surge arresters fitted to the AC input;
- Fuses or MCBs for the protection of semi-conducting rectifiers or thyristors;
• A “slow-start” circuit to protect the mains circuit against high inrush currents when the charger is switched on;
• A lockout relay to open the AC supply contactor in the event that the charger’s DC output voltage exceeds 2.3V/cell, or any other value recommended by the battery manufacturer, when on auto control.

9.3.5.2. BATTERY CHARGER PERFORMANCE

The batteries shall be maintained by float charging within ±5% of the set voltage for all loads from zero output, for any variation of between +10% of nominal a.c. input voltage or between 48-55 Hz in frequency. The set voltage shall be adjustable from 2.2 to 2.3 volts per cell.

When the battery voltage is between 1.80 volts per cell and the set voltage, the battery charger shall operate at a higher current output but shall not exceed 125% of rated output at 1.80 volts per cell and below. The current limit setting shall be adjustable down to 80% rated output.

The ripple in the DC output shall not affect the performance of equipment connected to the DC supply busbars under any conditions. The ripple voltage limit shall be 3.5 V peak to peak for the 110 V batteries.

The output voltage shall not exceed 105% of the set value under the following operating conditions:

• Automatic changeovers of the AC supply system;
• Switching the charger on to a battery discharged to 1.8 V/cell.

The Contractor shall ensure that there is no operation of the fuses or MCBs protecting the main circuit thyristor or diodes when switching.

9.3.5.3. CONTROL, INDICATION, ALARM FACILITIES

The control circuits shall be designed so that the chargers may be switched on and then brought up to full volts and deliver rated output current with the battery disconnected.

All instruments shall be at least 96 mm square. The voltimeters shall be of the type incorporating static auxiliary equipment to give an expanded scale similar to a suppressed zero instrument, but instead having a free zero. The ammeter shall be of the dual range type, but with the scale marked for the larger range only, and a switch shall be provided for each ammeter to divide the marking by ten.

Fuses for capacitors, silicon diodes or silicon controlled rectifiers shall be equipped with trip indicator fuses to initiate and alarm indication on operation. The alarm equipment shall include lamps to indicate the individual alarm conditions shown below, together with a common relay with a time delay adjustable from 0-10 seconds with hand reset flag and contacts for remote indication of the alarm group:

• Charger Volts High
• Charger Volts Low
• Charger AC Failed
• Charger Rectifier Fuse Blown
• Charger Capacitor Fuse Blown.
The “charger volts low” alarm shall be prevented from operating when the AC supply fails. The “charger AC failed” alarm shall operate in the event of the failure of any one phase or when the charger is switched off. This alarm shall be prevented from operating when the powerhouse common services board supply has failed.

The settings of the charger volts high and low alarms shall be provided with adjustment to cover the range of ±5% of the respective nominal float voltage setting (2.25 V/cell), so that the setting may be altered from time to time. Each alarm shall operate consistently within ±1% of the set voltage in the appropriate rising or falling direction and shall have an operate/reset differential of not more than 1%. Thermal relays shall not be used for this application.

### 9.3.5.4. CONSTRUCTION

The charger cubicles shall offer a degree of protection of not less than IP31 to IEC 60529, except for the top of the cubicles which shall be IP51. If practicable, ventilating screen or louvers shall be positioned only at the rear.

Electronic components shall be either mounted on plug-in printed circuit cards held firmly in racks or mounted so the components may be easily interchanged during fault finding.

The automatic voltage setting device inside the charger shall be positioned so that one man may make adjustments and observe the instruments on the front panel at the same time.

The shafts of potentiometers used for voltage control and alarm settings shall be clamped against alteration due to vibration.

Instruments, indicating lamps, ammeter range selector switches, auto/manual selector switches and manual voltage setting controls shall be mounted on the fixed upper front panels with rear wiring access.

Device labels and main equipment labels shall be provided. Panel mounted equipment shall have front and rear labels.

Cable entry to the chargers shall be from above.

### 9.3.5.5. DC DISTRIBUTION BOARDS

The Contractor shall provide one 110 V DC distribution boards for each substation. The boards shall be supplied from their respective battery chargers and batteries.

The 110V DC distribution board shall be located in the same room as its associated battery chargers, and the distribution board and battery charger may be integrated into a single item of equipment.

The continuous current rating of the distribution boards shall be determined by the Contractor and submitted for approval.

The boards shall be provided complete with disconnecting switches, moulded case circuit-breakers, and all necessary control, indication and alarm devices.

As a maintenance/contingency facility, each distribution board shall include a lockable disconnecting switch and the pair of distribution boards shall be interconnected through these switches so that they operate in parallel.
The DC distribution boards shall consist of floor-mounted cubicles with front and rear doors. All equipment shall be fully rated for the applicable DC voltages and currents.

The boards shall offer a degree of protection of not less than IP54 to IEC 60529.

A label shall be provided for each circuit, giving breaker type and size and a description of the circuit supplied.

The boards shall be designed so that all disconnecting switches, and indicating and control devices are mounted on the front of each board, while all the relays and circuit-breakers are mounted on an internal fixed panel behind the front door. The wiring terminal blocks and cable terminations shall be located in the area behind the internal fixed panel and shall be accessible from the board’s rear doors. No wiring to equipment mounted on the internal fixed panel shall be visible from the front of this panel. Cable entry to the boards shall be from the top and bottom.

All instruments shall be at least 96 mm square. The voltmeter, ammeter and ammeter switch shall be identical to those provided on the associated battery chargers.

9.4. 415/240 V AC DISTRIBUTION BOARDS

The Contractor shall supply and install 415/240V distribution boards at strategic locations to serve power supplies throughout the substation.

The distribution boards shall be suitable for installation indoor, and shall comply with IEC 60439 and with degree of protection IP54. Each distribution board shall comprise of incoming disconnecting switches, AC busbars and load circuit moulded case circuit-breakers. The supply disconnecting switches shall be padlockable in the open position.

The cable compartment shall be free of exposed live 415/240 V AC connections, so that cabling of circuits can be accomplished at any time with complete safety without shutdown of the distribution board and, to this end, all terminals for outgoing cables shall be fully shrouded with insulating covers. No outgoing circuits shall be mounted within 300 mm of the bottom of the board.

Some boards shall require front only access, otherwise access doors shall be provided for the rear cabling compartment. Appropriate detachable covers shall be provided to enable the tightness of all bolted and screwed electrical connections to be checked.

All instruments and switches shall be mounted on the front of the board, and all instruments shall be at least 96 mm square.

The busbars shall be provided in separate compartments, and supply and load circuits shall be segregated into compartments such that transmission of flame is minimised.

A copper earthing conductor running the full length of the distribution board shall be provided. It shall be dimensioned to withstand the maximum fault current for 1 second without its temperature exceeding 300°C and it shall be connected, at each end, to the earthing system. The neutral conductors in the distribution board shall be connected, through a bolted link, to the earth conductor.

The Contractor shall determine the continuous and fault current ratings of all components of the distribution boards.

The design calculations for the ratings of each of the distribution boards and associated equipment shall be submitted for approval.
The distribution boards shall be provided with 20 percent spare circuits, with a minimum of two.

Each distribution board shall include a circuit schedule mounted behind a transparent sheet on the inside of distribution board door. The schedule shall identify for each circuit:

- the name of the location
- the number and function (e.g. lighting, power, etc) of the distribution board for each final sub-circuit in tabulated form;
- the MCCB/MB or fuse number and phase colour;
- the MCCB/MB or fuse rating;
- the location of the points connected to the circuit; and
- the circuit identification.

The circuit identification shall be shown on the circuit schedules, on switches and on socket-outlets, and shall consist of alpha-numerical characters identifying the final sub-circuit by distribution board number and final sub-circuit number, e.g. DBPXX-Y identifies the circuit as final sub-circuit number Y of distribution board power DBPXX.

9.5. LIGHTING AND SMALL POWER

9.5.1. SWITCHYARD LIGHTING

The switchgear bay and transformer light level shall be 50 lux at 0.85 m above ground level. The perimeter light level shall be 20 lux. The perimeter lighting shall be controlled by photocells. All necessary supports, fixing material and cabling from the distribution board shall be included.

Lighting fixtures shall be of outdoor, flood type and with a symmetrical beam spread of not less than 2x30°, with built-in ballast. The housing shall be high-pressure die-cast aluminium with a non-corrosive finish; the reflector shall be high-grade aluminium or etched vandal-resistant polycarbonate. An aluminium door frame shall be designed for easy re-lamping. The front glass shall be heat shock-resistant, with a gasket for jet and dust-proof sealing. The enclosure protection shall be minimum IP65.

The lamps for switchgear bays and transformers shall be non colour-corrected, high pressure mercury vapour or high pressure sodium lamps, 400 W, 240 V and shall have minimum luminous flux of 20,000 lm with 16,000 hours service life.

Ballasts shall have at least 90% power factor, with a sound level not higher than 45 dB. Ballasts shall be designed to ensure low operating temperatures and low losses.

Wiring cables shall be single core, direct burial. They shall be laid underground or in a cable trench. Those cables rising along the steel structures should be run in conduits adequately secured using band-it strap.

A switchyard lighting control panel shall be provided in the control building. It shall include the automatic control of perimeter lights and an associated bypass switch, and manual control of other switchyard lights. Where appropriate, contactors shall be included in the control panel to achieve necessary current ratings.
9.5.2. INDOOR LIGHTING

Indoor lighting shall in general use tubular fluorescent lamps to IEC60081 with a rated life not less than 7,500 hours; lamp colour co-ordinates shall be X = 0.373, Y = 0.380. Unless otherwise approved, their circuits shall be of the switch start type with shunt capacitors. Ballasts shall comply with IEC60921.

Room lights shall generally be controlled by wall mounted light switches of industrial grade and of flush pattern with white finished plates. These switches shall be located at the access doors of the rooms and approximately 1.35 m above floor level. Two-way and intermediate switching shall be provided where appropriate. Loads in excess of 10 A shall be switched via contactors.

Explosion-proof light fittings shall be used in battery rooms.

Required minimum lighting levels are as follows. These levels include a 20% loading factor to cover aging:

- Control room – 500 lux;
- Switchgear rooms – 300 lux;
- Battery rooms – 240 lux;
- Other rooms – 120 lux.

Lighting cables for fluorescent lamps shall have a cross section of at least 2.5mm². All metal work on luminaries shall be connected to earth by an insulated conductor.

9.5.3. EMERGENCY LIGHTING

The Contractor shall provide emergency lighting for safe evacuation from the substation in the event of a blackout. Indoor emergency lights shall provide a light level not less than 50 lux. They shall operate from the 110 V DC supply or from normal station AC supplemented with an internal battery/charging system. In the latter case, the hold up time on loss of AC shall not be less than the hold up time of the 110 V battery. Emergency lights shall operate whenever the station AC supply is off, and shall have a manual test facility.

9.5.4. PORTABLE LIGHTS

The Contractor shall provide two portable lights at each substation for supplementary illumination.

The portable lights shall be housed in a lockable cabinet at the entrance to the substation, preferably inside the guard house. The cabinet shall include a permanently connected charging facility for the portable lights. It shall not be possible to recharge the lights without using this facility.

Each portable light shall be of the LED type, with an output not less than 200 lumens and a battery life not less than 2 hours.

9.5.5. SMALL POWER

The Contractor shall install single phase general purpose socket outlets (GPO), rated 10 A, three pin with an automatic safety shutter, in all rooms such that a socket outlet shall be available:

- on all open floor area walls and not more than 10 m apart;
- on opposite walls in enclosed plant and cubicle rooms, not more than 4 m apart and in other rooms not more than 2 m apart
• on walls within 2 m of all permanent equipment.

Socket outlets shall be installed at a height of 1.2 m above the floor.

The Contractor shall install similar GPOs throughout the switchyard such that there is one at the base of each structure and at each transformer, and at ground level no piece of equipment is more than 20 m from a GPO. These GPOs may be mounted in junction boxes, control cubicles or similar equipment, otherwise shall be weatherproof.

The Contractor shall install a weatherproof, 3-phase, 5-pin, switched and interlocked socket outlet for the connection of oil treatment plant at each transformer cell.

Where socket-outlets or switches cannot be mounted on walls or columns, suitable stands shall be provided. Such stands shall be manufactured from heavy gauge rolled steel or pipe, hot-dipped galvanised after manufacture and shall consist of a base plate, suitably drilled for fixing to the concrete floor, a single column and equipment mounting plate. The stand shall be predrilled before galvanising to allow fixing of the equipment and the supply cable or conduit.

All circuits supplying socket outlets throughout the substation shall be protected by sensitive core-balanced earth leakage circuit breakers, tripping at 30 mA earth leakage current.
10. SUBSTATION CONTROL & INSTRUMENTATION

10.1. SUBSTATION CONTROL SYSTEM

10.1.1. GENERAL

The overall control system for the Kenya Grid will have four control levels:

• Central supervisory control;
• Station level control through a human machine interface (HMI);
• Bay level control through a mimic on a bay control unit; and
• Local control at the equipment.

“Substation control system” refers to the station level and bay level controls.

It is envisaged that the bay level control will comprise control cubicles located in the substation control building, with protection equipment being in separate cubicles, or with the control facilities being integrated into one of the sets of protection equipment. However, alternatives such as with control and protection equipment, suitably segregated, housed in common cubicles either in the substation control building or in “bay control cubicles” adjacent to each bay of switchgear will be considered. Such alternatives will not be considered unless they are an “open” design which permits flexible use of equipment from different suppliers and allows incremental replacement or upgrade of equipment as a need arises. Equipment which requires that the Employer commit to using an individual supplier for the equipment lifetime or which requires that the complete set of equipment be replaced whenever an upgrade is required will not be accepted.

10.1.2. EXISTING SUBSTATIONS

At existing substations where the Contractor is providing additional bays, the substation control system shall be integrated as fully as is possible with the existing equipment provided the latter provides the essential facilities and performance set out below, especially with regard to transfer of data between the substation and a central control facility. If this is not possible, the Contractor shall provide a substation control system which includes:

• Station level equipment which is physically suitable for the complete substation;
• Bay level equipment which is suitable for the bays being provided by the Contractor; and
• Coding within the station level equipment for the bays being provided by the Contractor.

10.1.3. STATION LEVEL CONTROL

The station level control equipment shall include:

• 2 independent gateways (main and hot-standby) for external communications to the central control (SCADA) system;
• 2 independent station computers operating on a main and hot-standby basis;
• operator workstation (complete with appropriate desk and chair);
• black and white A4 printer;
• common bay control unit, for monitoring auxiliary power supply and all other equipment on a substation level (telemetry, telecommunication, HVAC, fire protection, etc.);
• Satellite clock, complete with GPS receiver, antenna and time synchronization ports.;
• interface for laptop computer for maintenance, information transfer and emergency HMI;
• non-fail power supply system if equipment cannot directly utilise the station 110 V DC supply;
• Communication network equipment (substation local area network, field communication network, optical couplers, etc.).

10.1.4. BAY LEVEL CONTROL
A bay controller shall provide:

• control for each individual circuit/bay with a LCD mimic and user interface for control and monitoring of the circuit/bay;
• interface for protection devices that cannot directly interface with the substation control system local area network;
• Interface for laptop computer for maintenance, information transfer and emergency HMI.

10.1.5. STATION LEVEL CONTROL FUNCTIONS
Station level control functions shall include:

• Control of all switching devices;
• Real time indication of events and alarms;
• Display of analogue values and high/low limit checking;
• Display of historical values;
• Data archiving;
• Disturbance monitoring and analysis;
• Trend display;
• Protection and control relay setting information;
• Protection relay fault and disturbance records;
• Time synchronisation.
• Operator action monitoring (display message if operator attempts an inappropriate action);
• Self check & diagnostic;
• Manual data setting by the operator, including:
  - Hand-dressed data entry
  - Control inhibit setting
  - Alarm inhibit setting
  - Maintenance tag setting
  - High/Low limit setting
Remote access to substation control system from the SCADA system using a TCP/IP link

10.1.6. DESIGN

10.1.6.1. GENERAL

The substation control system shall be suitable for operation under electrical conditions (including electrical discharge and disturbance level) prevailing in high-voltage substations. All input and output circuits and power supply circuits shall be provided with isolation and/or other facilities to provide immunity to electrical interference.

The substation control system shall store all data for at least three months. Historic data shall be accessible through the operator interfaces.

The substation control system shall have a minimum spare capacity as follows:

- Include at least 10% installed spares of all physical input/output devices of each type in each location;
- Include space and mounting facilities, including additional racks if applicable, for a further 20% additional physical input/output devices of each type at each location;
- Include at least 20% spare cores in each multi-core copper control or communication cable; and
- Include at least 100% spare capacity in communications links, databases and other non-physical facilities.

No single point of failure shall disable the complete substation control system or its communication with the central control centre. Failure of a bay controller shall only affect the faulty bay. To this end, all safety interlocks shall be hard-wired with the interlock logic replicated in software code.

Data storage shall be distributed with bay information stored within bay controllers. Data shall be stored in a non-volatile memory.

The substation control system shall be self-monitoring system with diagnosis that can continuously supervise vital functions on the main processor and distributed control units. The faults are to be displayed centrally on the station computer, locally on the faulty plant and to the central control centre through the substation gateway.

The software shall provide password protection that grants permission based on individual user and their role. It shall provide for at least three roles:

- View information;
- Operator monitor and control;
- Engineer monitor and modify system.

All control shall be based on select-before-execute, with interlocks being confirmed between the “select” and “execute” operations.

Software copying and program maintenance shall not interfere with the operation of the control system.
10.1.6.2. **COMMUNICATIONS GATEWAYS**

The substation control system shall be able to communicate with other systems on separate communication channels using a variety of open standard protocols. IEC 60870-5-101 communication protocol shall be used for data transmission to the central control centre. In general each gateway shall provide SCADA communication over OPGW or power line carrier, with the equipment at the central control centre selecting between routes and managing failover transfer.

The substation control system shall be capable of being remotely accessed from the central control centre over a TCP/IP link. This link shall be used for monitoring and modification of control, instrumentation and protection settings and code, and for remote access to protection relay fault and disturbance records.

10.1.6.3. **SUBSTATION LOCAL AREA NETWORK**

Local substation communications shall use an optical fibre local area network (LAN) to connect the components of the substation control system using open standard protocols. The LAN may be of star-coupler configuration or a fibre ring configuration. No single point of failure of the substation LAN shall result in any loss of substation control functionality.

10.1.6.4. **CLOCK**

The substation control system shall normally receive time synchronisation signals through the SCADA system, but shall include a satellite GPS clock as backup. The substation control system shall distribute time information throughout the substation to maintain equipment in time synchronisation and shall time tag events with a resolution not greater than 1 ms.

10.1.6.5. **AUDIBLE ALARM**

The substation control system shall include a sounder to give at least two distinct audible alarms. The sounder shall be configurable according to the event type. The sounder shall automatically cut out after sounding for 20 seconds, and the substation control system shall include a sounder on/off control.

10.1.6.6. **BAY CONTROLLER**

A bay controller shall provide a serial communications interface for any digital protection relays or other intelligent devices that cannot be interfaced directly to the substation LAN. The information obtained shall be available to the substation control system but need not be available locally at the bay controller.

Bay controllers shall provide time tagging and synchronism check facilities.

The synchronism check function shall include live-bus/dead-line, dead-bus/live-line and dead-bus/dead-line conditions. It shall be possible to select any combination of these conditions to allow closing.

Bay controllers shall include a watchdog facility to monitor correct software operation. Should a fault be detected, then all command outputs from the bay controller shall be inhibited and an alarm generated.

Bay controllers shall have inputs from current and voltage transformers. All associated electrical quantities shall be derived from these signals within the controller.
10.1.6.7. DATABASE MANAGEMENT SYSTEM

Each substation control system shall be provided with a database management system. The database management system shall include a means of verifying the database consistency and completeness. The database shall be fully tested prior to uploading on the substation control system.

The contents of a database shall not be lost if the power supply fails. After a power failure, the substation control system shall start and load its database automatically. The substation control system shall allow the user to configure the database on site or from the central control centre, irrespective of the substation point of control.

Any database modifications shall be time-tagged and automatically logged.

10.1.6.8. CONFIGURATION AND MAINTENANCE

The Contractor shall provide one notebook computer for each substation for maintenance of the substation control system. The computer may also be used for maintenance of other intelligent equipment, including protection relays.

The computer-based configuration and maintenance facility shall include all database and software interfaces required for the maintenance and configuration of the substation control system. This will include diagnostics, database compiler, software listings, configuration listings, etc.

The computer shall have diagnostics for the bay controller processor(s), memory, I/O ports, and any other functional areas. The computer shall also be used to monitor and test the bay controller operation and communication interfaces and shall be capable of emulating all levels of substation control except for local control at the equipment.

10.1.6.9. OPERATOR INTERFACE

Overview

The substation control system operator interface shall allow the operator to monitor the status of plant items and perform control operations securely and efficiently. Its main functions shall be:

- View plant status information and to acknowledge alarms;
- Perform primary and secondary plant switching and other control operations associated with the substation, securely and efficiently;
- View sequence of event and alarm logs.

The operator interface display screens shall be submitted for approval.

The operator interface shall comprise of a number of linked displays that provide the following:

- substation overview
- individual busbar groups
- detailed views of individual bays
- detailed views of individual transformers
- common facilities
- communication status
- alarm list
- event list
• trend displays (real-time and historical)
• report displays
• substation control system status

The main operator interface device shall be a multi-button pointing device such as a mouse. A keyboard shall be used for password entry, applying notes to plant and similar functions.

Point and click links shall be provided at the top of all user screens to allow the operator to navigate to screens quickly. If the mouse pointer hovers over a display screen icon, a pop-up shall be generated which provides full information on the status of the equipment represented by the icon.

Colour shall be used to identify different voltage levels and equipment status. The proposed colour scheme shall be submitted by the Contractor for approval.

**Substation Overview**

The substation overview display shall provide the operator with the electrical topology of the substation and will display the current status of plant items including maintenance tags. Depending on the size of the substation and to aid the clarity of presentation the overview may be split between two or more screens.

Circuit, circuit breaker and busbar names shall be displayed on the overview screen. Real time frequency and busbar voltages shall also be displayed.

**Individual Busbar Groups**

The individual busbar group screen shall provide a single screen view of each voltage level in the substation. The following plant items should be displayed on the Individual busbar groups.

The alignment of the plant on the individual busbar group screen shall match that of the overview screen. The detailed screen shall include the following information:

• Name of circuit
• Name of plant
• Plant status
• Plant Measurements
  o Amps
  o Volts
  o Active and Reactive Power, including direction of flow
  o Frequency

**Detailed View of Bay**

Detailed views of each bay shall be available by selecting the bay from the overview or individual busbar groups screen. Control of plant shall only be available from the detailed view.

The alignment of the plant on the detailed screen shall match that of the overview screen.

**Detailed View of Transformer**
Detailed views of each transformer shall be available by selecting the bay from the overview or individual busbar groups screen. This view shall show all measurements for the transformer, including tap changer positions, and shall include controls for on-line tap changers.

**Power Flow Summary**

The power flow summary screen shall detail all the substation active and reactive power flows, magnitude and direction, in tabular format, and provide a zero summation check.

**Hand Dressed Data**

The operator shall be able to hand dress (that is, assign a value to) any data point from a detailed view screen. The substation control system shall treat each such assignment as an event.

**Maintenance Tagging**

The operator shall be able to apply a maintenance tag to any equipment from a detailed view screen. A maintenance tag will generally impose an operational constraint on the equipment (for example, might inhibit circuit breaker close). Equipment which has been tagged will be highlighted with distinct colours on all screens and an explanatory message shall pop-up whenever the mouse pointer hovers over the equipment icon. Highlighting shall be colour coded to indicate the extent of operational constraint imposed by the maintenance tag.

The HMI shall have the facility of tagging selected plant items as being out for maintenance. This shall restrict the control of the plant item and provide a text box for explanation to other operators. All items of plant with a tagged message shall be highlighted as such on all screen displays.

**Alarm and Event Screens**

The operator interface shall include an event screen and an alarm screen. All alarms shall appear on the event screen. Each item on the event / alarm screen shall be time tagged. The status of all alarms shall be colour coded.

**Trend and Report Displays**

Trend displays shall allow the operator to view real time and historical trends.

Report displays shall allow the operator to generate reports.

Operators shall be able to develop ad hoc trend displays and reports.

Some trend displays and reports will be included as standard. The Contractor shall coordinate with the Project Manager to identify the standard trend displays and reports to be provided.

**10.1.7. CONTROL**

Control shall be on a select-before-execute basis. This facility shall have a time-out feature which cancels the selection if the command is not executed in a reasonable time.
10.1.7.1.  INDICATIVE DATA FOR SUBSTATION CONTROL SYSTEM

Switchgear Bay

Analog inputs:
- current
- voltage
- active power
- reactive power

Digital Inputs, two-bit:
- Circuit breaker open/closed indication
- Disconnector open/closed indication
- Earth switch open/close indication

Digital Inputs, single-bit:
- Local control selected
- CB faults
- Protection operated (each protection system/function)
- VT faulty
- Trip circuit faulty
- Intertrip send and receive (each signal)
- Auxiliary supply failure (each supply)
- Any other relevant alarms

Digital Outputs
- CB open/close
- Disconnector open/close

Transformers

Analog inputs (each winding):
- current
- voltage
- active power
- reactive power
- tap changer position

Digital Inputs, single-bit:
- Protection operated (each protection system/function)
- Transformer Buchholz alarm
- Transformer Buchholz trip
• Transformer oil high temperature alarm
• Transformer oil high temperature trip
• Transformer winding high temperature alarm
• Transformer winding high temperature trip
• Pressure relief valve operated
• Oil level low
• Cooling fans on
• Cooling system faulty
• OLTC Buchholz alarm
• OLTC Buchholz trip
• OLTC Pressure relief valve operated
• OLTC oil low level alarm
  • All status and alarms from the Tap changer/AVC relay
  • Trip circuit faulty
  • VT faulty
  • Auxiliary supply failure (each supply)
  • Any other relevant alarms

Other

• All alarms from busbar protection
• All alarms from AC auxiliary supply equipment
• All alarms from 110 V DC system
• All alarms from communications equipment
• All alarms from substation control system
• Any other relevant alarms.

10.1.8. PERFORMANCE

10.1.8.1. GENERAL

The system performance requirements apply to full utilisation of the specified substation control system spare capacity and expandability. This shall be simulated in the Factory Acceptance Tests. Tests on site shall be on the delivered system with all equipment in service and fully configured.

There shall be no loss of real-time data under any level of system activity.

10.1.8.2. SYSTEM ACTIVITY LEVELS

Steady-State Level

The system is considered to be at a steady state level when the following conditions exist over a 20-minute interval:
• the SCADA system is scanning all field data points and is processing received data;
• at least 10% of analogue data points change value during the interval;
• one alarm is processed and acknowledged during the interval;
• 50 cyclical calculations are performed every five minutes with up to 10 variables per calculation; and
• one operator workstation display is selected at random every minute.

### Peak Load Level

The system is considered to be at a peak load level when the following conditions exist over a five-minute interval:

• the SCADA system has been at a steady-state level for the previous 20 minutes;
• the SCADA system is scanning all field data points and is processing received data;
• at least 50% of analogue data points change value during the interval;
• ten alarms are processed and acknowledged during the first minute and a further 16 alarms are processed and acknowledged during the balance of the interval;
• one remote control command is being processed every 1 minute;
• 50 cyclical calculations are performed every five minutes with up to 10 variables per calculation; and
• six operator workstation displays are selected at random every minute.

No data link shall utilise more than 50% of the data channel’s capability measured over any one-minute period in the system activity level interval.

#### 10.1.8.3 DISPLAY RESPONSE TIMES

The display response time is the elapsed time from the time an operator requests a new display to the time the display is completed on the screen.

The display response times will vary according to system resource availability and activity. The maximum allowable response time shall be two times the average display response time.

Average display response time limits at a steady-state system activity level shall not exceed:

<table>
<thead>
<tr>
<th>Display</th>
<th>Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directory/Menus</td>
<td>1</td>
</tr>
<tr>
<td>System Displays</td>
<td>1</td>
</tr>
<tr>
<td>Single-Line Diagrams</td>
<td>1</td>
</tr>
<tr>
<td>Tabular Displays</td>
<td>1</td>
</tr>
<tr>
<td>Alarm/Event Log</td>
<td>1</td>
</tr>
<tr>
<td>Summary Displays</td>
<td>2</td>
</tr>
<tr>
<td>Historical Data</td>
<td>2</td>
</tr>
</tbody>
</table>
Under high activity or peak load levels, the display response times shall not be more than two times the response times for the steady state level.

**Field Input Response Time**

In steady-state level, all alarms transmitted through an interrupt and not a routine scan shall be reported at the respective workstation within three seconds of detection in the field.

In peak load level, not less than 90% of alarms shall be reported within five seconds.

**Operator Request Completion Time**

In steady or high activity level, the system shall complete the response to an operator's action within 1 second.

At peak load level, not less than 90% of the system responses to operator requests shall be greater than four seconds.

For other operator requests, if the response time in steady-state or high activity level exceeds three seconds, the request shall be acknowledged within one second and an action completed message when the task is completed.

10.1.9. TESTS

10.1.9.1. GENERAL

Substation control system tests shall comprise:

- factory acceptance tests;
- pre-commissioning tests;
- commissioning tests (tests after completion).

Unless otherwise specified, all capacity and performance tests shall provide for utilization of all spare capacity and all levels of system activity.

On completion of the factory acceptance tests all software and hardware shall be frozen and no change shall be allowed. Correction, replacement or upgrade shall be made only through a formal change-control procedure and shall be subject to the prior approval of the Project Manager.

Tests shall provide, where appropriate, for measurement of program execution times, processor utilization, system performance monitoring overhead and auxiliary memory transfer capacity in order to verify the Contractor’s design.

10.1.9.2. TEST PROCEDURES

The Contractor shall submit the test procedures for the factory acceptance tests and all field tests for approval at least 12 weeks in advance of the start of the tests.
The Contractor shall submit a test report within 2 weeks of completion of each test.

A variance report shall be prepared each time a deviation from the Specification is determined or a test procedure step fails to meet the predicted outcome. The variance report shall categorise the defect as one of the following.

- variance class 1: testing to stop for immediate evaluation and correction by the Contractor;
- variance class 2: testing to continue with the variance to be corrected at the end of the test session or day;
- variance class 3: testing to continue with the variance to be corrected prior to the completion of factory acceptance tests or site acceptance tests.

All measuring and testing equipment used in inspection or testing shall be calibrated and adjusted against certified equipment having a known valid relationship to nationally recognised standards. Where no national standards exist, the basis employed for calibration shall be approved by the Project Manager.

10.1.9.3. FACTORY ACCEPTANCE TESTS

General

Factory acceptance tests will comprise:

- design performance tests;
- routine tests;
- system tests.

System tests shall not be conducted prior to approval of all associated design performance tests and routine tests.

Factory acceptance tests shall include also type tests and unstructured tests. Type tests shall be performed on all equipment. Type tests may be dispensed with if the Contractor furnishes evidence to the satisfaction of the Project Manager that the relevant type tests have already been performed on identical equipment at an independent testing laboratory or witnessed by an independent testing agency.

Design Performance Tests

The design performance tests shall demonstrate that all equipment supplied satisfies the specified design performance requirements.

The Project Manager may waive the requirement to conduct a performance test if the Contractor can provide test reports which are certified by an independent testing agency and which confirm that the equipment has design performance equal to or better than that specified.

Design performance tests shall be conducted on all major components, assemblies and sub-systems over the full range of specified environmental and electricity supply conditions.

Routine Tests
Routine tests shall be carried out on all components, sub-assemblies, assemblies and subsystems. The Contractor's test plan shall fully describe all such routine tests.

The routine tests shall include:

- all components and modules shall be inspected and tested for quality in accordance with accepted sampling procedures. All sub-assemblies, assemblies, and subsystems shall be individually inspected, tested and aligned or adjusted;
- all routine tests nominated in relevant international standards or recommended by the manufacturers of each component or element of the computer subsystem and the man-machine interface subsystem;
- interface tests on every data modem and communications channel interface. Interface characteristics shall be measured in accordance with the procedures and standard test circuits described in the ITU-T recommendations;
- performance tests shall be conducted on each bay controller or equivalent to ensure all functions are operational. These tests may be performed with a test set simulating the control room equipment. Tests of inputs and outputs shall include simulation of interference and shall check the accuracy of the analogue inputs;
- performance tests shall be conducted on each sensor and power supply to ensure all functions are operational.

10.1.9.4. SYSTEM TESTS

The system tests shall ensure that:

- the substation control system operates correctly when connected in the operational configuration and under all specified operational modes;
- hardware (and software) errors and design weaknesses are identified and corrected before delivery;
- the overall system availability is better than 99.9 %;
- all interfaces function correctly;
- all contractor furnished software packages are operational;
- all alarm functions are verified;
- all diagnostic routines are verified;
- all fail-over and switching functions operate satisfactorily;

The Contractor shall assemble all elements of each subsystem and shall interconnect them using the cables to be delivered. The Contractor shall simulate the interfaces between his equipment and the process plant and shall take any other measures necessary to ensure system tests are realistic and meaningful. The system tests shall include a stability test run.

Prior to the commencement of the system tests, the Contractor shall demonstrate the operation of diagnostic and self-monitoring functions. A schedule of alarm and device failure printout and display messages shall be provided prior to the demonstration.

System Test Schedule

The system test schedule shall be formulated to demonstrate compliance with the requirements of the Specification, to frequently check the operation of routines and equipment that are normally
exercised only periodically and to prove the absence of unscheduled interaction between modules. The test program shall also be formulated to simulate the maximum system loading expected in order to expose any unforeseen software timing problems which may result in delays in updating or loss of data.

The system test schedule shall include at least the following:

- functional test of all computing functions including memory and program interrupt facilities, and shall also include periodical switching over to the backup computer and auxiliary memory;
- functional test of all outputs, displays and printout including any backup unit;
- test of analogue and digital inputs including accuracy tests of analogue inputs in the presence of interference;
- test of all output channels with signals generated by the system;
- loading and timing tests of:
  - network data transfer;
  - input data processing and storage;
  - keyboard response;
  - VDU screen response;
  - maximum feasible loading; and
  - time resolution within the substation;
- functional test of all fault detection;
- functional test of all switch-over facilities;
- functional test of human-machine interface;
- functional test of facilities for off-line program development;
- tests of historical data storage and retrieval;

**Stability Test**

The system tests shall include a stability test. The stability test shall be in periods of not less than 25 hours and the total duration of the stability test shall not be less than 100 hours.

During the stability test, no adjustment shall be made to any equipment without the prior approval of the Project Manager. Faulty equipment shall be replaced with spare units without interruptions of the test. The faulty unit shall be immediately repaired and returned to service. Any period of operation with a faulty unit shall be included as part of the test period. No automatic changeover to a standby unit shall occur unless the changeover itself is being tested.

If a stoppage of the test occurs due to equipment fault, the test will be deemed to be invalid and the Project Manager may require a repetition of the test.

At any stage during the test period the Project Manager may request a printout of any nominated parts of the main or auxiliary memory for verification purposes.
No additional program or data shall be read into the system during a test period without the prior approval of the Project Manager.

10.1.9.5. PRE-COMMISSIONING TESTS

General

Pre-commissioning tests shall be conducted on completion of installation. The commissioning tests shall include the equivalent to factory acceptance tests in addition to testing all features of the equipment which could not be tested during the factory acceptance tests, in particular the real time database. The Project Manager may waive any part of testing already performed during factory acceptance tests if this does not provide any added value.

The commissioning tests shall include visual inspection of all equipment and assemblies and voltage and insulation resistance tests on equipment and connections to which these are applicable.

The minimum requirements of commissioning testing are:

- all hardware and software shall be subject to commissioning tests;
- point to point tests shall be completed before the tests on the overall system;
- where real data are not available for some tests, the same dummy data as used in the factory acceptance tests may used subject to prior approval of the Project Manager;
- upon detection of a critical failure, the Project Manager may decide to stop a test. The test may be restarted after the Contractor has demonstrated that the fault has been rectified and any associated prior testing has been completed.

Field Equipment

All inputs from field equipment used for local process control and protection and for input to the system shall be tested. All analogue input devices shall be calibrated. The settings of all digital input devices shall be recorded. All settings of protection equipment (including associated alarms) shall be recorded. Operation of all input devices over their full operating range shall be simulated and their input to the relevant process equipment confirmed. Correct operation of all diagnostics and alarms internal to all protection and process equipment shall be confirmed.

The correct operation of all outputs from hard-wired protection equipment and process control equipment shall be confirmed. The correct operation of all automatic control sequences and processes shall be confirmed. The correct operation on receipt of all commands through the telemetry system shall be confirmed.

Control Equipment

After installation of the substation control equipment, and before connection to the communications network, diagnostic tests shall be run for a period of 24 hours.

The operational software shall then be loaded and a complete check of all human-machine interfaces shall be carried out. Point by point verification shall be made of copying of database information to the historian facilities.

Correct operation of all failover functions shall be proven.

Connections to the communications equipment shall then be made at an appropriate time during or after commissioning of relevant portions of the communications network.
When all site facilities have been connected and otherwise commissioned, final soak tests shall be carried out for a period of 120 hours. The tests to be conducted shall be selected from tests conducted in the factory acceptance tests, shall be proposed by the Contractor, and shall be subject to the approval of the Project Manager. The equipment shall be deemed to have successfully completed the final soak tests provided there have been no false control operations during the test period and not more than 5 erroneous alarms.

10.1.9.6. COMMISSIONING TESTS (TESTS AFTER COMPLETION)

General

The commissioning tests shall commence as soon as practical after all pre-commissioning tests have been completed and verified by the Project Manager. The commissioning tests shall test that the complete system satisfies the specified availability and performance requirements over a period of three calendar months of continuous operation.

The substation control system shall have a percent availability not less than 99.9%.

Through the period of the test the system shall operate normally except that one test at peak load level shall be made during the test.

Availability Definitions

The “percent availability” is given by:

\[
100 \times \frac{\text{accumulated run time}}{\text{accumulated run time} + \text{accumulated down time}}
\]

where the times are accumulated over the period of the test.

“Run Time” is the time when the relevant system is available.

“Hold Time” is time when the relevant system is not available for one of the following reasons:

- power interruption or environmental conditions outside limits;
- agreed service response times;
- required test downtime;
- scheduled shutdowns or logistical delays mutually agreed between the Contractor and the Project Manager.

“Down Time” is any other time that the relevant system is not available.

The test records shall identify all periods of down time and hold time, and their reason.

The substation control system shall be considered available when:

- hardware fails, but does not result in system degradation or loss of function;
- a successful fail-over or restart takes place;
- all critical functions are available.

Documentation

Comprehensive documentation shall be provided for all hardware and drawings, reference manuals, user manuals and maintenance manuals.

Comprehensive documentation shall be provided for all software and shall include the following as a minimum:
• Software Functional Design Specifications - This document shall provide a complete description of the system on a functional level. The functional design specification shall describe in detail what functions are to be performed by each subsystem of the software architecture.

• Detailed Software Design Documentation - The detailed software design documentation shall provide a description of how the software system realises the functions described in the software functional design specification.

• Software Maintenance Documentation

The Contractor shall provide an operator's manual, which describes the system configuration and all functions, including all algorithms necessary to understand the functions.

The operator's manual shall be written in a non-technical style and shall be organised for quick access to each description of the operator's system interface procedures.

This operator's manual shall present all information the operator needs to know in order to satisfactorily operate the control system.

The operator's manual shall also include sufficient detail to allow the operator to detect and isolate problems in the system. All alarm and error messages are to be listed with recommended remedial actions.

10.1.10. TRAINING

10.1.10.1. GENERAL

The Contractor shall provide training courses designed to provide the Employer’s staff with a thorough understanding of the substation control system capabilities, operational procedures, maintenance requirements and expansion techniques.

Training shall be conducted by experienced personnel at relevant on-site locations. Training courses shall have a class size of not more than 10.

Advance training documentation shall be provided to trainees at least one month prior to the course commencement with final material provided during the classes.

Training courses shall be based on trainees having little or no prior knowledge of computer systems, software applications or communications. Training courses shall be scheduled such that individual trainees do not undertake training on consecutive working days.

In addition to formal training, the Contractor shall provide informal on-the-job training to the Employer’s personnel attending factory tests and installation, testing and commissioning on site.

10.1.10.2. OPERATOR TRAINING

The Contractor shall provide training for operations personnel in the use of the substation control system. The course shall instruct operators and maintenance personnel in the general system design and concepts, its capabilities, user interface procedures, and workstation facilities and actions.

10.1.10.3. ENGINEER AND TECHNICIAN TRAINING, SOFTWARE

The Contractor shall provide one full day course on each of the following topics:
• Database Generation and Maintenance - detailed instruction on the database structure and maintenance requirements. The participants shall prepare database structures for use on the actual system as part of their training schedule;

• Database Management - detailed instruction on use and operation of the database management software, the database structure and its contents, as well as the performance analysis, modification or extension of existing facilities;

• Display Generation and Maintenance - detailed instruction on the display generation and maintenance requirements. The participants shall prepare displays for use on the actual system as part of their training schedule;

• Operating System - the complete software operating system and its scheduling, resource management, system services, input/output services, network and communications functions, and utility functions. The course shall describe software and hardware interrupt structures, priority levels, program execution control, diagnostic facilities, communications interfaces and executive system support services.

10.1.10.4. ENGINEER AND TECHNICIAN TRAINING, HARDWARE

Hardware training shall be provided to enable the Employer’s staff to understand the operation, maintenance, fault isolation and repair or replacement of defective equipment.

The training shall cover maintenance procedures and systematic trouble-shooting techniques, including use of the relevant documentation supplied by the Contractor. Specific training shall be given on use and maintenance of all measuring and test equipment. Trainees shall operate the equipment shall run any applicable diagnostic programs.
11. SUBSTATION PROTECTION SYSTEM

11.1. GENERAL REQUIREMENTS

This part of the specification calls for the supply, installation and commissioning of complete protection systems for the various plant and equipment to be installed the substations. The supply shall include all components such as Electrical protection relays, auxiliary relays, MCCBs, interposing relays, wiring and all accessories to constitute the complete system.

Electrical protection relays shall be of robust type, insensitive to changes of temperature, vibration, etc. Input from the measuring transformers shall be based on 1A, 110V AC. However, all Protection circuits shall use the substation 110 V DC system.

All protection relays shall be fully digital type and shall comply with relevant IEC standards. One protection relay of each feeder may be a combined protection and field control device, from where the feeder can be controlled. The relays shall indicate and store measured service values and fault events. Several protection functions can be combined in one protection relay. Main and back-up protection, however, have to be done by different relays which shall have independent sources of supply and shall preferably be supplied from deferent manufacturers.

A dedicated fibre(s) from the OPGW will be provided by others for the coupling of the distance protection relays to the remote end. The Contractor shall provide all necessary additional devices, plug connectors, conventional and short copper or fibre-optic connections up to the terminals of the fibre optic cable. The serial working interface for the asynchronous transmission shall have a hamming distance of 4. The plant shall be selected to allow for 20% attenuation reserve in the end-to-end transmission.

The following shall be required for serial interfacing:

- System interface, potential-free, suitable for asynchronous connection via local fibre optic connection to the central systems.
- All devices, connectors and fibre optic connections to the switchyard control system.
- Operator interface such RS232/RS485 terminal shall be required for parameterization, setting, and retrieving of stored event records via hand terminal or PC.
- The device used shall have self-supervision facilities that include but not limited to the following features:
  - Self-supervision of the main hardware components and of the serial communication to the remote end. The "device faulty" and "channel faulty" alarms shall be made available to the SCMS (Substation Control and Monitoring System).
  - Locally LED-indication.
  - "Channel faulty" alarm which shall be time-delayed (1… 50s).
  - Local LED indications (seal-in) or readable on the LCD display shall include:
    - in operation (green)
    - device faulty (red)
    - channel faulty (red)
    - direct transfer trip (red)
    - trip (red)
    - or readable LCD
Resettable by local push button or via centralized SCMS.

Typical alarms available at the SCMS shall include:

- device faulty
- channel faulty
- direct transfer trip
- trip

As a minimum the relays shall have the following functions/components:

- Disturbance and event recording, cyclic overwriting, min. event time 2s, with pre-fault history, transferable to the SCMS on request or retrievable menu-guided from the PC; the event recording shall be time-tagged by an included real-time clock synchronised to the SCMS.
- Long duration non-volatile storage capacity that can store system events for at least 3 months; alternatively, if the relays have short storage time, a separate storage device shall be provided with proper interface to allow the relays to update the storage in short periods of time.
- Settings, parameters and event records shall be stored in a non-volatile memory (with a capacity to store events for at least 100 successive events).
- One-end test facilities, display of the phase and zero-sequence service currents.
- External switch with the positions “in/out” (trip circuit interrupted).
- Heavy duty trip contacts suitable for the double-pole direct trip with station battery voltage of the main circuit breaker.

Protection cubicles shall be of self-ventilating type and shall comply with all construction requirements laid down in the abovementioned civil works chapter. The Contractor shall ensure that in the event of failure of the air conditioning system, the protective relaying systems and their associated signalling, monitoring, control and alarm plant remain in full operation.

In his case, suitable heating elements in the relay cubicles, controlled by humidity detectors, must prevent any condensation while keeping the temperature inside the cubicle within the operating limits of the devices.

Protection current transformer circuits shall have continuous thermal ratings of not less than 130% of the maximum continuous secondary current of the current transformer to which they are connected. Voltage transformer circuits shall have a continuous thermal rating of not less than that required to permit operation at maximum system voltage.

Where, in the course of correct protection operation, there are fleeting contact closures which could be of insufficient duration for associated alarm annunciation or change in status of a control system or SCADA input, a pulse lengthening facility shall be provided to ensure that all alarms and change of status are recognised.

All protection relays shall be suitable for connection into a protection monitoring system. In addition, each protection relay shall have facility for connection to a notebook computer for setting, monitoring and testing the relay. Protection relay setting shall be from the front of the relay using built-in pushbuttons and an alphanumeric display.

Two notebook computers shall be provided with relevant protection relay software installed for all protection relays provided under the Contract. Copies of all relevant software on CD shall also be
provided. All software provided must be suitable for installation and update without requiring internet access.

On 33 kV switchboards, a feeder protection relay may incorporate the associated feeder control facilities.

The Contractor shall determine all protection relay settings, and the associated calculations shall be submitted for approval.

11.2. BASIC ELECTRICAL PROTECTION REQUIREMENTS

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Electrical Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Lines</td>
<td>One set of differential current protection with integrated selectable distance protection</td>
</tr>
<tr>
<td></td>
<td>One set of distance protection (not the same type as the differential protection)</td>
</tr>
<tr>
<td></td>
<td>Three pole autoreclose</td>
</tr>
<tr>
<td>132 kV transmission lines</td>
<td>One set of differential protection.</td>
</tr>
<tr>
<td></td>
<td>One set of primary winding protection including functions for overcurrent, earth fault and restricted earth fault.</td>
</tr>
<tr>
<td>Transformers</td>
<td>One set of secondary winding protection including overcurrent, earth fault, sensitive earth fault and restricted earth fault.</td>
</tr>
<tr>
<td></td>
<td>Tertiary winding earth fault protection</td>
</tr>
<tr>
<td>Reactors</td>
<td>One set of differential protection.</td>
</tr>
<tr>
<td></td>
<td>One set of primary winding protection including functions for overcurrent, earth fault and restricted earth fault.</td>
</tr>
<tr>
<td>Busbars</td>
<td>Circuit breaker fail protection</td>
</tr>
<tr>
<td></td>
<td>Blind spot protection (each feeder)</td>
</tr>
<tr>
<td>All high voltage circuit breakers</td>
<td>High impedance differential, with overall check zone</td>
</tr>
<tr>
<td>High voltage busbar or busbar section, double bus substation</td>
<td>High impedance differential</td>
</tr>
<tr>
<td>33 kV busbar</td>
<td>Feeder protection relay including functions for overcurrent, earth fault and auto reclose</td>
</tr>
<tr>
<td>33 kV feeder</td>
<td></td>
</tr>
</tbody>
</table>

Other protection functions available in the protection relays shall also be applied if they enhance the capability of the protection scheme.

Fault clearance time shall not exceed 100 ms for all transformer, busbar and distance protection zone 1 faults.
11.3. RELAY CONSTRUCTION AND MOUNTING

The relays shall comply with the requirements of IEC 60255 and such national standards as may be appropriate in the country of manufacture. Modular constructed plant (example, rack mounted solid state relaying plant) shall be tested as a complete assembly and details of such tests shall be agreed with the Employer when details of the construction are known. Particular attention shall be given to resonant frequency scanning. Constructional details shall satisfy the following requirements as appropriate:

a) Means shall be provided to positively locate each withdrawable unit in the 'service' position. It shall not be possible to remove any unit without first rendering the relay outputs inoperative.

b) Each protection relay, or protection scheme shall be provided with an adequate number of output contacts of suitable rating to carry out the prescribed tripping functions as may be necessary for the initiation of automatic reclosing or automatic switching control. In all cases, the swell of the output contacts shall be not less than 50ms and they shall have a rating appropriate to the maximum possible duty, due account being taken of the range of voltage variation in the DC supply source of the associated circuit. For contacts intended to be used to directly energise circuit breaker tripping coils the peak value of the permissible peak current shall be stated on the appropriate Technical Data Sheet in Section 39 by the Contractor/Bidder. Where appropriate, details shall also be given of the operating characteristics of any reinforcing contactor and, in particular, the pick-up and drop-off threshold levels of a series connected (current dependent) contactor. The Contractor/Bidder shall also quote the maximum breaking capability of the trip output circuit (in mA) when associated with an inductive burden having a time constant of not less than 40ms at a rated voltage of 110V DC.

c) All static protection relays shall be designed to withstand the high voltage interference which is normally experienced in high voltage substations. Static protections which require an independent low voltage DC supply shall preferably use DC/AC/DC converter power pack for this purpose. Separate power packs are preferred for each individual discriminative relay unit.

d) If the power pack is separately housed from the relay unit(s) which it is supplying, care must be taken that the cabling between the power pack and the relay unit is adequately screened and physically separate from all "power type" circuits associated with the CT, VT and DC tripping circuits. All interconnecting screened cables shall preferably be terminated by plugs and sockets.

e) It shall not be possible to gain direct access by means of external connection to any low voltage DC power supply without first removing an appropriate protective cover suitably engraved with a warning that high voltage tests shall not be applied. That is, there shall be a degree of mechanical segregation between the "Power type" circuits associated with the CT, VT and DC tripping connections and low voltage circuits.

f) All input and output terminals of the power packs which are connected to "power type" circuits shall be subjected to the same overvoltage, impulse and interference tests as specified for the static protection.

g) The low voltage supply to each discriminative relay unit shall be continuously monitored and an alarm shall be given whenever the voltage exceeds the limits for reliable protection operation.
h) In order to minimise the high voltage interference to acceptable level, the station multicore cables shall be screened and earthed according to the latest standards for high voltage switching stations.

i) Each relay, or relay scheme shall be provided with an adequate number of indications to facilitate post fault analysis including identification of the faulted phase and faulted zone, etc. Mechanically operated output indications are acceptable but consideration shall be given to other methods of presentation provided that:

- Long term storage of the indication is not dependent upon an auxiliary supply.
- Means are provided to ensure that the indication is complete, e.g. relays which are provided with lamp indicators must have lamp testing facilities.
- Each indicator, whether of the electrically or mechanically operated type, shall be capable of being reset without opening the relay case.
- Each indicator shall be so designed that it cannot move before the relay has completed its operation.
- Unless otherwise approved, indication shall only be given by the protection(s) which causes the fault to be cleared.
- All indication shall be clearly visible without opening of relay cases or relay panel doors.

All relays which are of the hand reset type shall be capable of being reset without the necessity of opening the case.

Wherever practicable the design of the relay schemes shall be based on the “fail-safe” principle. For example, care shall be taken to ensure that loss of DC supply or an open circuit does not cause incorrect opening or closing of circuit breaker. Circuit breaker or isolator repeat relays should be of the latching type and a discrepancy alarm shall be provided to check correct operation of the relays following a circuit breaker or isolator operation.

All tripping relays shall be of the heavy duty type suitable for panel mounting and shall have operating coils rated to a sufficiently high value that they are suitable to work in conjunction with series trip flags. "Cut-throat" contacts, when provided on the relays, shall be delayed in operation sufficiently long as to ensure that the series flag relays, if fitted, operate correctly.

All other contacts on the tripping relay shall operate within the prescribed time for the particular category which shall not, in any case, exceed 10 milliseconds from the time at which the operating coil of the relay is first energised.

The lockout tripping relays shall be of the latching type and shall be hand and electrically reset.

All primary faults which are of such magnitude that they jeopardise continued operation of the grid, represent a risk to persons or could cause appreciable material damage to plant or to the system, shall be isolated. Also in the event of a single failure in the relay protection plant, its supply of measuring quantities, auxiliary voltage, etc. or primary breakers shall be isolated.

All protection relays shall be mounted in racks or enclosed in cases and shall have silver plated contacts. The relays shall be of the modular, plugged type. The plug mechanism shall be such that when the relays or part of the relays which are connected to the current transformer circuits are pulled out, the circuits of the current transformers are automatically shunted.
Each relay protection shall have test facilities of a type enabling testing of the entire relay combination when the protected part is in service. Furthermore it shall be possible to switch off the tripping impulses by means of switches or links. Relays with integral test facilities or test blocks will be preferred.

Indications shall be provided on each individual relay to show if they have operated and to facilitate analysis of the fault including identification of the faulted phase and faulted zone. Portable test plant shall be provided to facilitate testing of the relays at site. For static type relays, trip test facilities shall be provided.

All necessary intermediate current and voltage transformers, converters and auxiliary power supply units shall form part of this supply.

11.4. RELAY SUPERVISION

The supply shall include a system for remote supervision and data acquisition of protection relays, fault locators, and fault recorders. The software shall be installed on a central pc with “Windows 7” operating system. The centrally installed software shall make it possible to contact the relays over the telephone network via modems installed in each substation. The Contractor shall supply and install the modems, connect the relays and test the complete chain of control.

11.5. BASIC PROTECTION SYSTEMS

11.5.1. DUPLICATED PROTECTION & PROTECTION SEGREGATION

In order to achieve a high degree of security in function, the protection system of each high voltage main component (lines, power transformers, shunt reactors, etc.) shall consist of two separated protection sets, main and back-up where applicable. The two protection sets shall be divided into two electrically and mechanically separate parts by means of:

- Separated DC power supply.
- Separated switchboards.
- Separated current transformer cores.
- Separated voltage circuits.
- Separated tripping devices.
- Separated cables.
- Separated relay protection channels.

Protection d.c. circuits shall as far as is practical be segregated from control circuits.

Each protection shall operate into both trip coils of the associated circuit breakers. Where necessary to achieve this and maintain segregation between sets of protection, high speed protection quality interposing relays may be used.

11.5.2. BUS COUPLER BYPASS TRIPPING LOGIC

Where a bus coupler is specified, the tripping signals of any bypassed circuit breaker shall be instantaneously transferred to the bus coupler.
Electrical interlocks shall be provided to ensure that only one circuit breaker can be put on bypass at any one time. This is only possible through the reserve busbar.

The bus coupler protection shall consist of a 3-pole IDMTL overcurrent relay and one IDMTL earth fault relay, all with standard inverse characteristics.

11.5.3. DISTANCE PROTECTION

Each distance relay shall operate for all types of phase and earth faults in the protected direction. Distance relays shall have at least three zones. Separate phase and earth fault distance measuring elements shall be provided for each zone.

Zones 1 and 2 shall operate only for faults in the protected direction. Under no circumstances shall the relay operate for reverse faults even when the voltage supplied to the relay falls to zero on all three phases. Zone 3 shall be non directional and shall be capable of being independently offset in both directions. Starting shall be by impedance measurement.

The relay characteristic shall cover the protected line plus the longest line emanating from the remote station taking current infeed into account. The starting relays shall not operate during maximum power transfer. During single phase to earth faults coinciding with maximum power transfer, only the starting relay associated with the faulted phase shall operate.

The reach of each measuring zone and starting relay shall be individually adjustable.

Zone 2 and Zone 3 shall have a time delay setting range of 0.0 to 1.0 second and 0.5 to 3.0 seconds respectively. The maximum operating time of the zone 1 measuring element measured at the output terminal shall be less than 30 ms for a fault near the zone 1 boundary. The operating time for each zone shall be independent of fault current magnitude.

The operating time of each zone shall be substantially independent of fault current magnitude.

The relay shall include a switch-on-fault (SOTF) function to ensure instantaneous tripping without auto reclose in the event that the circuit breaker is closed onto a fault on a previously de-energized line.

The protection shall remain fully operational during and following an auto reclosing cycle irrespective of load transfer during the period. Where single pole tripping is specified, the protection must discriminate correctly between single phase, phase to ground faults and multi-phase fault.

Voltage transformer supervision (VTS) relay shall be provided to supervise the voltage transformer supply to each distance relay. In the event of loss of one or more phases, the monitoring system shall inhibit relay operation and initiate alarm.

Configurable power swing blocking (PSB) feature shall be provided to selective blocking of all zones in the event of transient power swing in the power system. The power swing blocking (PSB) feature shall inhibit relay operation and initiate alarm.

The protection for the 132kV lines shall be suitable for three-pole tripping and delayed auto reclosing.

Associated automatic reclose and check synchronisation facilities may be integrated into the distance protection.
Tele-protection shall use OPGW and power line carrier signalling, and shall be arranged such that tele-protection remains operable should any one of these communications system fail. Permissive transfer tripping (selectable either under reach or over reach scheme) arrangement whereby receipt of the carrier signal is monitored by the second zone characteristic before allowing accelerated tripping shall be provided.

11.5.4. LINE DIFFERENTIAL PROTECTION

The line differential protection shall be current differential with phase-segregated measurements. It shall include selectable distance relay functionality.

The line differential protection shall generally comply with the requirements for distance relays set out above.

Where line current differential is employed as the main protection, such a scheme must have the auto re-close feature.

Line differential protection communication shall be optical and/or power line carrier.

11.5.5. AUTOMATIC RECLOSE

11.5.5.1. GENERAL

A counter shall be provided to record the number of reclosures and to lockout the equipment after a pre-selected number of reclosures has been reached.

The dead line live busbar check relays shall monitor the condition of the line and the busbar and permit reclosing when the line is de energized and the busbar energized. The line is considered de energized when the voltage is less than twenty percent (20%) of rated voltage and the busbar is considered energized when the voltage is at least eighty percent (80%) of the rated nominal voltage.

The synchronism check relay shall monitor the magnitudes of the voltage on both sides of the open circuit breaker terminals and the phase angles and frequency difference between the voltages. Closing will be permitted when these are within prescribed limits. The voltage setting shall be adjustable between 80% and 90% per cent of rated voltage and the phase angle setting adjustable between 20° and 40°. The slip frequency shall be of the order of 20 mHz.

Autoreclose shall be blocked when the circuit breaker is normally open such that an inadvertent initiation of the auto reclose equipment does not energize a normally dead line.

Autoreclose shall be blocked for a short period after energizing the line irrespective of whether the energisation is done by the local circuit breaker or a circuit breaker at some other point in the primary system.

The autoreclose relay shall be able to inhibit the power swing-blocking feature of the distance relay for the duration of the circuit breaker closing signal.

A signal shall be provided from the three phase under voltage dead line check relays for interlocking of the line earth switches to prevent the switches being closed on to a live line.

The autoreclose scheme for 1½ CB configuration shall be equipped with dedicated autoreclose facilities for each circuit breaker in a diameter that controls overhead line feeders. All autoreclose
facilities in a diameter shall be able to engage priority scheme to determine the closing sequence priority between circuit breakers.

11.5.5.2. AUTO RECLOSE FOR 132 KV LINES

Three phase, single shot automatic reclosing equipment, including dead line and synchronism check relays, shall be provided. Reclosure shall be initiated following tripping by the distance relay zone 1 or receipt of a tele-protection permissive inter-tripping signal. Reclosure shall not be initiated in the event of a three phase fault or for any type of fault in the second or third distance zones or when the circuit breaker is closed onto a fault on a previously de-energised line.

It shall also be possible to block autoreclose from other protections. In addition, the auto re-close feature in any relay shall also be able to be remotely disabled.

The following modes of operation shall be selectable:

High Speed, Auto Reclose.

Auto reclose shall only be initiated in the event of a single phase to earth fault. All other types of faults shall result in tripping without autoreclose.

Delayed Reclosing.

Delayed reclosing shall only be initiated in the event of a single phase or two phase fault. Three phase faults shall result in tripping without auto reclosing.

Conditions for High Speed and/or Delayed Auto Reclosing as appropriate (HAR/DAR).

High speed auto reclosing shall be initiated only in the event of a single phase earth fault and delayed reclosing initiated in the event of a two phase fault. Three phase faults shall result in tripping without auto reclosing.

The high speed and delayed reclosing dead times shall be coordinated with the equipment being provided at the remote substation.

“OFF”, No Auto Reclosing

Tripping without auto reclose shall be able to take place for any type fault.

The dead time following fault clearance shall be adjustable between approximately 3 and 30 seconds. The reclaim time, i.e. the time period following automatic reclosure during which further faults result in tripping and lockout, shall be chosen to match the circuit breaker duty cycle assuming the shortest available dead time is selected. The reclaim time shall not, however, be less than 5 seconds. The closing command shall be limited to 2 seconds after which time the reclosing equipment shall be automatically reset without resetting the reclaim timer.

The reclosing equipment shall also be reset to the dead line live busbar check if synchronism check conditions are not fulfilled within 5 seconds of the check relays being energized. In addition, it shall be possible to select to “auto-reclose without synch-check” where applicable.
11.5.6. TRANSFORMER DIFFERENTIAL PROTECTION

The transformer differential protection shall be a biased type with maximum sensitivity and minimum operating time consistent with stability for through faults and magnetising inrush current.

Independent facilities shall be provided to enable bias and operating settings to be adjusted. The minimum operating setting shall not be greater than 20% of the rated full load current of the transformer.

The protection shall be designed to ensure stability on any transformer tap position under maximum through fault conditions with maximum DC offset. An infinite source is to be assumed and the through fault current calculated using the transformer impedance only. The protection shall have magnetising inrush current restraint of the harmonic type.

The transformer differential protection shall also incorporate:

- overcurrent protection
- restricted earth fault protection
- disturbance and event recording facilities
- single and three-phase time delayed under-voltage and overvoltage protection.

11.5.7. BUSBAR DIFFERENTIAL PROTECTION

At existing substations where the Contractor is providing additional bays, busbar, circuit breaker failure and blind spot protection shall be integrated as fully as is possible with the existing equipment. If this is not possible, the Contractor shall coordinate with the Project Manager to develop a means of providing these functions.

Busbar protection of the high impedance differential type shall be provided capable of detecting three phases to phase and phase to earth faults, under all system conditions.

The operating time of the measuring relays shall not exceed 40 ms at five times the relay current setting and shall be consistent with reliable and secure operation.

The rated stability limit of each fault detecting system for phase faults shall not be less than the rated breaking capacity of the associated switchgear. The maximum through-fault current for earth faults may be in excess of the phase fault value. The sensitivity shall not exceed thirty percent (30%) of the minimum fault level for all types of faults.

Automatic and continuous supervision of current transformer circuits shall be provided to give an alarm when the out-of-balance current reaches an undesirable value. Where the operation of the supervision device is dependent upon the load current in the primary circuit, operation shall occur at a current of 25 amperes or 10% of the circuit rating whichever is greater. Operation of current transformer supervision equipment should take the defective protection zone out-of-service by short-circuiting current transformer bus wiring.

All circuit breakers connected to a faulty busbar shall be tripped simultaneously, whether they feed fault current or not.

At double busbar substations where busbar protection CT inputs are switched based on disconnector position, an overall check zone shall be provided and tripping from busbar protection shall be two-out-of-two, that is, the busbar protection for an individual zone and the check zone must both operate
before tripping occurs. The equipment for the overall check zone shall effectively be the same as that used for individual zones except that CT inputs shall not be switched.

If CT input switching is implemented physically rather than through protection relay internal logic, switching shall use auxiliary contacts of the bus disconnectors. The contacts shall be silver-plated and two contacts shall be used in parallel.

11.5.8. **CIRCUIT BREAKER FAILURE PROTECTION**

Circuit breaker failure protection shall be provided for all 132 kV circuit breakers. It shall operate if, after protection operation, fault current persists. Time shall be set in the range 50 ms to 500 ms.

If the circuit breaker protection operates, all circuit breakers closed onto the same bus section as the faulty circuit breaker shall be tripped, and, if appropriate, an intertrip shall be sent to the far end of the circuit with the faulty circuit breaker.

11.5.9. **BLIND SPOT PROTECTION**

Blind spot (dead zone) protection shall be provided for all high voltage feeder circuit breakers

11.5.10. **OVERCURRENT AND EARTH FAULT PROTECTION**

Overcurrent and earth fault protection shall be multi-functional, multi-characteristic, three phase and earth overcurrent relays.

Relays shall have independent settings for operating curve, currents and times. The design of the relay shall be such that the setting adjustments can be carried out without taking the relay out of service. Time multiplier settings shall be at least 0.05 to 1.00 in steps of not exceeding 0.025. Phase fault elements shall have a setting range at least 5-200% of rated current in 5% steps, and the time setting adjustment shall be 0 to 3 seconds at ten times the setting current. Earth fault elements shall have a setting range at least 5% to 80% of rated current in 5% steps. The thermal withstand of the relay shall not be exceeded the highest practical current levels on any combination of current and time multiplier settings.

For overhead lines, back-up over current and earth fault protection shall have a ‘directional’ feature as a settable option. In addition, the earth fault element shall have 2 stages, with stage dependent on tele-protection signaling and operating under definite time as set, while the other will operate independently. Relays for overhead lines shall also incorporate the ‘echo’ function.

Each relay shall be equipped with at least one RS232 serial port.

11.5.11. **TRIP CIRCUIT SUPERVISION**

All trip circuits shall be duplicated with one group tripping the circuit breaker directly and the other routed via a trip relay with heavy duty contacts. All lockout trips shall be routed via a hand reset/electrical reset relay with heavy duty contacts. Closing of circuit breakers from substation control systems or local operation cubicle shall be inhibited if the lockout trip relays are not reset.

A trip supervision relay shall be provided for each circuit breaker trip coil. The trip circuit supervision shall be provided to monitor each pole of each trip circuit with the circuit breaker in both the open and closed position.

It shall provide continuous supervision of the trip circuit irrespective of the status of the circuit breaker or tripping/control devices. The relay shall have a time delay to prevent an alarm for circuit
breaker change of status or other transients. The relay shall have current limiting such that no fault within the relay can initiate or prevent circuit breaker tripping.

All DC/DC converter feeding protective relays shall have DC fail monitoring facilities.

An alarm shall be given to signal faulty trip circuits. The alarm shall be time delayed to prevent operation during momentary dips in the DC supply.

11.5.12. DC CIRCUIT SUPERVISION

All DC control circuits shall include a circuit supervision relay which initiates an alarm (after a time delay) in the event of loss of the DC supply. To the extent that it is practical, the supervision relay shall be wired at the end of the DC supply loop so that it also monitors the continuity of the DC supply wiring.

11.5.13. TRIP RELAYS

Trip relays shall be a multi-contact tripping relays designed for electrical protection application.

Trip relay contacts shall be suitably rated to satisfactorily perform their required duty and relay operating time shall not exceed 10 ms from initiation of trip relay operating coil to contact closure.

11.6. TESTS

11.6.1. INSPECTION AND TESTS

The Employer or Project Manager may inspect the protection equipment at any stage of manufacture or be present at any tests. Such inspection shall not relieve the manufacturer of his responsibility for meeting all requirements of the specification. Similarly any such inspection will not prevent subsequent rejection where any materials or component of a power transformer are subsequently found defective.

The Contractor will meet all costs for three representatives of the Employer to witness the factory tests on protection equipment.

Timing of tests shall generally be in accordance with the agreed work programme. The Contractor shall provide at least two weeks notice of the intention to conduct factory tests and their location. Associated inspection and test plans and procedures shall be submitted for approval not later than the time that the notice is given.

No high voltage equipment shall be prepared for transportation or dispatched from the manufacturer’s works without the prior approval of the Project Manager.

11.6.2. TYPE TESTS

All protection equipment shall be deemed to have satisfied all type test requirements set out in relevant IEC standards. The Contractor shall submit type test reports of tests conducted by a third party testing agency which have been undertaken in the last 5 years and which cover all type tests required in IEC standards. If the Contractor has not submitted acceptable type test reports prior to the factory tests, the outstanding type tests shall be included in the factory tests and shall be performed on one equipment item of each type. Where a type test might impair the performance or service life of the equipment, it shall be conducted on equipment equal to but not part of the equipment being provided under the Contract.
11.6.3. FACTORY TESTS

All routine tests included in relevant IEC standards shall be performed on all protection equipment as part of the factory tests.

The Contractor shall coordinate with the Project Manager to determine if any routine tests which are identified in the IEC standards as optional are required to be performed.

11.6.4. TESTS AT SITE

Site tests shall confirm correct interconnection of equipment and shall repeat relevant routine tests. They shall include primary as well as secondary injection tests, and shall prove the correct operation of all protection circuits.
12. REVENUE METERING SYSTEM

12.1. GENERAL

To enable trading between generators and the transmission entity and between the transmission entity and distribution entities, revenue meters shall be provided for each incoming generator circuit at designated points and after 33 kV winding of each transformer supplying distribution concessioners. The specific point where meters shall be installed shall be discussed and agreed upon between the Contractor and Project Manager.

12.2. TECHNICAL

At least 2 x four quadrant energy meters shall be provided for each revenue metering location, comprising:

- Main meter with active energy meter element operating in the first and second quadrants and a reactive energy meter element operating in the third and fourth quadrants.
- Check meter with active energy meter element operating in the first and second quadrants and a reactive energy meter element operating in the third and fourth quadrants.

Active energy meters shall not be less than class 0.1 and reactive energy meters shall not be less than class 0.5. The main and check meters shall be supplied from separate current and voltage transformer cores. The current and voltage transformers shall not be less than class 0.2. Current and voltage transformer ratios shall be programmable.

Energy meters shall be installed in dedicated cubicles. More than one set of energy meters may be installed in one cubicle. Meter readings shall be visible from outside the cubicle. Individual meters and, if appropriate, their terminal block and front covers, shall be sealed to prevent tampering.

Energy meters shall include pulsed outputs, and shall include a communications module which allows remote interrogation and management of the meter. In addition, energy meter interrogation and management shall be possible through a local connection to a computer. Associated software shall be installed on the notebook computers provided for control or protection system maintenance. Cables to connect the energy meters to the notebook computers shall be provided.

The meters shall have a non-volatile memory so as to ensure no loss of data during power failures, and shall be capable of storing at least 12 months of metering data.

The energy meters shall support multi-tariff metering and have the capability to freeze billing readings on any selected date of the month.

All meters for commercial usage shall have programmable time of use bands (TOU).

The number of programmable pulsing relays for the energy meters should not be less than four (4).
13. COMMUNICATIONS SYSTEM

13.1. GENERAL

Communications facilities shall be provided for all data, voice and teleprotection communications between substations and other elements of the transmission network. Primary communications shall be optical, using the OPGW on transmission lines. Voice communications shall only be required for new substations.

There is an existing optical communications network based on the transmission grid and an associated SCADA system. It is generally configured as Open System with non-proprietary hardware and an open software structure complying with IEC 60850. Ultimately it will comprise physical loops with some radial links integrated into the loops. The optical communications equipment provided by the contractor shall satisfy immediate communication requirements at the substation and shall also be suitable, without adaptation or expansion, to operate as a node in an STM-1 loop which uses two circuits per link. In addition, it shall be expandable to STM-4 with minimal modification, i.e. by the addition of relevant cards.

Data requirements comprise:

- SCADA data to allow the central control centre to monitor and control substations and power stations;
- Engineering data over TCP/IP links which comply to IEC 60850 to allow central control centre to monitor and adjust software code, protection and instrumentation settings, review fault records, etc.

Voice communication shall include:

- Administrative voice communication to provide the equivalent to a telephone exchange covering all substation and power station sites and with connections to the public telephone network. In addition, the voice infrastructure shall be ready for VOIP;
- Operational communications for communications between control room staff at substation and power station sites.

Tele-protection communications will be that associated with current differential and distance protection for transmission lines.

The communications network will also include capability to provide a wide area general purpose computer network for the Employer.

The optical communications network will be required to have an availability not less than 99.99% for data and operational voice communications, and an availability not less than 99.95% for administrative voice communications. A channel will be deemed to be not available if the bit error rate (BER) exceeds $1 \times 10^{-8}$ for ten consecutive seconds. The Contractor shall provide equipment which is compatible with that requirement and shall submit availability calculations to confirm the suitability of his design.
13.2. OPTICAL COMMUNICATIONS

13.2.1. GENERAL

The optical communications equipment shall satisfy immediate communication requirements but shall allow the Employer to fully utilise STM-1 data transmission without adaptation or expansion.

The Employer has standardised the makes and models of equipment used in the optical communication system, and the Contractor shall comply with the Employers standard. In particular, for large multiplexers the Employer uses Keymile International Gmbh model UMUX equipment.

Optical communications equipment shall comply with relevant International codes and standards, in particular, it shall comply with the relevant recommendations of the International Telecommunication Union (ITU).

The network shall be based on the synchronous digital hierarchy (SDH) and shall have an STM-1 transmission rate (155 Mb/s). The optic fibre component of the OPGW should comply with ITU G.652D Standard, the detailed fibre-core specifications are indicated in the Table below.

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>REQUIREMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No of Fibres</td>
<td>$\geq 48$</td>
</tr>
<tr>
<td>2. Mode Field Diameter</td>
<td>$9 \mu m \pm 1 \mu m$</td>
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<tr>
<td>3. Mode Field Diameter Deviation</td>
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<tr>
<td>4. Cladding Diameter</td>
<td>$125 \mu m \pm 3 \mu m$</td>
</tr>
<tr>
<td>5. Coating Diameter</td>
<td>$250 \mu m \pm 15 \mu m$</td>
</tr>
<tr>
<td>6. Mode Field Concentricity Error</td>
<td>$\leq 1 \mu m$</td>
</tr>
<tr>
<td>7. Mode Field Non-circularity</td>
<td>$\leq 6%$</td>
</tr>
<tr>
<td>8. Cladding Non-circularity</td>
<td>$\leq 2%$</td>
</tr>
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<td>9. Cladding Configuration (depressed/matched/other)</td>
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<tr>
<td></td>
<td>b) $&lt;18$ ps/nm.km</td>
</tr>
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<td>11. Attenuation</td>
<td>a) $&lt;0.38$ dB/km</td>
</tr>
<tr>
<td></td>
<td>b) $&lt;0.25$ dB/km</td>
</tr>
<tr>
<td>12. Splice Loss</td>
<td>a) $&lt;0.15$dB</td>
</tr>
<tr>
<td></td>
<td>b) $&lt;0.1$dB</td>
</tr>
<tr>
<td>13. Cut off wavelength</td>
<td>$=1270$nm</td>
</tr>
<tr>
<td>14. Zero Dispersion wavelength</td>
<td>1310nm</td>
</tr>
<tr>
<td>15. Proof Strain (1 second)</td>
<td>$\geq 1%$</td>
</tr>
</tbody>
</table>
Optical links shall utilise normal output level optical transmitters (typically, -4 dBm or 0 dBm output level). If the optical path margin cannot be met using standard transmitters, the Contractor shall provide an alternative design. Designs that utilise higher power optical transmitters shall be preferred over designs utilising optical regenerator sites; where optical regenerator sites will not be avoidable, they shall be used with the written consent of the Engineer. The use of optical transmitters with laser power greater than +4 dBm shall be avoided if possible, and if unavoidable each instance shall be subject to the Project Manager’s approval. All transmitter equipment shall use the same laser type.

The optical communications equipment shall include all associated facilities including terminal equipment, multiplexers and cross-connect equipment as applicable.

Each SDH terminal equipment shall provide at least two analogue and four digital service channels for voice communications and testing purposes between any two terminal stations exclusively for the use of installation and servicing personnel.

13.2.2. MULTIPLEXERS

As far as possible, Tele-protection should use a direct optical connection between the relays at each end of a transmission line (Main protection may be connected directly through the fiber (probably SWT), while the backup may be through the UMUX (probably Tibet); otherwise tele-protection data may be multiplexed with other data. In this case, the main and backup line protection shall use separate multiplexers which are segregated to the extent that it is practical, including using separate source power supplies.

13.2.3. OPTICAL JOINTING

OPGW terminating at substations shall be jointed at the nearest substation structure to a standard optical cable which extends the OPGW to the substation communications room. The extension cable shall be an armoured optical cable with the same optical characteristics as the OPGW.

Joint enclosures shall be of the “hood” type with encapsulated cable entry, and shall have a minimum of three cable inlets in order that they can be used for interconnecting cables at a junction.

Joint enclosure materials and physical layouts shall ensure that fibres and joints are maintained without impinging on the system performance during the lifetime of the system and, in particular, without giving rise to micro-bending losses or increased dispersion at 1550 nm wavelengths.

Further requirements for the enclosures are as follows:

- It shall support, organise, and protect the optical fibres and the fibre splices whilst ensuring that the optical fibre minimum-bending radius is not exceeded.
- The splice tray shall not have any sharp edges or protrusions that may damage the optical fibre cable.
- It shall provide entry for a minimum of 3 cables which may be of different diameters i.e. one crush resistant and one armoured.
- The method of cable entry sealing shall be compatible with enclosure and optical fibre cable jacket material.
- Number tags for tube and fibre identification are to be included.
Optical cable connected to joint enclosures installed on substation gantries or other easily accessible points shall be protected against accidental or intentional damage between ground level and up to a height of 3 metres above ground level, or to such a level that damage cannot readily be inflicted from access via adjacent structures.

### 13.2.4. OPTICAL DISTRIBUTION FRAMES

Optical fibre distribution frames shall be provided as necessary by the Contractor to facilitate the termination of fibres, testing and isolation of both the optical fibre cable and fibre optic terminal equipment, and to provide interface and/or cross-connect facilities between the digital multiplex equipment. Sufficient space shall be available on the frame to allow ease of access and minimise the possibility of interference or damage to fibres carrying traffic during maintenance testing on the back-up or spare fibres.

Optical fibres shall be terminated by detachable connectors, complying with the requirements of IEC 60874, at the optical fibre distribution frame and shall be properly labelled with fibre identity, destination or source, go or return. It shall be possible to connect each optical fibre to the appropriate point on any terminating equipment. Fixed couplers shall be provided for each fibre comprising a link.

The following basic functions of the fibre distribution frame are required:

- Circuit re-routing/jumpering.
- Circuit disconnection.
- Patching and test connections.
- Bridging measurements.

Plug-in connection shall be used, and the transmit and received direction of the transmission shall be segregated. The optical fibre tail cables and connections shall be substantially protected from possibility of damage due to maintenance or installation activity.

The capacity of the fibre distribution frame shall be chosen to accommodate the maximum capacity of the fibre optic communication system plus 50% spare capacity to cater for any future expansions. All fibre distribution frames shall have an earth connection provided, and shall be protected from corrosion by painting or galvanising.

### 13.2.5. POWER SUPPLY

Nominal equipment voltage shall be -48 V dc positive grounded. Specified characteristics shall be maintained when power supply voltage is within -42 V to -56 V.

Equipment shall continue operating with power supply voltage variations of up to -15%/+25% of nominal value.

Equipment shall withstand the following ripple at power supply input terminals.

<table>
<thead>
<tr>
<th>Frequency Band (kHz)</th>
<th>Maximum DC Power Supply Voltage Distortion</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>2 mV</td>
<td>phosphometric value</td>
</tr>
<tr>
<td>0-50</td>
<td>48 mV RMS (-60 dB0)</td>
<td>dB over-rated power supply voltage</td>
</tr>
</tbody>
</table>
13.2.6. MECHANICAL

Extensions shall be furnished with the test equipment to permit access to module components. Incorrect insertion of modules in subracks shall not damage equipment. Subracks shall plug-in to racks, and be secured by adequate means.

The cabinet shall be provided with leveling screws for fixing to the floor. The rear of the subracks shall have access from front of cabinet (swing-rack cabinet).

The cabinet shall have a lockable front door. All components shall be easily removable.

Equipment shall withstand vibrations as specified in IEC standards.

The rack shall be provided with a 240 V ac outlet for connecting test instruments.

All power supply, coaxial and ground terminals shall be easily accessible, located in the lower or rear part of cabinets.

A screen shall be provided for ventilation and protection, located in the lower part of cabinets.

13.2.7. EQUIPMENT AND COMPONENT IDENTIFICATION

All modules, sub-racks, and racks shall be marked with type and schematic numbers. Modules shall also be provided with easily visible identification of function, measuring and adjustment points. All frequency-dependent modules and sub-modules shall present this data in an easily visible location.

13.3. LINE TUNING UNIT

13.3.1. GENERAL

The line tuning unit shall function normally when exposed to sun, rain, fog, hail, and industrial pollution.

The line tuner shall adhere to the requirements and specifications herein.

The line tuner shall be designed and built to ensure that a fault on the power line shall not cause a permanent interruption in the functioning of the line tuner. Line tuner design shall be such as to prevent the occurrence of a dangerous potential on the carrier-frequency connection due to service voltage or transient overvoltage which may occur on the power line.

The line tuner shall be designed such that voltage at rated frequency, between primary terminal(s) and ground, is as low as possible, and never exceeds 20 V. This low impedance shall be guaranteed by a drain coil or matching transformer winding.

The drain coil or matching transformer winding, when acting as drain, shall:
• Guarantee total ground terminal connection continuity.
• Withstand any transitory overvoltage which may occur on the power line, taking into account the effect of the main arrester.
• Have insertion loss not exceeding 0.5 dB over the carrier frequency range.

A grounding switch shall be provided for temporary direct connection between primary terminals and ground. This switch may be inside or outside the line tuner cabinet, provided that contacts are visible and easy access is possible. The grounding switch shall operate under the same conditions established for drain coils, with nominal voltage and amperage not lower than 3 kV and 20 A respectively.

If an air gap is used, it shall be robust and easily maintained. In addition, it is recommended that its rated frequency sparkover be of the order of 4.2 kV rms and that it be able to sustain a 8/20 microseconds wave shape impulse discharge current of at least 5 kA. It is desirable that the arrester withstand power frequency current of at least 5 kA rms during 0.2 seconds and assure adequate protection, even when damaged, of other line tuner parts.

If a nonlinear resistor type arrester is used, it is recommended that nominal voltage be of the order of 1 kV (corresponding to an impulse sparkover of approximately 4 kV) and that it be capable of withstanding an 8/20 microseconds wave shape impulse discharge current of a least 5 kA.

For additional terminal equipment protection, the line tuner may be provided with an arrester for limiting -line tuner secondary terminal voltage to a level compatible with that of the terminal equipment protection device(s) if present.

13.3.2. TECHNICAL CHARACTERISTICS
Rated Average Continuous Power shall be 400 W P.E.P. at 50 kHz.
Rated Frequency Insulation Level shall be 1000 W P.E.P at 1000 kHz.
Line tuner insulation level shall be 10 kV/50 Hz/min.

13.3.3. IMPULSE LEVEL
The line tuner shall be designed in such a manner as to withstand a 1.2/50 microseconds impulse voltage of 10 kV peak.

13.3.4. INSERTION LOSS
The compound insertion loss which limits bandwidth shall not exceed 2 dB frequencies up to 100 kHz, and 1.5 dB for frequencies over 100 kHz.

13.3.5. RETURN LOSS
The line side and equipment side return loss shall be greater than 12 dB over the bandwidth.

13.3.6. NOMINAL PRIMARY IMPEDANCE
Nominal primary impedance for phase/ground coupling shall be adjustable for 240/320 ohms.

13.3.7. NOMINAL SECONDARY IMPEDANCE
Nominal line tuner secondary impedance shall be 75 or 125 ohms unbalanced.
13.3.8. TUNING

The high pass line tuner shall be capable of tuning the entire service band specified for the link in which it will operate. For frequencies above 40 kHz, tuning shall be possible to any frequency band without requiring component or unit substitution, fulfilling the requirements for the various coupling capacitor and nominal primary impedance values.

Band-pass type line tuners shall be designed to meet these particular requirements.

13.3.9. DISTORTION AND INTERMODULATION

The produced levels of distortion and intermodulation shall be at least 80 dB below the level corresponding to peak envelope power.

13.3.10. OPERATION WITH ASSOCIATED COUPLING CAPACITOR

The line tuner shall attend above specifications for coupling capacitor values between 3000 and 10000 pF.

13.3.11. NAMEPLATE MARKINGS

The line tuner shall be provided with a weatherproof nameplate in an easily visible location. Inscriptions shall be indelible.

The nameplate shall contain the following data:

- Manufacturer name
- Type
- Manufacturer's serial number
- Rated power
- Coupling capacitor range
- Nominal primary and secondary impedances
- Year of manufacture

13.4. TELEPROTECTION

The following transmission times and failure probabilities shall apply to teleprotection for distance protection and inter-tripping:

<table>
<thead>
<tr>
<th>Type of Signalling</th>
<th>T (ms)</th>
<th>Pm</th>
<th>Pu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocking command</td>
<td>3 - 25</td>
<td>10^{-3} to 10^{-1}</td>
<td>1 in 10 years</td>
</tr>
<tr>
<td>Permissive trip</td>
<td>8 - 10</td>
<td>10^{-2} to 10^{-1}</td>
<td>1 in 100 years</td>
</tr>
<tr>
<td>Direct tripping</td>
<td>30 - 60</td>
<td>10^{-3} to 10^{-1}</td>
<td>1 in 500 years</td>
</tr>
</tbody>
</table>

Where:

- T = the actual transmission time of the teleprotection channel including transmission delay plus teleprotection transmitter and receiver functions
Primary communication shall be provided through the OPGW and backup tele-protection through the PLC. The Contractor shall submit for approval details of how this functionality is achieved.

On the OPGW, teleprotection equipment may be dedicated equipment or may be integrated into other SDH equipment provided measures are taken to ensure the specified reliability and security.

Typically each end of a transmission line will be protected by current differential protection with an integrated selectable permissive scheme (underreach + overreach) as main protection, a permissive scheme as backup protection and a direct inter-trip scheme.

### 13.5. VOICE COMMUNICATION

#### 13.5.1. GENERAL

Voice communications equipment shall comprise an operational telephone system and an administrative telephone system.

The operational telephone system is a standalone telephone exchange located in the Lugogo system control centre. Operational telephones in substation control rooms are extensions from this telephone exchange.

The administrative telephone system is a network of telephone exchanges with exchanges at all substations and power stations.

The telephone systems shall comply with relevant international standards and shall be approved by the appropriate regulatory authority.

#### 13.5.2. OPERATIONAL TELEPHONE HANDSETS

Operational telephone handsets shall have a built-in microphone and speaker for hands-free operation.

Operational telephone handsets shall have intercom facility to strategic locations in the switchyard. The associated handsets in the switchyard shall be weather-proof, incorporate a simple call button and have an external bell.

#### 13.5.3. ADMINISTRATIVE TELEPHONE SYSTEM

An administrative telephone system with one operator console shall be provided in each substation.

The telephone system shall be integrated with other existing administrative telephone systems at the system control centre and other substations to form an integrated administrative telephone system for the complete electricity network.

The operator console shall have access to all of the facilities available to any extension in the system which it controls and shall have the ability to override any settings selected by that extension.

The following minimum facilities should be available to the operator:

- Operator controlled connections
• Serial calls
• Exchange line and tie line assignment
• Intrusion, priority break in
• Camp on
• Call intrusion and splitting
• Night switching
• Call forwarding monitoring and override for extensions in either segment
• Exclusive operator lines
• Operator defined route priorities
• Reversion of calls to the operator that originally extended them, with extension called information
• Headset or handset operation, cordless headset option if available
• Programmable function keys, and auto dial keys
• Visual display of:
  
  o call status
  o calls waiting
  o extension number and category
  o trunk / extension status

The console shall be expandable by at least 25%.

The system shall be capable of using in built digital recorded announcements to automatically process calls without operator assistance. The announcements, recorded by the Employer, may advise callers to key in numbers to connect with specific staff or groups within the organisation.

Incoming calls not answered by the operator within a programmable time period shall be directed to a recorded voice announcement, recorded by the Employer. After receipt of the recorded message callers shall be returned to the operator. If, after a further programmable time period, the call still remains unanswered by the operator, the caller shall receive a second message and shall have the choice of being returned to the queue or leaving a voice message.

When the operator switches the console to night services, console calls shall be capable of being directed to:

• An operator console at another location. Any of the three operators in the network may receive and handle all network calls if required.
• An automated attendant.
• An alternative programmable answering position or queue.
• Selected centralised bells, at each location so that any extension within audible range may dial a code to answer the call.
All of the above options shall be programmable.

Programming options shall ensure that calls to unallocated numbers are redirected to the operator or a recorded announcement system.

The Contractor shall coordinate with the Project Manager to determine the telephone numbering system to be used.

The capacity of the administrative telephone system shall not be less than 50 extensions at each substation.

13.5.4. PUBLIC TELEPHONE NETWORK

The administrative telephone system shall include two connections to the public telephone network.

These connections shall include a queuing facility for incoming calls.

The administrative telephone system shall include a barring mechanism which may be used to limit access to the public telephone network.

13.5.5. SUBSTATION TELEPHONE HANDSETS

Administrative telephone system handsets in substations shall be provided in all rooms and at selected locations in switchyards. Outdoor handsets shall be weather-proof and have an external bell with a distinct tone from that used for the operational telephone. A facsimile machine shall be provided in the central control building and in the control room of every substation which is not associated with a power station.

13.5.6. POWER SUPPLY

Power supply for communications equipment shall preferably be from the substation 110 V DC system. If this is not practical, the Contractor shall provide communications power supply equipment with performance at least equal to that of the 110 V DC system.

If the Contractor chooses to provide a 48 V DC supply for the communications system, that equipment shall have the same specification and shall be duplicated as for the 110 V DC equipment except that the 48 V positive shall be connected to earth. A 48 V DC system may comprise a free-standing cubicle containing batteries, charger and distribution facilities.
14. STANDARD TECHNICAL REQUIREMENTS

14.1. GENERAL
These Standard Technical Requirements define minimum requirements acceptable to the Employer. It is recognised that the Contractor may have standard materials or designs which may also be acceptable. The Contractor may propose for approval, alternatives which meet or exceed these minimum requirements. Where these Standard Technical Requirements conflict with the Part B Substation Technical Requirements, the Part B Substation Technical Requirements shall prevail.

14.2. DEFINITIONS OF TERMS
Whenever used in connection with the Contract, the under mentioned terms shall have the following meanings assigned to them:

i. Abbreviations referred to the Employer’s Requirements are listed below:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISC</td>
<td>American Institute of Steel Construction</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute, Inc</td>
</tr>
<tr>
<td>ASME</td>
<td>American Society of Mechanical Engineers</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for testing and Materials Standards</td>
</tr>
<tr>
<td>BS</td>
<td>British Standard</td>
</tr>
<tr>
<td>FLC</td>
<td>Full-load current</td>
</tr>
<tr>
<td>FSD</td>
<td>Full-scale deflection</td>
</tr>
<tr>
<td>FSL</td>
<td>Full supply level</td>
</tr>
<tr>
<td>HRC</td>
<td>High rupture capacity</td>
</tr>
<tr>
<td>IEC</td>
<td>International Electrotechnical Commission</td>
</tr>
<tr>
<td>IEE</td>
<td>Institute of Electrical Engineers</td>
</tr>
<tr>
<td>IPB</td>
<td>Illuminated pushbutton</td>
</tr>
<tr>
<td>ISA</td>
<td>Instrument Society of America</td>
</tr>
<tr>
<td>ISO</td>
<td>International organisation for Standardisation</td>
</tr>
<tr>
<td>LED</td>
<td>Light emitting diodes</td>
</tr>
<tr>
<td>MCB</td>
<td>Moulded circuit breakers</td>
</tr>
<tr>
<td>MIMS</td>
<td>Mineral-insulated metal-sheathed</td>
</tr>
<tr>
<td>MOL</td>
<td>Minimum Operating Level</td>
</tr>
<tr>
<td>NDT</td>
<td>Non Destructive Testing</td>
</tr>
<tr>
<td>NEMA</td>
<td>National Electric Manufacturers Association</td>
</tr>
<tr>
<td>OPGW</td>
<td>Optical ground wire</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible power supply</td>
</tr>
</tbody>
</table>
14.3. COMPLIANCE WITH STANDARDS

The design, materials, manufacture, testing, inspection and performance shall conform to the current ISO, IEC, IEEE or British Standards, where applicable, and/or recognised national standards approved by the Project Manager. Where particular standards have been specified, other standards will be approved only where they are equivalent to the specified standard and provided these standards are written or translated into English and the equivalent standards are indicated. The standards applied shall be the standards in force at the date of issue of the Employer’s Requirements unless otherwise approved by the Project Manager.

Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical of Great Britain shall apply to the Plant & Equipment. This requirement is mandatory.

The Plant & Equipment shall also comply with all the relevant Laws of the country in which the equipment is to be installed.

These Standard Technical Requirements shall prevail where its requirements conflict with or exceed those of any standard. For applications where no relevant standard exists, up-to-date recognised good practice shall apply, to the approval of the Project Manager.

14.4. QUALITY OF DESIGN, MATERIALS AND MANUFACTURE

All Plant shall be new and shall be designed and manufactured in accordance with the Employer’s Requirements, using materials most suited to the particular service. The design and materials shall be such as to achieve service life, operational reliability and ease of maintenance, inspection and adjustment.

Items of proprietary equipment to be incorporated into the plant shall be of high quality produced by reputable manufacturers and of adequate capacity to perform the required service under all operating conditions.

Operational reliability of the Plant is of the first importance and the Contractor shall take account of this requirement at all stages of design, manufacture and erection.

All wearing parts and all joints, rings, seals and gaskets shall be replaceable.

The method of rectification of manufacturing errors, material defects and performance shortcomings shall be to the approval of the Project Manager.

Corresponding parts shall be designed to be interchangeable wherever possible. All drawings for both manufacture and installation shall be defined on the Contractor’s drawings.

14.5. MAINTENANCE EQUIPMENT

The Contractor shall provide maintenance equipment required or likely to be required for the proper maintenance of the Plant during its service life. The maintenance equipment shall be sufficient to enable full dismantling and reassembly of the Plant, testing for wear or distortion of all wearing parts and to enable the replacement of any item with the associated spare parts provided under the Contract. The Contractor shall provide a list of equipment to be provided under the Contract for diagnosing and locating faults in the installed equipment for review by the Project Manager.

The maintenance equipment shall include but shall not be limited to:
• handling and lifting devices including slings, lifting beams, skates, trolleys and jacks;
• portable ladders, scaffolding and platforms to permit maintenance service;
• one set of special tools and appliances to enable all maintenance tasks to be performed;
• hydraulic tensioning equipment for all bolts and studs of 50 mm diameter and greater, suitable for simultaneously tensioning two bolts or studs of any one size;
• one complete set of hand tools and appliances sufficient for all maintenance tasks associated with the Plant in this contract. The set shall include, but not be limited to:
  - two sets of spanners to fit each and every size of nut and bolt used in the plant, screwdrivers, scrapers, files, hammers, pliers, wrenches, wiring tools, etc., as appropriate;
  - suitable insulation tester, multimeter and other specialised electrical testing instruments; and
  - any other portable or hand operated equipment required for the complete maintenance of the Plant.
• Hydraulic tensioning equipment for all bolts and studs of 50 mm diameter and greater, suitable for simultaneously tensioning two bolts or studs of any one size.

The individual tools and appliances shall be listed in the Technical Schedules. The prices of the tools and appliances shall be included in the Contract Price.

Any additional maintenance tools and appliances which are required for the normal maintenance of the Plant as defined in this Clause and which are not listed in the Price Schedules shall be deemed to be included in the Contract Price.

The Contractor may use the mechanical handling equipment for initial erection of the Plant but shall make good any wear and tear or damage before handing over. The mechanical handling equipment shall be supplied in lockable cabinets fitted internally so that the parts may be safely stored in an orderly manner and delivered to the workshops or store rooms as directed by the Project Manager.

Maintenance equipment shall be suitably arranged in metal tool boxes or cabinets, each fitted with a padlock with two keys. Each tool box or cabinet shall be clearly and permanently marked with the name of the plant to which the maintenance equipment applies and with a list of the equipment it contains.

Special lifting and handling equipment, to be supplied by the Contractor in accordance with the Employer’s Requirements, shall be shipped together with the component for which they are provided.

A final list of special lifting devices shall be submitted to the Project Manager at least 90 days before commencement of erection.

Sling racks shall be supplied together with the slings.

14.6. SPARE PARTS

The Tenderer shall complete the Price Schedules for Spare Parts. The Price Schedules shall include the description and quantity of all spare parts which the Tenderer considers the Employer should hold in stock for a five year operating period, bearing in mind the remoteness of the Site.
The Employer may order all or any of the spare parts at his discretion. The Contractor shall supply the spare parts selected at the individual prices stated in the Price Schedules, subject to the qualification that, if any spares are ordered after the date of the Taking-Over Certificate for the last Section of the Plant & Equipment, the prices will be subject to adjustment.

The prices of specified spare parts listed in the Price Schedules shall be included as part of the Tender Price and the prices of recommended spare parts listed in the Price Schedules shall not be included in the Tender Price.

The Tenderer shall list the individual prices of each and every specified spare part listed in the Price Schedules whether or not he considers it necessary for the Employer to carry such spares. In the event that the Tenderer fails to quote the price of a specified spare part the cost of such spares shall be deemed to be included in the Contract Price.

Under recommended spare parts Tenderers shall list the description and quantity of additional spare parts not included under specified spare parts which the Tenderer considers should be supplied.

Where the Tenderer considers that the number of specified spares listed is either insufficient or excessive, he shall state in the Price Schedules against each such item the number he recommends should be ordered by the Employer. All spares in the Price Schedules shall be identified as either expendable or non-expendable items. The Tenderer shall also state the delivery time from the date of the Employer’s order of any item, if such delivery time is longer than twelve months.

All spares supplied are to be strictly interchangeable with the parts for which they are intended to be replacements and are to be treated and packed for long storage under the climate conditions prevailing at the Site. Small items are to be packed in sealed transparent plastic bags with desiccator packs as necessary. Each spare is to be clearly marked or labelled on the outside of its packing with its description and purpose and, when more than one spare is packed in a single case or other container, a general description of the contents is to be shown on the outside of such case or container and a detailed list enclosed. All cases, containers and other packages must be suitably marked and numbered for purpose of identification.

All electronic card spare parts shall be factory tested for quality assurance and performance before shipment.

The Contractor shall not depend on the use of the spare parts to be provided to the Employer under the Contract for carrying out the Contractor’s obligations.

The Contractor shall open the shipping crates containing the spare parts, on arrival at site and identify the parts to the Employer and show that the quantities are in accordance with the Contract. The Contractor shall then re-pack the parts for permanent storage and place them in the store as directed by the Employer on shelving or in cabinets provided by the Contractor. The packing shall be labelled to identify the contents by Contract number and scheduled part number.

Detailed spare parts lists shall be submitted, and shall include:

- The Contractor’s reference number as used on packing lists and invoices;
- A column for the Employer’s part number;
- Complete part description, including part name, manufacturer’s name, model numbers and size;
- Drawing number and item number;
• Number of parts in original equipment; and
• Number of parts supplied as spares.

14.7. OPERATION AND MAINTENANCE INSTRUCTIONS

The Contractor shall provide operation and maintenance instructions, the scope of which shall be suitable for fully informing the Employer’s staff on all aspects of the erection, operation and maintenance of the Plant and Equipment, as further defined in this Clause.

The content of the instructions shall be directly applicable to the Plant. Typical instructions will not be accepted. Standard instructions and brochures covering a number of sizes and/or models of proprietary equipment will be accepted provided they cover the items supplied and these items are clearly identified throughout the instructions and brochures. Clear and concise cross-references to these brochures and standard instructions shall be made in each appropriate section of the operation and maintenance instructions.

The Contractor shall, in preparing the instructions, assume the lack of experience and lack of familiarity of the operating and maintenance staff with the type of equipment supplied. The information shall be presented as simply, clearly and precisely as possible.

The Contractor shall keep one copy of the instructions in his site office. This copy shall be available at all reasonable times for inspection by the Project Manager. The Contractor shall require his site supervisor to comment from time to time on the instructions.

In order that the instructions are complete and clearly understandable they shall be produced by some combination of the following:

• Specialist technical authors;
• The designers; and
• The site erection and testing personnel.

The instructions shall be subdivided on a plant feature by plant feature basis, with the content for any one feature in a self-contained volume, complete and separate in all respects from the content for other features. The list of features for the purpose of these instructions shall be prepared by the Contractor and submitted to the Project Manager for approval.

The instruction content for each feature of the instructions shall comprise the following separate sections:

• Section 1 - Contents
• Section 2 - Description
• Section 3 – Operation
• Section 4 – Maintenance (Preventative Maintenance and “Trouble Shooting Guide”)
• Section 5 – Testing and Adjustment
• Section 6 - Work as Executed Drawings (As-Built Drawings)
• Section 7 - Brochures for Proprietary Equipment
The subdivisions and the section reference numbers shall be adhered to, except that brochures covering more than one section will be accepted for minor components of proprietary equipment. The detailed content for each section shall be as defined in Subclause 14.7.2 below.

14.7.1. FORMAT AND COMPILATION OF THE INSTRUCTIONS

The text, diagrams, drawings, brochures and all other instructions content shall be reproduced in ink by letterpress or offset printing or in carbon by electrostatic printing. Reproductions obtained by using dyes, chemicals or photo-sensitive or heat-sensitive materials are not acceptable. (Note: The purpose of requirements for printing and paper quality is to ensure that the instruction manuals will remain readable and in good condition for at least the useful lifetime of the plant to which they refer - assumed 50 years).

All text shall be on size A4 paper except that brochures of smaller sizes will be accepted for minor components of proprietary equipment, provided they have adequate binding margins.

Diagrams and drawings provided as part of the instructions shall be size A3 wherever the original is size A3 or larger and size A4 for all others. Drawings bound into the text shall have a size A4 margin on the left-hand side so that they may be unfolded and viewed in full while reading the associated text. Insertion of loose drawings into cover pockets is not acceptable.

Text, drawings, diagrams and illustrations included in the instructions shall be easily readable by a person having normal eyesight. Coloured interleaves with text on white paper may be substituted for coloured sheets where required under this Clause.

The main text shall be on white paper. The tabulated design and other data shall be on yellow paper. The instructions shall be clearly and sequentially numbered, and each page shall also show the following information at the top of the sheet :

- Project feature number and title; and
- Plant feature number and title.

The paper used in the instructions shall be of the following archival quality material:

- White sheets - offset or bond of 70 g/m2 to 106 g/m2; and
- Coloured sheets - bond of not less than 70 g/m2.

The Contractor shall arrange for the compilation of the instruction material into volumes, including the provision of strong, durable and washable binders and punching, trimming and collating the material.

The Contractor shall deliver his material in 12 copies and on CD – ROMs (5 copies).

14.7.2. CONTENT OF THE DETAILED INSTRUCTIONS

14.7.2.1. GENERAL

The requirements for instruction content set out in this Subclause apply to the draft and final content unless specifically stated otherwise.

The instructions for each plant feature shall include, but not necessarily be limited to, all the requirements of this Subclause.

**Section 1 – Contents**
This section shall show the project feature number and title, plant feature number and title and list of sections and subsections as appropriate.

Section 2 – Description

Subsection 2.1 – History

This subsection shall include a brief statement of the organizations involved in the design, manufacture and erection of the Plant, including main subcontractors and the date when the Plant entered commercial service.

Subsection 2.2 – Performance Data Settings

This subsection shall be printed on yellow paper and shall include the following:

- All performance data and charts over the full range of operating conditions, both normal and abnormal. Tables shall list all design clearances, settings, adjustments, voltages, currents, pressures, levels and flows, together with the actual values measured or observed during manufacture, delivery, erection or testing, as appropriate; and
- Setting data for all adjustable quantities.

Subsection 2.3 - Description

This subsection shall include, for each of the major items of plant, comprehensive descriptions of the plant, including the following information:

- Basic type of plant and equipment;
- Purpose and function of the plant as provided for;
- Erection procedures (if appropriate);
- Method of construction (if appropriate);
- Materials of main components (if appropriate);
- Design features;
- Control and protection functions;
- Relationship with other plant;
- Auxiliary equipment specific to the plant;
- Any associated drawings or diagrams that will assist in providing a clear understanding of the purpose and function of the plant; and
- Concise cross-references to any associated brochures and pamphlets included in Section 7.

Section 3 - Operation

Subsection 3.1 - Operating Sequences

The operation instructions shall include a brief description of the normal and emergency operating procedures for the equipment. These descriptions shall be in the form of sequence diagrams where appropriate.
Subsection 3.2 - Pre-start Check List

Comprehensive tabulated list or sequence diagram of all conditions which must be checked before the Plant may be started after being out of service.

Subsection 3.3 - In-service Check List

Comprehensive tabulated list of all observations to be made during periodic inspections and tests, defining the location, range of acceptable values and action to be taken if incorrect values are found.

Subsection 3.4 - Abnormal Conditions

This subsection shall be printed on pink paper and shall contain a table of all abnormal conditions which can arise due to malfunctions of the Plant. The table of abnormal conditions shall include the following:

- Nature of the abnormal condition;
- Details of how the malfunction becomes apparent;
- Alarm annunciation descriptions (local and remote) where applicable;
- Immediate action to be taken following the abnormal condition to ensure safety of personnel and equipment; and
- Diagnosis, including flow charts where applicable, to establish details of the nature and cause of the abnormal condition.

Section 4 - Maintenance

Routine maintenance instructions are required for all equipment supplied under the Contract.

Subsection 4.1 - Maintenance Schedules

This subsection shall include the following:

- Component and condition to be checked;
- Required frequency of checking;
- Maintenance equipment and spares required;
- Required plant condition for service or maintenance, including required isolation; and
- Service limits on replaceable parts.

Subsection 4.2 - Isolation and Restoration

This subsection shall include the following:

- Instructions for isolating the whole of any section of the plant so that maintenance or repair operation can be carried out in complete safety;
- Instructions for the restoration of the plant to service after maintenance or repair. List of checks required after maintenance or repair, additional to the checks required before routine starting;
- All of the above shall include easily readable diagrams, flow charts or drawings whenever this will assist in understanding the descriptions.

Subsection 4.3 - Inspection and Diagnosis

This subsection shall describe and illustrate the procedure for dismantling, adjusting and reassembling of each component, system and machine. This description shall include, but not be limited to, the following:

- Dismantling sequence and methods based on drawings and photographs;
- Inspection of components, including detailed checks for condition, and criteria for acceptance, rejection or reconditioning;
- Reconditioning, replacement and adjustment procedures;
- Fault diagnosis based on symptoms of malfunction and wear;
- Reassembly sequence and methods;
- A comprehensive lubrication chart to illustrate all points at which lubricants are required, the types of lubricants and the intervals between replacing lubricant and/or cleaning and with instructions on filter maintenance. Instructions shall be provided on testing and maintenance of lubricating oil, hydraulic oil and transformer/switchgear oil, where applicable; and
- Concise cross-references to any associated brochures and pamphlets included in Section 7.

Subsection 4.4 - Maintenance Equipment and Spare Parts

- Sufficient data to allow any part or sub-assembly to be re-ordered and/or a satisfactory substitute to be manufactured on site. Nameplate information including model and serial number is required for each item of equipment supplied;
- Separate lists of the spare parts and the maintenance equipment supplied under the Contract; and
- Recommendations for storage and handling of spare parts and maintenance equipment.

Subsection 4.5 – Re-commissioning

This subsection shall include details of re-commissioning procedures after major overhaul.

Section 5 – Testing and Adjustment

The complete procedure of testing and adjusting the system or any parts during operation, after overhaul, or during recommended periodic checks must be covered. For all important items of equipment, test schedules in tabular form shall be included.

Section 6 – Work as Executed Drawings

This section shall contain one copy of each drawing referred to in the text or necessary for clear understanding and use of the text, including all assembly, layout and arrangement drawings, and circuit and sequence diagrams, drawn as Work as Executed drawings. The drawings shall be preceded by a list with titles and numbers, in numerical order. As these drawings will be submitted after the final instructions are submitted, they shall be submitted...
separately in a form suitable to be bound into the final instructions by the Employer. The final instructions as submitted shall include “Final” drawings in lieu of Work as Executed Drawings.

Section 7 – Brochures for Proprietary Equipment

This section shall contain manufacturers’ brochures, instruction pamphlets and the like, containing the operation and maintenance information as specified in sub-clauses c., d. and e. above, in respect of proprietary equipment.

14.8. DRAWINGS

14.8.1. GENERAL

All drawings produced for this Contract shall be drawn on the International Standards Organisation (ISO) ‘A’ series of drawing sheets, standardising where possible on the A1 size. Drawings shall comply with IEC 60617. Information and details shall be written in the English language and the SI system of units shall be used for all dimensions and data.

14.8.2. TITLE BLOCKS

The Contractor’s or his subcontractor’s title block shall show his name, the date, the title and number of the drawing and each new issue of the drawing shall be identified by a revision letter as part of the drawing number. In addition, each drawing shall show Project specific details in the lower right hand corner as agreed to by the Project Manager.

14.8.3. NUMBERING SYSTEM

The primary reference to drawing numbers on all drawings, correspondence, operation and maintenance instructions and elsewhere shall be the number from the Project Manager’s numbering system, which system shall be notified within one month of the date of Letter of Acceptance.

14.8.4. QUALITY

Preliminary (initial), final (approved) and Work as Executed (as built) drawings shall be submitted in the form of reproducible drawings from which legible dyeline prints may be produced. In addition to the above, the Work as Executed drawings shall also be submitted as CAD files readable by the latest version of Autodesk’s AutoCAD. All drawings shall be clear and legible.

Work as Executed drawings presented by the Contractor in accordance with the Employer’s Requirements shall be the Contractor’s original drawings or transparencies made by an electrostatic process in non-fading ink on a durable plastic base film without any folds. Transparencies reproduced chemically from the original will not be accepted as Work as Executed drawings.

The Work as Executed CAD files shall be delivered to the Employer in the form of CD-ROMs. Five copies of the CD-ROMs shall be provided.

14.8.5. DRAWING INDEXES

The Contractor shall compile a complete drawing index of all drawings produced by himself and his subcontractors giving Contractor’s manufacturer’s and Project Manager’s drawing number, title, revision, approval status, together with reference number and date of all relevant correspondence.
The Contractor shall send three up-to-date copies of the index to the Project Manager at three-monthly intervals or on request by the Project Manager.

14.9.  COPIES OF ORDERS AND NOTICES

Three copies of the Contractor’s orders to his subcontractors shall be supplied to the Project Manager. This requirement shall apply also to those cases where a subcontractor further subcontracts his work except for items of a minor nature and which are not specifically manufactured for the Contract.

The copies of Contractor’s and his subcontractor’s orders shall not indicate prices. The orders shall be marked “Subject to Inspection” by the Project Manager on behalf the Employer and shall include those requirements of the Contract with which the items concerned must comply.

The Contractor shall provide the Project Manager with three copies of all correspondence and notices served in complying with any law, or of any order, regulation, or by-law having the force of law in the Employer’s Country.

14.10.  PACKING, STORAGE AND IDENTIFICATION

All Plant shall be effectively protected against damage (including all deterioration) during transport from the place of manufacture to the Site and during storage en-route to and at the Site. Large parts shall be supported to distribute their mass uniformly and thus avoid any permanent deformation.

All parts exceeding 90 kg gross weight shall be prepared for shipment so that they can be readily handled by crane and/or forklift.

Immediately upon arrival at Site, the Contractor shall arrange for all packages to be checked against the shipping list for loss and inspected for damage during transit.

The Employer will not provide covered storage at the Site. The Contractor shall ensure that all packages are suitable for the storage conditions provided. The Contractor shall provide covered storage, temporary heating, weatherproof shelters, loading and unloading facilities as required for the Plant.

Machined surfaces shall be protected against corrosion. Parts on which final alignment and running clearances depend shall have adequate blocking to prevent distortion of their machined surfaces, and shall be positively prevented from coming into contact with timber packing or supports, paying due regard to movements which may occur during transport. If machined surfaces show signs of damage on delivery, the corrosion protection shall be removed, the rust and moisture eliminated, the defects repaired by approved means and the protection re-applied.

Electrical insulation shall be protected against sweating and entry of dust during transport and storage.

Flange faces and openings shall be covered by metal blanks and gaskets. Rubber parts shall be protected against light and air. Moisture absorbent crystals shall be included with all items enclosed in plastic or other impervious material.
Plant likely to be damaged by shock or vibration, shall be packed in protective containers in accordance with the recommendations of the original supplier and suitable for the method of transport used.

All packing material, except that required for storage of spare parts shall remain the property of the Contractor and shall be removed from the Site. Only parts for immediate use shall be delivered from the central storage area and their packing material shall be removed quickly from the installation site and disposed of to the satisfaction of the Employer.

All Plant parts shall be marked to facilitate erection. All packing crates shall be clearly and indelibly marked before shipping to indicate the Contract number and shipping address, volume, weight, name, number and unit number of the contents, slinging and weight bearing points.

Each packing crate shall contain a packing list in a waterproof envelope. Three copies of the packing list shall be forwarded to the Project Manager prior to despatch. Parts shall be described and also identified by their numbered markings in the packing lists.

Each package shall be marked with the Employer’s identification mark, details of which will be provided by the Employer.

14.11. **UNITS OF MEASUREMENT**

The units of measurement of the Contract shall be System Internationale (SI) units unless otherwise approved by the Employer.

14.12. **PHOTOGRAPHS**

The Contractor shall submit, to the Project Manager, photographic records of the work during manufacture, factory assembly, delivery, erection, commissioning and rectification of major assemblies or components and as required by the Project Manager.

The Contractor shall supply photographs which will:

- Provide a progress record;
- Assist in training people who may have little or no experience in the operation, routine maintenance, major maintenance and testing of the plant;
- Record information which may not be possible to obtain at a later date; and
- Record details of how work, which is not frequently required, is done.

A volume of photographs shall be included with the operation and maintenance instructions. They shall be adequately edited and provided with captions and descriptions to the satisfaction of the Project Manager.

The Contractor shall provide the Project Manager with the CD-ROMs of all photographs included in the operation, maintenance and erection instructions.

All costs in this connection with the provision of photographs shall be deemed to be included in the Contract Price.
14.13. PROGRAMME AND PROGRESS REPORTS

The Contractor shall submit to the Project Manager, for comment and approval, a detailed programme of plant manufacture, testing at works, delivery, erection, testing and commissioning for the whole Plant & Equipment, indicating how it meets the programmed dates set out in the Contract.

This program shall indicate, for each major item of Plant, as defined by the Employer’s Requirements main section headings, the various phases of work from the commencement of the Contract to its final completion, that is, design, preparation of drawings, submission to the Employer of information and drawings, placing of orders for materials, manufacture, testing at works, delivery to Site, erection, testing and commissioning of each major item and section of the Plant & Equipment.

The Contractor shall modify the programme to comply with all reasonable requirements of the Project Manager under the Contract and shall carry out the work in accordance with the programme approved by the Project Manager.

The Contractor shall be responsible for planning and coordinating the work carried out by his subcontractors to ensure the satisfactory completion of the Plant & Equipment in accordance with the approved programme.

Immediately a departure from the approved programme appears imminent the Contractor shall submit to the Project Manager a detailed short time programme indicating the steps it is proposed to take in order to regain the lost time and return to the approved programme.

The submission of a modified programme shall not constitute a claim by the Contractor for an extension of the time fixed by the Contract for completion of any portion of the Plant & Equipment nor shall the approval of such modified program be regarded as the granting of an extension of the time fixed by the Contract for completion of any portion of the Plant & Equipment.

The Contractor shall submit to the Project Manager, within 7 days after the end of each calendar month, detailed progress reports. These reports shall indicate for each item included in the programme the actual position at the end of the month concerned, showing, as appropriate, the percentage of design, manufacture, delivery or erection. Where progress departs from the programme the report shall include a statement setting out reasons for the departure and steps which are proposed to prevent such departure affecting the contract completion date. The items in the programme may be required to be further subdivided for the purpose of clarity and accuracy in recording progress. The details of and the form in which the progress reports are supplied shall be to the approval of the Project Manager.

The expatriate manpower of the contractor employed at the site shall be listed for the reporting period of each individual category, such as:-

- Manager;
- Supervisor;
- Erectors; and
- etc.

The progress reports shall be supplied to the Project Manager in triplicate.
15. **EQUIPMENT REQUIREMENTS – GENERAL**

15.1. **LABELS FOR EQUIPMENT**

15.1.1. **WARNING NOTICES**

The Contractor shall provide movable warning notices and signs for the Plant & Equipment of a form and wording to be determined by the Project Manager to suit the Employer’s high-voltage safety regulations. The Project Manager will provide the Contractor with copies of the relevant regulations.

15.1.2. **LABELS**

The Contractor shall provide labels in sufficient size and detail to permit rapid and positive identification to be made for operational and maintenance purposes of all pieces of equipment including enclosures, power outlets, switches, luminaries and devices whether enclosed in cubicles or separately mounted.

Labels not in direct sunlight shall be engraved on a plastic laminate composed of white and black layers. When engraved they shall have black letters not less than 3.0 mm high on a white background. Alternatively, labels may be machine engraved aluminium with lettering filled with black paint of not less than 0.5 mm line thickness. Letters shall be neat in appearance not less than 3 mm high and engraved not less than 0.2 mm deep.

Labels exposed to sunlight shall be of matt stainless steel with engraved letters filled with black paint.

Pipe labels shall be of the adhesive type approved by the Project Manager.

All steel and plastic labels more than 100 mm long and used indoors shall be fastened by nickel-plated brass screws. Fixings for long labels shall cater for expansion. Indoor labels of length less than 100 mm shall be fastened by epoxy adhesive.

Labels for cubicles and equipment mounted within 2.0 m above floor level shall be positioned so that they can be read by a person of average height standing in front of the cubicles.

Labels for devices mounted on or in enclosures shall be provided on the inside of the enclosure adjacent to the device as well as on the device. Device labels shall not be located on removable covers.

Warning labels shall be provided on or in all electrical equipment where terminals at dangerous voltages (including 415/240 V) may be exposed during maintenance. Warning labels shall be of plastic laminate with white lettering on a red background.

The text of each label shall include the device number in accordance with Clause R3.2 and a clear and complete description of the function. Valve labels shall include a valve number of the form XXXX-bbb where XXXX is the schematic drawing number showing the valve and bbb is the valve number appearing on that drawing. Where relevant, valve labels shall also include the notation ‘NO’ or ‘NC’ indicating whether the valve is normally open or normally closed. Fuses and links shall be identified by their function, voltage, polarity, phase colour and fuse link rating. Equipment such as luminaires, switches and power outlets shall be identified by L, S or P followed by a consecutive number and the supply circuit identification.
The wording for warning labels shall be in Arabic and English language and for other labels in English language only.

15.1.3. RATING PLATES

A rating plate complying with the requirements of the appropriate Standard shall be provided on each item of plant. In addition to the information listed in the appropriate Standard, the rating plate shall be marked with the Contract number and other information requested by the Project Manager. A drawing of the rating plate for major items of plant shall be submitted, during the design phase, to the Project Manager for approval.

Where the rating plate is affixed to an item of plant, but not an individual component of an item of plant, of a mass in excess of 100 kg, it shall also specify the mass of the item. The rating plates shall be of engraved or stamped matt stainless steel, brass or of other approved metal.

15.1.4. SUPPLY OF WARNING NOTICES, LABELS AND RATING PLATES

Failure to complete the supply and fixing of warning notices, labels and rating plates shall be sufficient reason for the Project Manager to withhold the issuing of a Taking-over Certificate in accordance with the Conditions of Contract.

15.2. ASSEMBLY DURING MANUFACTURE

All parts of the Plant shall be assembled during manufacture at the Contractor’s discretion, unless specified, to the full extent necessary for the purpose of inspection, testing and otherwise ensuring that they will function satisfactorily and are mutually correct as regards dimensions. During such assembly, all parts shall be correctly doweled and match-marked to facilitate erection at Site.

15.3. INSPECTION AND TESTING

15.3.1. TESTS DURING MANUFACTURE

15.3.1.1. GENERAL

All equipment, materials and components shall be subject to type, sample and routine tests and inspection while in process of and upon completion of manufacture. For each piece of material, equipment or component, the inspection and tests shall consist of:

- the relevant tests and inspections as specified in the Standard Technical Requirements;
- the tests and inspections required by the relevant Standards; and
- such other tests and inspections as may be necessary in the opinion of the Project Manager to demonstrate compliance with the Contract.

The Contractor may offer type test results for identical equipment in lieu of the type tests specified; in which case the specified type tests may be waived by the Project Manager. If type tests for identical equipment are offered in lieu of the specified type tests, the Contractor shall provide evidence to the satisfaction of the Project Manager that the equipment tested was similar to the Contract equipment.
The Contractor shall prepare and submit to the Project Manager at least three months prior to the commencement of testing, schedules in approved format for each test detailing the extent and nature of the tests, together with a programme for the tests during manufacture.

The Contractor shall submit evidence to the Project Manager that the instruments used for the testing have been calibrated prior to the test at an approved testing laboratory within a period of up to three months for a portable instrument and six months for a fixed instrument.

The Contractor shall submit two copies of the results of each of the tests during manufacture to the Project Manager within one week of the tests being carried out. Four copies of the certified results of each of the tests, in the form of test reports, shall be provided to the Project Manager within one month of the tests being carried out.

The Employer may observe and participate in the tests during manufacture.

15.3.1.2. MATERIAL TESTS

All equipment shall be subject to the following tests where applicable:

- The acceptability of the material as judged in accordance with ASTM E186, E280 and E446, severity level two, for cracks and hot tears, and severity level four for all other forms of defect. Any areas found on examination to contain unacceptable defects shall be subject to re-examination after repair.

- Crack detection of all steel castings and forgings.

- Dimensional checks of all components and assemblies.

15.3.1.3. ELECTRICAL EQUIPMENT TESTS

All control wiring and equipment shall be subject to a withstand voltage test of 2 kV r.m.s. for one minute on 415 V, 240 V and 110 V circuits, and of 500 V d.c. for one minute on 48 V and lower voltage circuits.

All relays and instruments shall be routine and batch tested in accordance with the relevant IEC Standard. In addition, solid state relays shall be tested in accordance with IEC 60255-3.

All contactors and motor starters shall be type and routine tested in accordance with IEC 60947 and IEC 60470 as appropriate, to verify compliance with the Standard Technical Requirements.

All cubicles and switchgear shall be subject to inspection during manufacture and on completion to verify compliance with the relevant Clauses of the Particular Technical Requirements, including surface finish and insulation resistance. 415 V switchgear and associated current and voltage transformers shall be routine tested in accordance with the requirements of the relevant IEC Standards.

Small transformers shall be type and routine tested in accordance with an appropriate Standard.

All control and protection systems shall have operational tests carried out at the factory before despatch to prove that all components operate together as a system and that all operating sequences and device responses comply with the Particular Technical Requirements.

Cables shall be routine tested to ensure compliance with the appropriate Standards.
15.3.1.4. APPROVAL TO DESPATCH

Unless otherwise approved, no equipment shall be despatched from the Contractor's premises to Site, or from a Subcontractor to the Contractor or to Site, until it has been inspected by the Project Manager and the appropriate release certificate has been issued.

15.3.1.5. FAILURE TO COMPLY

The passing of factory inspection and tests shall not prejudice the right of the Project Manager to reject the whole or part of the Plant if it does not comply with the Contract when erected on the Site.

In the event of any test piece failing to comply with the requirements of the Contract, the Project Manager may reject the whole of the material represented by the test piece.

15.3.2. TESTS AT SITE

15.3.2.1. GENERAL

The Contractor shall conduct the tests at Site in accordance with the Conditions of Contract and the Standard Technical Requirements.

The Contractor shall provide all equipment and personnel required to carry out the tests, including the provision, installation and removal of all test instruments, the connection and disconnection of plant items and obtaining of all records.

The Contractor shall prepare and submit to the Project Manager at least six months prior to the commencement of testing, the test protocol, which shall include schedules in approved format for each test detailing the extent and nature of the tests, correction curves and other factors to be considered, together with a programme for the tests at Site.

The Contractor shall submit evidence to the Project Manager that the instruments used for the tests at Site have been calibrated at an approved testing laboratory within a period of up to three months prior to the tests at Site.

The Contractor shall submit two copies of the results of each of the tests at Site to the Project Manager within one week of the tests being carried out. Four copies of the certified results of each of the tests at Site, in the form of test reports, shall be provided to the Project Manager within one month of the tests being carried out.

The Employer will observe and participate in the tests at Site.

15.3.2.2. SCOPE OF TESTS

Tests on the plant and equipment at Site, to be carried out by the Contractor and passed prior to Taking Over of the Plant & Equipment, shall comprise four main stages of testing as follows:

- Functional Tests, which are tests prior to rotation of, energising at normal voltage or admission of air, water or oil at normal pressures to the main or auxiliary plant under test, to demonstrate readiness for commencement of the Commissioning Tests.
- Commissioning Tests, which are tests to progressively prove the correct and safe operation of complete auxiliary systems and of the main plant items.
• Performance Tests, which are tests to demonstrate achievement of the associated Performance Guarantees.
• Reliability Tests, which are tests to demonstrate achievement of the Reliability Criteria.

The Commissioning, Performance and Reliability Tests are to be collectively known as the Tests on Completion.

If the prevailing conditions at the time of conducting the Performance Tests are not the Optimum Conditions, as defined in the Standard Technical Requirements, then the Performance Tests shall be repeated and passed when the Optimum Conditions are present.

15.3.2.3. ELECTRICAL EQUIPMENT TESTS

The following tests shall be carried out:

• Insulation resistance measurements at the specified voltages appropriate to the circuits and equipment.
• Proof of phasing or polarity of power supply cables.
• Proof of correct connection and continuity of wiring for all control, protection, auxiliary and alarm equipment.
• Operation of all control and protection equipment at 80%, 100% and 120% of rated voltage.
• Demonstration of sensitivity of electrical protection relays to approved settings, preferably by primary injection testing.
• Overall CT Injection Tests

15.3.2.4. INDICATIONS, DISPLAYED QUANTITIES AND ANALOGUE OUTPUTS

These tests shall include:

• High-voltage tests of all power equipment, including anti-corrosion sheath tests on high voltage cables.
• Small transformers shall be type and routine tested in accordance with the appropriate Standards.
• Check all fuses and moulded case circuit-breakers for correct rating.

15.3.2.5. RELIABILITY TEST PERIOD

The Tests on Completion shall include a Reliability Test Period for each part of the Plant & Equipment, which shall commence when the part of the Plant & Equipment has passed all other related Commissioning and Performance Tests. During the Reliability Test Period, the Plant & Equipment will be required to operate under normal conditions without failure or interruption of any kind for the period or periods specified in the Particular Technical Requirements.

The part of the Plant & Equipment will be operated by the Employer's operation and maintenance staff under the direction of the Contractor, and the Contractor shall provide suitable representatives to advise on the operating techniques and the operation of the part of the Plant & Equipment.

The Contractor may make minor adjustments to the part of the Plant & Equipment during the Reliability Test Period, provided that such adjustments do not in any way interfere with or prevent
the normal use of that part of the Plant & Equipment by the Employer or result in reducing the output or efficiency.

Should any failure or interruption occur in the operation of the part of the Plant & Equipment due to faulty design, materials or workmanship under the Contract, the Reliability Test Period shall recommence after the Contractor has remedied the cause of the defect. The onus of proving that any defect is due to causes other than faulty design, materials or workmanship shall lie with the Contractor.

15.3.2.6. INSPECTION BY THE PROJECT MANAGER

Before Taking Over and prior to issuing of the Taking-Over Certificate, the Contractor, at the request of the Project Manager, shall open up or dismantle any part of the Plant & Equipment for inspection by the Project Manager.

After Taking Over and prior to the expiration of the Defects Notification Period and before issue of the Performance Certificate, the Project Manager may open up or dismantle any part of the Plant & Equipment for inspection. Such dismantling for Inspection may be witnessed or carried out by the Contractor if he so requests in writing.

15.4. PROTECTIVE COATING SYSTEMS

15.4.1. GENERAL

The Contractor shall carry out surface preparation and apply surface protection as specified in this Clause.

All parts of the Plant & Equipment shall be protected against corrosion during transport, storage and erection and in service by surface treatment appropriate to the particular material and service. Machined surfaces required to be left bright in service shall be protected during transport, storage and installation by a tough coating readily removable during erection, to the approval of the Project Manager.

Where items of plant are stored on site, the protective coatings shall be periodically inspected. Any damaged coatings shall be immediately repaired.

Surfaces of non-ferrous components, active iron, insulation and other parts for which the Contractor has special finishing requirements shall be painted or protected by methods to be proposed by the Contractor for approval.

Surfaces to be embedded in concrete shall be free of loose material but shall not be coated except that coatings of exposed sections of embedded surfaces shall extend to 75 mm into the concrete or the full depth where this is less than 75 mm.

In general, prime painting only shall be carried out at the manufacturer’s factory, with touching up and subsequent coats to be applied after erection and before Taking Over by the Employer.

15.4.2. PAINTING OF PLANT AND EQUIPMENT

The Contractor shall submit for approval coating schedules including the following details:

- makes and types for the proposed coatings for each main surface of the equipment;
• methods of preparation, application, repair and inspection;
• sequences and intervals of all procedures;
• standards to which procedures or products conform;
• precautions and restrictions to be observed; and
• methods of protection of factory applied coatings during transport to Site.

All coating products shall be supplied from reputable manufacturers. If requested, the Contractor shall supply samples of the products proposed.

Erection marks shall remain visible after coating where the coating is applied prior to erection.

15.4.2.1. SURFACE PREPARATION

Surfaces to be coated shall be prepared by methods in accordance with BS 7773 or an equivalent International Standard approved by the Project Manager. Ferrous surfaces to be painted shall be abrasive blast cleaned to the specified quality of finish in accordance with BS 7079 or an equivalent International Standard approved by the Project Manager.

Cleaned surfaces shall be kept free of contamination and shall not be touched by bare hand. If any areas become contaminated they shall be cleaned as necessary.

Cleaned surfaces shall be coated as soon as practicable after cleaning. Cleaned surfaces shall not be allowed to stand overnight without being coated.

15.4.2.2. PAINT SYSTEMS

The paint systems shall comprise approved sequences of surface preparation, primer coating, undercoating where appropriate and finish coatings. The various coats of each system shall be of the same brand. Table R2.1 gives details of approved paint systems and the applications for which they are intended. Table R2.2 gives details of paint colours to be applied to the various parts of the Plant & Equipment. Paint systems in which some coatings do not comply with Table R2.1 may be offered. Details of manufacturers test records to substantiate this selection shall be submitted to the Project Manager for approval.

Equipment which is not specifically manufactured for this project may be to the manufacturer’s standard painting system provided that the system has been agreed to by the Project Manager and that the finished colour is acceptable.

Finish coat colours shall be nominated by the Project Manager. Successive coats shall be distinguishable by colour.

Paint may be applied at the Factory or at Site, providing the products and procedures are suitable for the intercoat exposure and for the environment during application.

All paint shall be delivered to the point of use in sealed containers clearly labelled with the product name, batch number and use-by date and accompanied by the manufacturer’s application instructions.

TABLE R2.1– PAINT SYSTEMS
**NOTE:** All paint system codes used in this Table are in accordance with the relevant BSEN and ISO standards. All nominated Dry Film Thickness (DFT) are minimum values.

<table>
<thead>
<tr>
<th>SYSTEM A</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>For indoor/outdoor structural steelwork required to be painted,</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>Zinc Silicate/Epoxy Micaceous Iron Oxide</td>
</tr>
<tr>
<td><strong>Surface Preparation</strong></td>
<td>Abrasive blast to Class Sa 2½</td>
</tr>
<tr>
<td><strong>Profile</strong></td>
<td>60 - 70 µm</td>
</tr>
<tr>
<td><strong>Primer</strong></td>
<td>EPIA Inorganic Zinc Silicate</td>
</tr>
<tr>
<td></td>
<td>DFT: 65 - 75 µm</td>
</tr>
<tr>
<td><strong>Bodycoats</strong></td>
<td>KU1D Epoxy - Micaceous Iron Oxide</td>
</tr>
<tr>
<td></td>
<td>DFT: Two coats, each 100 - 200 µm</td>
</tr>
<tr>
<td><strong>Finish Coat</strong></td>
<td>KF1E Epoxy finish</td>
</tr>
<tr>
<td></td>
<td>DFT: 30 - 40 µm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYSTEM B</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>For internal and external surfaces of electrical cubicles and for ferrous surfaces subject to abrasion, oil, grease and condensation.</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>Polyurethane</td>
</tr>
<tr>
<td><strong>Surface Preparation</strong></td>
<td>Class Sa 2½</td>
</tr>
<tr>
<td><strong>Profile</strong></td>
<td>20 - 30 µm</td>
</tr>
<tr>
<td><strong>Primer</strong></td>
<td>KP1B, Zinc dust/2-pack epoxy</td>
</tr>
<tr>
<td></td>
<td>DFT: 75 µm</td>
</tr>
<tr>
<td><strong>Undercoat</strong></td>
<td>KU1A, 2-pack epoxy</td>
</tr>
<tr>
<td></td>
<td>DFT: 40 µm OR</td>
</tr>
<tr>
<td></td>
<td>KU2A, 2 - pack polyurethane</td>
</tr>
<tr>
<td></td>
<td>DFT: 45 µm</td>
</tr>
<tr>
<td><strong>Finish Coat</strong></td>
<td>KF1A or KF2A, 2-pack epoxy or 2 - pack Polyurethane</td>
</tr>
<tr>
<td></td>
<td>DFT: 40 µm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYSTEM C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>For galvanised surfaces required to be painted.</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>Calcium Plumbate/Alkyd</td>
</tr>
<tr>
<td><strong>Surface Preparation</strong></td>
<td>Degrease and phosphate treatment in accordance with BS 7773.</td>
</tr>
<tr>
<td><strong>Primer</strong></td>
<td>FP1D, Calcium Plumbate</td>
</tr>
<tr>
<td></td>
<td>DFT: 40 µm</td>
</tr>
<tr>
<td><strong>Undercoat</strong></td>
<td>FU2A, Alkyd</td>
</tr>
<tr>
<td></td>
<td>DFT: 35 µm</td>
</tr>
<tr>
<td><strong>Finish Coat</strong></td>
<td>FF3A, Alkyd</td>
</tr>
<tr>
<td></td>
<td>DFT: 35 µm</td>
</tr>
</tbody>
</table>
TABLE R2.2 REQUIRED PAINT SYSTEMS

<table>
<thead>
<tr>
<th>Description of Parts</th>
<th>System</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal surfaces of tanks, receivers etc. Containing oil.</td>
<td>To be submitted for approval.</td>
<td>-</td>
</tr>
<tr>
<td>Internal surfaces of generators (including inside of stator frame and rotor).</td>
<td>A (Zinc silicate/MIO)</td>
<td>White</td>
</tr>
<tr>
<td>Enclosures on operating floor in view from the machine hall.</td>
<td>A (Zinc silicate/MIO)</td>
<td>To be advised.</td>
</tr>
<tr>
<td>External surface of other electrical enclosures.</td>
<td>C (Polyurethane)</td>
<td>Light grey No 631 to BS 381C</td>
</tr>
<tr>
<td>Fascia above excitation panels on operating floor.</td>
<td>C (Polyurethane)</td>
<td>Same as control panels</td>
</tr>
<tr>
<td>Internal surfaces of electrical enclosures.</td>
<td>C (Polyurethane)</td>
<td>White</td>
</tr>
<tr>
<td>External surfaces of ancillary components.</td>
<td>To be submitted for approval.</td>
<td>Light grey No 631 to BS 381C</td>
</tr>
<tr>
<td>Earthing Busbar</td>
<td>To be submitted for approval.</td>
<td>Green</td>
</tr>
<tr>
<td>Supports, stools, clamps etc.</td>
<td>Hot-dip galvanising to ISO 1461</td>
<td>-</td>
</tr>
<tr>
<td>Other ferrous surfaces to be painted; structural steel.</td>
<td>A (Zinc silicate/MIO)</td>
<td>To be submitted for approval.</td>
</tr>
</tbody>
</table>

15.4.2.3. METAL COATINGS

All galvanising shall be by the hot-dip process in accordance with ISO 1461. Parts shall be pickled thoroughly before being galvanised, with all materials likely to resist the pickling liquid removed beforehand.

Where possible, working, fabrication and deburring of the material shall be carried out prior to galvanising. Where the galvanising has been damaged, the exposed surface shall be painted as soon as possible in accordance with the following system:

- clean back to bright steel;
- feather the edges of the surrounding galvanising coating;
- degrease in accordance with BS 7773; and
- apply two coats of a zinc rich primer for a total film thickness of not less than 0.075 mm.

Electroplating shall be nickel plus chromium plating in accordance with BSEN 12540 or zinc or cadmium plating in accordance with BSEN 12329 and BSEN 12330. Nickel plating alone shall not be used.
15.5. LOCKING FACILITIES

15.5.1. GENERAL

The Contractor shall provide locking facilities for a security locking system and an isolation locking system for cubicles, equipment and rooms together with padlocks for access gates and doors as specified below. The locking facilities shall be of ABLOY make.

15.5.2. SECURITY LOCKING SYSTEM

The security locking system shall be a grandmaster key system with construction keying facility designed for the following purposes:

- to reduce the number of keys required for access to any of the areas or groups of equipment listed in Subclause b. below to a maximum of 2 grandmaster keys;
- to prevent unauthorised access to cubicles, equipment and rooms ; and
- to prevent unauthorised operation of high-voltage switchgear and other critical plant.

Locks shall be provided for all equipment in the Contractor’s supply as below with a master key for each of the following groups of equipment:

- Unit Master Key - for locks on all equipment associated with each turbine-generator unit and unit auxiliaries except control room equipment and including padlocks on generator enclosure doors;
- Main Transformer Cell Master Key - for locks on all equipment in the main transformer cells including padlocks on the main transformer cell gates;
- Mechanical Auxiliaries Master Key - for locks on all equipment associated with station mechanical auxiliary plant except control room equipment;
- Electrical Auxiliaries Master Key - for locks on all equipment associated with station electrical auxiliary supplies and other electrical auxiliary plant except control room equipment and including padlocks on station transformer cell access gates;
- Control Room Master Key - for locks on all equipment located in the Control Equipment Room and associated equipment rooms except protection cubicles;
- Substations Protection Panels Master Key - for locks on all substations protection cubicles;
- Main Plant Protection Panels Master Key - for locks on all main plant protection cubicles;
- Building Services Master Key - for locks on all equipment associated with the power station and building services, including ventilation and air-conditioning, lighting and power;

Every lock in the Contractor’s supply shall also be able to be opened by the Contract Grand Master Key.

All locks shall have a construction keying facility such that the locks shall be capable of being opened by construction keys in the possession of the Contractor’s workforce only until the equipment is taken over by the Employer. All construction keys shall become inoperative and the permanent keys shall become operative after a simple mechanical modification to each lock by the Employer.
Before the Contractor begins erection of equipment which is locked or installs equipment or door locks on Site, he shall forward two copies to the Project Manager of the construction master key which opens every lock in the Contractor’s supply; one for the Employer’s use and one for the Project Manager’s use.

The Contractor shall formally hand over, directly to the Project Manager, and when requested by the Project Manager, two keys for each lock, two Master Keys of each kind and two grand master keys, together with all lock manufacturer’s authorisation paper to enable the Employer and no one else, to purchase additional copies of the keys. Each key shall be fitted with a permanent label clearly identifying the lock location and including the cubicle, device or valve number which is shown on the equipment label and on the respective drawings.

The following types of locks shall be provided for security locking:

- cubicle locks shall be ‘key in handle’ cylinder locks;
- door locks shall be ‘key in handle’ type except that door locks in a master key group other than the building door master key group shall be padlocks;
- valve locks shall be padlocks with non-detachable chain or hinged locking plates;
- operational security locks on all high-voltage switchgear (above 650 V a.c.) shall be padlocks; and
- gate locks shall be padlocks.

Padlocks for security locking shall be high quality tumbler operated cylinder locks manufactured from hardened steel.

15.5.3. ISOLATION LOCKING SYSTEM

The isolation locking system shall be a padlock system completely independent from the master key security locking system. Padlocks shall be provided in sufficient number and suitable to lock every electrical and mechanical isolating device which may be required to be isolated and locked in accordance with the Employer’s access permit system for equipment maintenance and operation. Equipment requiring isolating padlocks includes but is not confined to electrical disconnecters, earthing switches, fuse switches and lockable circuit-breakers, other lockable electrical devices and all isolating valves.

The padlocks shall be high quality locks with a tumbler operated cylinder mechanism and manufactured from brass or unhardened steel. All padlocks shall preferably be identical in type and shall be of a size suitable to fit the locking facility of every device required to be locked. The keying system shall be a simple independent system in which each lock shall be able to be operated by its own key only and without any master key facility.

The Contractor shall formally hand over, directly to the Project Manager and when requested by the Project Manager, two keys for each lock, together with all lock manufacturer’s authorisation papers to enable the Project Manager, and no one else, to purchase additional copies of the keys. Each key shall be fitted with a blank label tag suitable for the Project Manager to add his own label.

15.6. TROPICALISATION

In choosing materials and their finishes, due regard shall be given to the humid tropical conditions under which the Plant is to work, and the recommendations of BS CP1014 shall be observed unless
otherwise approved. Some relaxation of the following provisions may be permitted where plant is hermetically sealed but it is preferred that tropical grade materials should be used wherever possible.

15.6.1. METALS

Iron and steel shall generally be painted or galvanised in accordance with Clause S16.5. Indoor parts may alternatively be electroplated or have other approved protective finish. Small iron and steel parts (other than rustless steel) of all instruments and the metal parts of relays and mechanisms shall be treated in an approved manner to prevent rusting. Cores, etc., which are built up of laminations or cannot for any other reasons be anti-rust treated, shall have all exposed parts thoroughly cleaned and heavily enamelled, lacquered or compounded. When it is necessary to use dissimilar metals in contact, these shall be so selected that the potential difference between them in the electrochemical series is not greater than 0.5 V. If this is not possible the contact surfaces of one or both of the metals shall be electroplated or otherwise finished in such a manner that the potential difference is reduced to within the required limits, or, if practicable, the two metals shall be insulated from each other by an approved insulating material or a coating of approved varnish compound.

15.6.2. SCREWS, NUTS, SPRINGS, PIVOTS, ETC.

The use of iron and steel shall be avoided in instruments and electrical relays wherever possible. Steel screws, when used, shall be electroplated, or when plating is not possible owing to tolerance limitations, shall be of corrosion-resisting steel. All wood screws shall be of dull nickel plated brass or of other approved finish. Instrument screws (except those forming part of a magnetic circuit) shall be of brass or bronze. Springs shall be of non-rusting material, e.g. phosphor-bronze or nickel silver, as far as possible.

15.6.3. WOOD

The use of wood in equipment shall be avoided as far as possible. When used, woodwork is to be thoroughly seasoned teak or other approved wood which is resistant to fungal decay and shall be free from shakes and warp, sap and wane, knots, faults and other blemishes. All woodwork shall be suitably treated to protect it against the entry of moisture and from growth of fungus and termite attack, unless it is naturally resistant to those causes of deterioration. All joints in woodwork shall be dovetailed or tongued and pinned as far as possible. Metal fittings where used shall be of non-ferrous material.

15.6.4. ADHESIVES

Adhesives are to be specially selected to ensure the use of types which are impervious to moisture, resistant to mould growth, and not subject to the ravages of insects. Synthetic resin cement only shall be used for joining wood. Casein cement shall not be used.

15.6.5. RUBBER

Neoprene or similar synthetic compounds, not subject to deterioration due to climatic conditions, shall be used for such items as gaskets, sealing rings and diaphragms. Natural rubber-based materials are not acceptable.

All plant shall be designed to prevent entry of vermin, dust and dirt. Where wiring, piping or ductwork passes through openings in equipment housings, such openings shall be constructed to prevent entry of vermin. Wiring and piping enclosures and ductwork shall also be vermin-proof.
15.6.6. ENTRY OF VERMIN, DUST AND DIRT

All equipment shall be designed to prevent entry of vermin, dust and dirt. Where wiring, piping or ductwork passes through openings in equipment housings, such openings shall prevent entry of vermin. Wiring and piping enclosures and ductwork shall also be vermin proof.

15.6.7. MISCELLANEOUS METALWORK

- The Contractor shall provide and install the following miscellaneous metalwork: support structures, brackets and fittings for support of pipes, cable and equipment;
- soleplates, bedplates, foundation bolts and anchor bolts;
- floor plates and kerbing required for completing the floors around and over the Plant;
- platforms, stairways with toe and kick plates, ladders, guards, handrails necessary for easy and safe access to items of the Plant requiring access for operation, maintenance and testing;
- safety guards at each point where normal access would permit personnel to come within reach of any moving item of plant; and
- lifting lugs, eyebolts or other lifting attachment points on each item having a mass of more than 40 kg.

All miscellaneous metalwork shall be hot-dipped galvanised in accordance with Clause S16.5 unless otherwise approved.

15.7. EMBEDMENT, FOUNDATIONS AND PLINTHS

Except where stated otherwise, all embedded supports and other embedded metalwork shall be provided by the Contractor consistent with dimensioned concrete outline and miscellaneous metalwork drawings which will be progressively forwarded to the Contractor according to an agreed schedule, generally consistent with the requirements indicated by the Contractor in his Tender.

The Contractor shall ensure that adequate provision has been made in these civil drawings for the complete installation of his Plant and shall coordinate all interfaces between the civil works contract(s) and the Plant & Equipment and shall inform the Project Manager, in accordance with the Contract programme, of any additions or alterations he requires to be made to the civil works. Unless the Contractor informs the Project Manager of his requirements within the specified periods, such additions or alterations to the civil works shall be made by the Contractor or, if the Project Manager so requires, by the Employer at the expense of the Contractor. Because of the civil contract program, some areas of the civil works which will be nominated by the Project Manager may not be able to be altered according to this Sub-Clause.

Equipment for mounting on floors shall be installed on concrete pads to be constructed by the Contractor with the finished level up to 75 mm above the floor level to cater for normal variations which will occur in foundations. The Contractor shall supply all foundation bolts and packing plates between the concrete and the plant equipment bases.

Plant which is mounted on the floor and which does not require supporting steelwork grouted or embedded in the concrete foundations and Plant which is surface mounted on concrete walls or the lower face of concrete shall be fixed in position by approved masonry anchors. Masonry anchors shall be expansion type or resin adhesive type, and shall be of adequate strength and corrosion-proof.

The Contractor shall provide the fastenings and shall forward to the Project Manager full details of
the proposed masonry anchors including typical pull-out values and, if requested, shall submit samples for approval.

Items of Plant supplied by the Contractor which are to be embedded in mass concrete shall be accurately placed and secured by the Contractor prior to placement of the concrete reinforcement and formwork.

15.8. **NOISE, VIBRATION AND BALANCE**

Equipment supplied under this Contract shall be designed and constructed to operate within the following noise limits:

- Within the building or structure containing the Plant & Equipment not exceeding ISO 1996 level NR 85 between 62.5 and 8000 Hz, except that, during any plant starting or stopping sequence, noise pressure levels up to the NR 100 curve shall be permitted.
- Within control rooms not exceeding ISO 1996 NR 50 between 250 & 2000 Hz.

Noise levels shall be measured by the Contractor during commissioning of the Plant and approved by the Project Manager.

The amplitude of vibration of new hydropower plants, when measured on the bearing housings under steady state conditions at the designed operating speeds shall not exceed the values of 170 µm, given by VDI 2059.

Provisions shall be made for the reduction of vibration transmitted to covers, cladding, platforms and structures that are liable to vibrate. The vibration of any such radiating surface shall not exceed the following:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Amplitude (peak to peak mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.20</td>
</tr>
<tr>
<td>25</td>
<td>0.08</td>
</tr>
<tr>
<td>50</td>
<td>0.04</td>
</tr>
<tr>
<td>100</td>
<td>0.02</td>
</tr>
<tr>
<td>120</td>
<td>0.017</td>
</tr>
</tbody>
</table>

15.9. **POSITION OF INSTRUMENTS, CONTROLS AND HAND-WHEELS**

Instruments shall be located conveniently for access and reading. Instruments which must be read frequently shall be located between 750 mm and 1800 mm from the floor. Those which are read occasionally may be located between 500 mm and 2000 mm from the floor.

Controls and valve hand-wheels shall be located conveniently for access and operation. In general, controls should be within the range 750 mm to 1500 mm and valve hand-wheels 1000 mm to 1500 mm above floor level.

15.10. **PRECAUTIONS AGAINST CORROSION DUE TO HYDROGEN SULPHIDE**

The Contractor shall adopt the following protective measures as applicable.
15.10.1. ELECTRICAL

Relay contacts shall be plated with either gold, tungsten, platinum or other suitable material. Relays shall be hermetically-sealed.

Anti-condensation heaters shall be fitted to all cubicles and enclosures as well as to terminal boxes and smaller enclosures where condensation is likely to occur.

Terminal lugs on power and control cables shall be tin-plated.

Cables outside electrical enclosures and copper earthing bars shall have tinned-copper conductors. PVC sheathing containing lead based plasticisers shall not be used.

Copper tracks of printed circuit boards shall be covered with a varnish coating of adequate thickness.

15.10.2. MECHANICAL

Epoxy Coating System B shall be used on immersed metalwork. Lead based paints shall not be used.

Galvanised surfaces shall be designed to be free-draining where possible. Non-free-draining surfaces shall be painted locally.

Air intakes for compressed air systems and air-conditioning/ventilation shall be carefully positioned to avoid intake of H₂S gas. Positioning of air intakes on the draft tube side of the power station shall be avoided.

15.11. PRECAUTIONS AGAINST METHANE

The Contractor shall take into account that methane may develop in the reservoir because of decaying vegetation, and that methane and other flammable gases may develop underground.

For plant installed underground, and wherever the Contractor detects or the Project Manager indicates the risk that concentration in the atmosphere of methane or other flammable gases may exceed one percent, electric motors shall be explosion-proof, and the Contractor shall provide the Plant & Equipment as applicable with proper spark absorber and any other accessory and device necessary for assuring the required safety. The provision of such safety measures shall not be construed by the Contractor as a basis for additional compensation over the stipulated prices.

15.12. FIRE AND SMOKE BARRIERS

All openings in walls and floors shall be closed with a barrier after the installation of cables, pipes and other equipment.

Barriers shall provide not less than 1 hour fire rating and shall prevent the passage of smoke, vermin and insects. Barriers shall be capable of being removed when necessary for replacement or installation of additional cables, pipes and other equipment.
16. EQUIPMENT REQUIREMENTS – ELECTRICAL

16.1. SCHEDULES AND SAMPLES OF ELECTRICAL DEVICES

16.1.1. PROPOSED DEVICES

The Contractor shall submit to the Project Manager within six months of the Commencement Date the manufacturer's name, type and full technical details of all electrical devices which it proposes to provide for the Plant & Equipment. An electrical device is any device that has electrical connections or that connects directly to any control system equipment.

16.1.2. SAMPLES TO BE PROVIDED

One sample of each manufacturer, type and rating of the items listed below shall be supplied if requested by the Project Manager:

- Electrical relay;
- Each Type of Transducers;
- Contactor or motor starter;
- Control or control selector switch;
- Illuminated pushbutton switch;
- Pushbutton switch;
- Moulded case or miniature circuit-breaker;
- Luminaire; and
- Power socket outlet.

16.1.3. INSPECTION AND TEST OF SAMPLES

The Project Manager will inspect and may test these samples and, if they are approved, will return them to the Contractor at Site for inclusion with the spare parts. Approval of such samples shall not relieve the Contractor of any of its obligations under the Contract. In the event that any such sample is not approved, a device of a type which is in accordance with the Particular Technical Requirements shall be submitted.

16.1.4. WIRING SAMPLES

Samples of the enclosure wiring, wire terminations and terminal blocks proposed to be used in the Plant & Equipment shall, if requested by the Project Manager, be submitted by the Contractor for approval before any wiring work is carried out.

16.2. AUXILIARY POWER SUPPLIES

Electrical equipment shall be designed for continuous operation from the auxiliary power supplies within the following limits:

- Nominal 415/240 V a.c.
- Voltage: 415V (3-phase) or 240 V (1-phase), +5%, -15%
- Frequency: 50 Hz, +5%, -5%
- Combined variation of voltage and frequency: +10%, -15%
- Nominal 110 V d.c.
16.3. MOTORS

16.3.1. SPECIFICATIONS

All motors shall be in accordance with IEC 60034 and suitable for continuous running duty. The starting current at full voltage shall not exceed six times full load current. Motors larger than 0.75 kW shall be of three-phase type. Suitable starting facilities shall be installed in accordance with IEC 60034 for all motors.

Motor rated outputs shall be at least 10% in excess of the continuous maximum power required by the respective driven equipment.

Direct current motors shall be provided as required and shall be of the shunt motor type.

Materials and workmanship shall be of the highest quality. All motors shall in all respects be suitable for operation in service conditions typical for 132 kV in tropical areas.

Motors and auxiliary equipment shall be designed and manufactured such that no abnormal wear and no dangerous vibration, which will affect the steady operation of the complete set, can occur.

16.3.2. OPERATING CONDITIONS

Direct-on-line starting of a.c. motors with the driven equipment connected shall be possible when, at rated frequency, the voltage at the motor terminals is not less than 85% of rated voltage.

A.C. motors shall be capable of operation for up to fifteen seconds under running conditions at rated load and frequency with a minimum of 70% of rated voltage at the motor terminals.

Unless otherwise required by the driven equipment, two consecutive starts from motor warm condition and three consecutive starts from motor cold condition, both with subsequent steady continuous operation for 20 minutes, shall be guaranteed without exceeding the specified temperature rise limit.

A.C. motors shall be capable of withstanding, without damage, unsynchronised automatic transfer of power supply with motor residual voltage of 100% and of 180 degree phase difference from the source voltage.

Motor insulation shall correspond to Class F.

Motors shall not suffer any damage when subjected to 120% nominal speed for 2 minutes. Motors will be subjected to significant frequency rises following generator load rejection. Motors shall be protected from damage in this event. Protection which trips the motor on overspeed and restores it to service when the speed falls will be accepted.

16.3.3. DEGREE OF PROTECTION

Motors to be used outdoors exposed to the weather shall have degree of protection IP 54 to IEC 60034. Openings of motors shall be effectively screened against ingress of vermin.

a. Thermal Protection

Motors larger than 0.40 kW shall be supplied from separate circuits which are provided with overcurrent protection. The motors shall be connected in three phase groups which shall have means of isolating the whole group.

b. Grease Nipples
Where ball and roller bearing housings are fitted with grease nipples they shall incorporate an approved grease escape valve.

c. Terminal Box

The terminal box shall be weather and vermin proof and firmly fixed to the motor frame. The terminal studs shall be sized to be adequate for the current duty required and marked in accordance with IEC 60034 where applicable. All terminal boxes shall have approved cable adaptor plates, sealing chambers or conduit entries.

The arrangement of the terminal box shall be such as to facilitate installation of cables, and allow interchanging of any two phase leads, without disturbing the sealing compound, if this is used at cable terminations.

16.4. CONTACTORS AND MOTOR STARTERS

16.4.1. SPECIFICATIONS

The rated voltage, current and duty of contactors and motor starters shall be appropriate to the service conditions. Starters and contactors shall comply with IEC 60158, IEC 60947 and IEC 60470 and be suitable for continuous electrical duty and for direct on-line or soft starting as applicable. The utilisation category shall be not less than AC-3 to IEC 60158, IEC 60947 or IEC 60470.

16.4.2. ENCLOSURE

Individual enclosures with degree of protection not less than IP 31 to IEC 60947 shall be provided for all contactors and motor starters, including those within cubicles.

16.4.3. CONTACTORS

At any voltage at which pick-up occurs contactors shall close completely.

a. With 70 per cent voltage at the coil terminals, contactor main contacts shall not chatter nor part when the locked-rotor current is being conducted.

b. Latching contactors shall have a mechanical latching mechanism which is positive in operation under all conditions of service and with operating coil voltage range of 80% and 110% and trip coil voltage range from 50% to 110%. If both coils are energised at the same time the contactor shall trip.

c. Latching contactors shall not exceed the temperature rise limits specified when the coils are energised at rated voltage for 30 seconds.

16.4.4. MOTOR PROTECTION

a. Motor starting equipment for a.c. motors shall include thermal overload relay with single-phasing detection fitted to each phase or group which shall have ambient temperature compensation:

b. Motors with embedded thermistor protection shall have two sets of thermistors installed – one set to be used for protection and the other set spare.

16.4.5. AMMETERS

Ammeters, to read current in one phase, shall be provided for all motors over 0.75 kW.
16.5. CIRCUIT-BREAKERS AND FUSES

16.5.1. MOULDED CASE AND MINIATURE CIRCUIT-BREAKERS

a. General

• Moulded case (MCCB) and miniature circuit breakers (MCB) shall be rated at 500 V AC and have trip-free operating mechanisms of the quick-make quick-break type with de-ionising arc shutes and fitted with adjustable thermal release and instantaneous magnetic release. MCCB’s and MCB's shall comply with the relevant IEC standards.

• Multipole MCCBs and MCBs shall be contained within a common dust-proof moulded case of high mechanical strength. All poles of such circuit breakers shall be operated simultaneously by a common operating lever.

• The MCCB's and MCB’s used shall be standardised as far as possible to facilitate interchangeability and reduce the number of spares required.

b. Operation Indication

• Clear indication shall be given on each circuit breaker to show whether it is in the closed, open or tripped condition. Each circuit breaker shall be provided with one set of auxiliary contacts necessary for remote and group annunciation. Auxiliary contacts shall indicate "CB open" upon manual opening and a momentary or re-settable contact to indicate "CB trip".

• The circuit-breakers shall have provision for locking in the "OFF" position.

c. Shrouding

• Live metal on MCBs shall be fully shrouded to prevent accidental human contact.

d. Trip Setting

• Where MCBs with adjustable trip settings are used the Contractor shall determine the most suitable setting for each particular application. At the time of commissioning, the Contractor shall ensure that the correct setting has been applied.

16.5.2. FUSES

Fuses shall not be used in power supply or control circuits, apart from in exceptional circumstances where they may be used subject to prior approval by the Project Manager. Special fuses for protection of electronic components may be used if they are part of proprietary equipment.

16.6. ELECTRICAL CONTROL DEVICES MANUALLY OPERATED

16.6.1. CONTACTS

The contacts in all electrical control devices shall be adequately rated for the service conditions. Contacts shall be silver or silver-plated, except where the conditions of operation require the use of harder materials such as tungsten, or where special contact assemblies are of gold or of the mercury wetted type.

16.6.2. CONTROL SELECTOR SWITCHES

Control selector switches shall have approved handles and fixed operating positions spaced 90 degrees apart.
An escutcheon shall be fitted, engraved with the following information in the positions stated:

- Switch function (at top);
- Mode selected (opposite each switch position); and
- Device number as shown on circuit diagram (bottom right).

Control selector switch contacts shall be of heavy-duty spring snap-action type.

### 16.6.3. CONTROL SWITCHES

Control switches, unless otherwise specified, shall be of three position heavy-duty spring return-to-neutral type. Control switches for circuit-breaker OPEN and CLOSE control shall have approved pistol-grip handles. All other control switches shall have appropriate and approved handles.

An escutcheon shall be fitted, engraved with the following information in the positions stated:

- Switch function (at top);
- Control function selected (opposite each switch position); and
- Device number (bottom right).

### 16.6.4. DIRECTION OF ROTATION

Control devices shall be arranged to turn:

- Clockwise for RAISE, CLOSE (switches), START, ON and OPEN positions.
- Anti-clockwise for LOWER, OPEN (switches), STOP, OFF, and CLOSE positions.

### 16.6.5. PUSHBUTTON SWITCHES

Pushbutton switches shall be of heavy duty type and constructed for definite over-travel in both directions. Pushbutton operating mechanisms shall be recessed to prevent accidental operation.

Emergency stop, trip or shutdown pushbuttons shall have a protective flap held in front of the button by a spring or gravity and the exposed face of the flap marked "EMERGENCY STOP", "EMERGENCY TRIP" or "EMERGENCY SHUTDOWN" in red.

### 16.6.6. ILLUMINATED PUSHBUTTON SWITCHES

Illuminated pushbutton (IPB) switches shall be of the rectangular single button flush panel-mounted type. No fixing screws shall be visible from the front of the panel.

Where IPB switches are gang mounted, barriers shall be fitted to separate the display screens.

Lens caps shall be translucent with one colour field only, with separate legend inserts behind the cap. A minimum number of two lamps shall be provided in each IPB. Coloured lamps or coloured sleeves over lamps shall not be used.

Lamp replacement shall be possible from the front of the panel.

IPB switch units shall have double-break contacts and be suitable for the service conditions.
16.7. ELECTRICAL RELAYS

16.7.1. CASES
Relays shall be provided with non-flammable dust and moisture proof cases.

Relay elements shall be of the plug-in or withdrawable type and the plug-in connections shall be made and broken by pressure contacts. Where appropriate, the Project Manager will approve the use of cases containing multiple plug-in relay elements.

16.7.2. COIL RATING
The coils shall be continuously rated and shall have a tropicalised finish. Alternating current operated coils shall be suitable for operation at 240 V a.c., +10 per cent to -15 per cent and d.c. operated coils of control and trip relays shall be suitable for operation at 110 V d.c. in the range of 80 per cent to 120 per cent of nominal voltage for control relays and 50 per cent to 110 per cent for trip relays.

16.7.3. TIME DELAY RELAYS
Time delay relays shall be of the solid-state type. It shall be possible to adjust the timing delays easily and the relays shall hold that adjustment. The timing range of the relays shall overlap the expected setting by at least +50 per cent. The setting adjustment shall be calibrated clearly.

16.7.4. CONTACTS
At least one spare normally-open contact and one spare normally-closed contact shall be provided on each relay in addition to the contacts required by the control scheme. Relay contacts shall be adequately rated for the service conditions.

16.8. TRANSDUCERS
Transducers shall have 4 to 20 mA output linear over the measuring range. The output shall be ungrounded, be proof against open- and short-circuit conditions, and capable of operating continuously in the open state. Transducers shall be immune to radio frequency interference such as caused by a hand-held VHF transceiver or a nearby radio station.

The rated value of the input shall be equivalent to approximately 16 mA output.

The maximum error shall not be more than 1%.

16.9. AUXILIARY SWITCHES
All high-voltage and low-voltage switchgear and control gear shall be provided with the necessary auxiliary switches for the closing and opening mechanisms and for control, indications, interlocking and other functions, and shall include at least one make and one break contact as spare.

Auxiliary switches shall be mounted on the equipment and directly coupled to the operating mechanism. The switches shall be arranged so that they will not be damaged by over-travel of the
drive. Contacts shall be inherently self-cleaning to ensure low contact resistance at all times. The electrical rating of auxiliary switches shall be adequate for the service conditions.

16.10.  INDICATING LIGHTS

16.10.1.  SPECIFICATIONS

Indicating lights shall be of the miniature type using lamps to a manufacturing standard in common usage to ensure continuity of replacement supplies. Rating of indication lamps shall be nominally 24 V to 28 V and they shall be operated at 22 V a.c.

Where permissible, high capacity LEDs providing the same illumination may also be used in place of the Indicating lights except that the make, type and mounting arrangement shall be to the approval of the Project Manager.

16.10.2.  FITTINGS

The fittings shall withstand 500 V d.c. for one minute and shall be so constructed that the lamp can be readily fitted and removed and the lens changed from the front of the panel.

The fittings shall be capable of continuous operation at the nominal lamp voltage regardless of the position in which they are mounted. The lamp supply shall be derived from a suitable transformer on each panel, or suite of panels, on which indicating lights are fitted.

16.10.3.  LENSES

Lenses shall be of translucent glass or other approved material. Plastic lenses will be accepted if fitted with a robust anti-shrink ring or other approved device to prevent the lenses becoming loose due to deformation or shrinking. Where colour indication is required, coloured lamp covers are not acceptable.

16.10.4.  LAMP HOLDERS

Lamp-holders shall be made of metal or an approved high grade plastic material. Plastic used in the lamp-holder body or for clamping rings shall be dimensionally stable so that jamming of threads shall not occur.

16.11.  INDICATING INSTRUMENTS

16.11.1.  GENERAL

All instruments shall be capable of withstanding, or shall be adequately protected from, the vibrations which are encountered in service. Instruments and associated apparatus shall be capable of maintaining their accuracy and sensitivity without excessive maintenance.

16.11.2.  ENCLOSURE

Instruments on the outside of enclosures shall be square case not less than 48 mm side nor greater than 192 mm, flush mounted, have non-reflective glass and be provided with narrow bezels. The bezels shall have a uniform high-grade finish.

All instrument cases shall be dustproof.
16.11.3. **SCALES**

All instrument scales shall be in accordance with BS 3693 or ANSI C39.1, or equivalent, printed in black figures and divisions on a white background. The unit measured shall be clearly marked on the instrument dial in black capital letters in an abbreviated form (eg. A for amperes). Printing which may interfere with the clear observation of the reading shall not appear on the dials. Scales shall be provided with red-coloured marks at points corresponding to the normal working values (or full-load current of the equipment in the case of ammeters).

Unless otherwise specified or approved all instruments shall have circular scales with a total pointer deflection of not less than 240 degrees. Normal working indication shall be at a point corresponding to approximately 75 per cent of full-scale deflection.

The scales for ammeters in motor circuits shall be compressed. Full load current shall be indicated at about 75% full scale deflection, and the scale shall be approximately linear to this point. Above it the scale shall be compressed so that full scale deflection indicates about 6 times full load current.

Instruments with scales shall have black bar-type pointers, except in the case of instruments having more than one pointer and then only one of the pointers shall be black and the other red. Suspension for electrical instruments shall be of the taut band type. End stop devices shall be provided to prevent damage to movement, pointers and suspensions under transient conditions.

16.11.4. **CALIBRATION**

Devices for routine checking, zero adjustment and recalibration shall be easily accessible from the front of the enclosures. Where such devices are not included in the instrument case they shall be flush-mounted on the enclosures adjacent to the associated instruments, so that adjustments can be made conveniently while watching the indicator.

16.11.5. **CONTACTS**

Instruments provided with initiating contacts shall be arranged so that operation of the contacts neither impedes nor restricts the movement of the indicating pointers over the full range of the instruments. The initiating contacts shall be adjustable.

Expansion dial type thermometers shall be equipped with electrically separate alarm and shutdown contacts, and hand reset maximum indication pointers. The thermometers shall be unaffected by variations in temperature of the capillaries.

16.11.6. **MULTIPLE RANGE INSTRUMENTS**

Dual or multiple range instruments shall be provided with a range selector which shall be readily accessible to the operator without opening the front cover of the instrument.

16.11.7. **READING**

Instruments intended for routine reading in service shall be clearly legible to operators at normal standing distance.

16.12. **ENCLOSURES FOR ELECTRICAL EQUIPMENT**

16.12.1. **GENERAL**

Enclosures complying with this Sub-Clause shall be provided for assemblies of electrical equipment.
16.12.2. SHEET METAL ENCLOSURES

Sheet metal enclosures shall be constructed of folded and welded sheets of thickness which is appropriate to the size of the enclosures. The thickness shall be not less than 2.0 mm for floor standing cubicles and 1.6 mm thickness steel to enclose a single small device. Rolled steel sections may be used in large cubicles for forming the frame and stiffening. Where equipment is to be mounted on a panel the thickness of the sheet steel shall be sufficient to prevent vibrations affecting the correct operation of the equipment. All floor mounted cubicles shall be mounted on a steel channel section base frame.

Enclosures comprising a suite of cubicles shall have a solid metal sheet between adjacent cubicles, apart from a space at the top to provide for inter-cubicle wiring.

16.12.3. DOORS AND COVERS

Doors shall be provided where access is necessary during normal operation of the Plant, eg. for resetting relays or circuit breakers, taking equipment out of service or routine inspection of contactors, relays or similar equipment. Where access is necessary only for cleaning or repair, or to equipment such as current transformers, removable covers may be provided. Where a removable cover is too large for one man working alone to handle then hinges shall be provided. Covers shall be fixed in place by captive bolts. Doors and covers shall either lap or be rebated with the enclosure. Doors shall be constructed of steel sheet 2.5 mm minimum thickness with double returned edges and additional stiffeners if necessary to prevent distortion. Door opening stops shall be provided on all doors.

The Contractor shall ensure that clearance from an open enclosure door to adjacent walls or equipment is not less than 450 mm for enclosures under 3 m long and 800 mm for enclosures over 3 m long. Access to the areas behind enclosures over 3.5 m long shall be available from both ends of the enclosure.

Furniture on doors shall include substantial hinges of the lift-off type and provision for padlocking and positive latching with non-locking lever handles. Floor standing enclosure doors shall have internal extension mechanisms fitted to the handle to latch positively at the top, centre and bottom of the door.

16.12.4. ARRANGEMENT OF EQUIPMENT

The arrangement of equipment in and on the enclosures shall be such that maintenance can be carried out easily without dismantling other equipment. Equipment mounted on doors shall be kept to a minimum and no electrical relays shall be mounted on doors. Control devices and instruments shall be mounted as required by Sub-Clause S13.12 of the General Requirements.

16.12.5. DEGREE OF PROTECTION

Indoor enclosures shall provide a degree of protection not less than IP 44 and outdoor enclosures shall provide a degree of protection not less than IP 54 to IEC 60947. Separately mounted devices shall be enclosed with the degree of protection not less than IP 54 to IEC 60947.

16.12.6. GLAND PLATES

Detachable gland plates of sufficient size and number shall be provided for either top or bottom cable entry or both, except that outdoor enclosures shall not have top entry. Gland plates for single core cables shall be of non-ferrous material. Floor mounted indoor enclosures may have their bottom entry gland plates substituted by channel mounted cable clamps for cable support. Alternative
methods of prevention of vermin entry are required where channel mounted clamps are provided instead of bottom entry gland plates.

16.12.7. **ANTI-CONDENSATION HEATERS**

Anti-condensation heaters, 240 V a.c., complete with isolating switch and adjustable thermostat (with factory setting at 29°C), shall be provided in junction boxes and enclosures containing control or relay equipment, except where the external surface is less than 0.5 m² (excluding the bottom). Such heaters shall be installed in enclosures located outdoor or indoor whether or not they are ultimately to be located in an air-conditioned area. The heater shall be designed to provide adequate heating when energised at 240 V a.c.

The rating of the heaters shall be 20 W for each square metre of exposed surface area of the enclosure. Heaters shall be mechanically protected and live parts shall be shrouded. The surface temperature of any part of the heater shroud which is accessible shall not exceed 70°C. All heaters shall be provided with expanded aluminium covers to prevent accidental touching.

All enclosures fitted with anti-condensation heaters shall have ventilation openings in the doors. Openings shall be provided with fine brass gauze or a suitable filter to prevent entry of insects, water and vermin and to minimise entry of dust.

16.12.8. **SEALING OF DOORS**

Sealing of enclosure doors and covers shall be by closed cell neoprene foam sections on to surfaces at least as wide as the sealing section; estafoam type material is not acceptable for seals.

16.12.9. **CUBICLE LIGHT**

Luminaires shall be provided to light the inside of each enclosure large enough for a person to work inside. Luminaires shall be controlled by a fully enclosed door-actuated switch. Outdoor enclosures with 450 mm or larger roof overhang shall be provided with fluorescent luminaires fitted under the extremities of the roof. Such luminaires shall be controlled by a weatherproof, manually operated switch external to the enclosure.

16.12.10. **PAINTING**

Finish painting inside enclosures shall be gloss white and the finished surfaces outside shall present a first class appearance free from all blemishes, of uniform colour to adjacent enclosures. Equipment contained in enclosures shall be finish painted as if it were exposed to view.

16.12.11. **CUBICLE DESIGNATION**

The Contractor shall assign a three-letter alphabetic abbreviation to each enclosure and shall use this abbreviation on all diagrams. The cubicle abbreviations shall be subject to approval by the Project Manager. A label showing the cubicle abbreviation shall be provided on the outside rear or cabling side of each enclosure.

16.13. **EQUIPMENT WIRING AND WIRING ACCESSORIES**

16.13.1. **GENERAL**

All wiring within enclosures for electrical equipment shall comply with the requirements of this Sub-Clause. All electrical connections not within enclosures for electrical equipment shall comply with the cabling requirements of Sub-Clauses 14.20 to 14.23.
16.13.2. WIRING SYSTEM

Equipment wiring shall preferably be arranged and constructed entirely on a comprehensive modular system. The Contractor shall submit full details of the modular wiring system for the approval of the Project Manager. For equipment for which a modular wiring system is not available or not approved the following requirements shall apply:

- All wiring shall be carried out in accordance with wiring diagrams so that the arrangement of wiring is consistent throughout the Plant and identical for those parts of the Plant performing the same duties.

- Wiring shall be neatly and securely bunched or cleated, or enclosed in ducts or conduits, or supported on trays and run in the most efficient manner from point to point. Wiring shall be kept in bunched condition by means of strips of approved, non-flammable, self-locking plastic ribbon cable strapping at suitable intervals. Lacing of wire bunches with textile or plastic cord or metal buckle type clips will not be accepted. Wherever wiring is cleated to metalwork, it shall be insulated from the metal surface and shall be cleated by means of insulated straps in an approved manner. All wiring shall be left sufficiently long and neatly looped to allow a fresh termination to be made should the original termination device break off. Where wiring crosses between a side sheet and a hinged panel it shall be bunched and arranged so that flexing is reduced to a minimum and strain is not transmitted to any terminal.

- Each end of each wire shall be provided with a crimped termination with copper sleeved insulation and applied with a tool of the ratchet type. Not more than one wire end shall be fitted into any termination. The number of wires per terminal shall not exceed two. There shall be no jointing or teeing of wires between terminals and the number of wires on each terminal shall be as shown in the wiring diagrams.

- Wire numbers shall be allocated on the overall circuit diagrams and shall be used on all the Contractor's diagrams and equipment.

- Wire marker ferrules shall be fitted to each end of each wire to give the wire numbers as shown in the wiring diagram. Wire markers shall be white with black characters, except that where the letter "T" (signifying TRIP) is included in a wire number that marker shall have a white character on red background.

- Circuits of similar nature shall be grouped together on terminal blocks.

- All wiring provided under the Contract shall be adequately rated for the service conditions, employing conductors of cross-section not less than 0.5 mm² for alarm and solid state circuits and 1.5 mm² for other circuits. Conductors shall be copper with not less than seven strands. Internal wiring of miniaturised and solid-state equipment may use solid conductors having a minimum size of 0.5 mm² where wiring is made off by wire wrapping.

16.13.3. CURRENT TRANSFORMER WIRING

Current transformer secondary circuits shall be wired with copper conductors of not less than 2.5 mm² for transformers with 1 A secondaries and 4 mm² for transformers with 5 A secondaries.

Insulation

Insulation shall be 0.6/1 kV grade appropriate to the service conditions. It shall be self-coloured and used according to the following colour code:

<table>
<thead>
<tr>
<th>Colour</th>
<th>Abbreviation</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
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</table>
16.14. TERMINAL BLOCKS

16.14.1. SPECIFICATION

Terminal blocks shall be of an approved make and type and suitable for the particular application. Approval of terminal blocks will be given on presentation of samples and type test certificates demonstrating voltage rating, current rating and reliability.

Terminal blocks shall withstand 500 V r.m.s. for one minute and for circuits of 110 V and above shall withstand 2 kV r.m.s. for one minute between adjacent terminals and between terminals and earth.

For each terminal block the Contractor shall allocate an identifying number and shall show this number both on his wiring diagram and on the terminal block itself.

In each enclosure the Contractor shall provide sufficient terminal blocks to terminate all incoming cable cores, excluding spare cores. In addition, 10 per cent spare terminal blocks shall be distributed amongst the functional groups of terminal blocks.

The Contractor shall group terminals such that outgoing cables to the same destination terminate on the same or adjacent terminal blocks.

Terminal blocks in CT and VT circuits shall be of the disconnect type with plug-in test facilities. Terminal blocks in CT circuits shall have integral short-circuiting facilities, and the disconnector shall be easily operated when test connections are in place.

All disconnect type terminal blocks shall be complete with plug-in test facilities.

16.14.2. INTERFACE BETWEEN CONTRACTS

Terminal blocks for connections which are to be made by other Contractors shall be grouped separately from other blocks on the same terminal block assembly. All such terminal blocks shall be of the disconnect type, and shall be initially installed with the disconnect device in the OPEN position. Further, a wire bridge shall be provided between the incoming and outgoing terminal.cable cores.
blocks on the current source side of the terminal block for all connections to current transformers, transducer outputs and other current sources.

The disconnect devices shall remain open and wire bridges in place until such time as the Project Manager agrees that they may be closed or removed respectively. This will generally occur progressively during the course of pre-commissioning and commissioning.

16.15. ELECTRICAL SYMBOLS, DEVICE NUMBERS AND INDEXING

16.15.1. SYMBOLS

The symbols used for electrical diagrams shall be in accordance with IEC 60617.

16.15.2. COLOURS

The positive phase sequence and colours for three-phase a.c. power supplies shall be RED-YELLOW-BLUE. Transformation vectors and terminal markings shall be to IEC 60076 and BS 171.

DEVICE REFERENCES

The Contractor shall allocate numbers, for all control and other devices, to a device numbering scheme which shall be submitted to the Project Manager for approval. A device is an item of equipment containing an electrical coil, element or contact.

The Contractor shall show the device numbers in all of the following places:

- On all drawings relating thereto, whether key diagrams, circuit diagrams, wiring diagrams or arrangement drawing;
- On the devices themselves by labels (or by signwriting on electronic equipment to which labels cannot be applied);
- On a label on the back of the panel on which the device is mounted; and
- For plug-in devices, on the front of the panel adjacent to the device.

The Contractor, on each request, shall provide a separate updated list of device numbers for the Plant & Equipment to the Project Manager, arranged in numerical and alphabetical order.

Each device, or part thereof, shown on a circuit diagram shall be tabulated on that diagram, with its functional description, the make and type, the circuit diagram on which its principal element is shown (where separate), and the abbreviation of its location.

The Contractor shall provide a tabulation showing for each type of electrical device the terminal markings and ratings. This record shall be indexed according to device numbers.

16.16. EARTHING OF EQUIPMENT

16.16.1. GENERAL

The Contractor shall provide, on the frame of every item of equipment to which electrical supplies are taken or which would be connected under fault conditions, an earthing terminal of brass or stainless steel, complete with washers and nuts and of a size appropriate to the current rating of the largest supply. The construction of these frames shall be such that electrical continuity of exposed
metal (tanks, bases, pipes, cable trays and ladders, enclosures, etc) is maintained to the earthing terminal.

16.16.2. **EARTHING BUSBAR**

An earthing busbar of 25 mm x 3 mm (or larger) copper shall be provided near the bottom of each enclosure for electrical equipment and be painted green. The frame of electrical devices shall be connected to the earthing busbar. For enclosures with bottom cable entry the enclosure earthing busbar shall have provision for connection of an external earthing conductor of similar size. For enclosures where only top cable entry is provided the enclosure shall include copper strip connection to the vicinity of the top gland plate for connection of an external earthing conductor. A suite of enclosures shall have the earthing busbar interconnected and available for earthing internally at each end. Fixed terminal(s), shall be provided for this purpose.

16.16.3. **EARTHING CONDUCTOR**

Individual items with a supply protected by a circuit breaker or fuse of less than 20 A shall use stranded copper earthing conductor, and 20 A and over shall preferably use bare copper bar to give direct earth connection to the nearest main earthing conductor.

16.17. **CONTROL AND INDICATION TRANSFORMERS**

16.17.1. **GENERAL**

The 415/240 V control transformers shall be in accordance with IEC 60742, and shall be single-phase, 50 Hz, enclosed, non short-circuit proof, with secondary centre tap earthed through a 5 kilohm wire wound resistor. The resistor element shall have a vitreous enamel or other heat proof coating and be complete with mounting feet.

240/22 V indication transformers shall be in accordance with IEC 60742 and shall be single-phase, 50 Hz, enclosed and non short-circuit proof.

16.17.2. **SPECIAL REQUIREMENTS**

Control and indication transformers shall conform generally to the following requirements additional to or different from IEC 60742 but some variations of details will be considered:

- All terminals shall be suitable for use with approved wire terminations. The primary and secondary terminals shall be completely segregated within the enclosure by suitable fixed rigid insulating barriers forming separate compartments for the primary and secondary terminals. 20 mm diameter holes fitted with insulating bushes or grommets shall be provided for both input and output connections. No provision for cords is required.

- No fuses or other protective devices are required within the transformer enclosure.

- A centre-tapping is required for 240 V output windings of control transformers only.

- "Mechanical Strength" requirements shall not apply.

- The tolerance on the rated output voltage shall be ±2.5 per cent and the difference between the no-load output voltage and the voltage at rated output shall not exceed 5 per cent of the voltage at rated output for all transformers.

- Where transformers are required to supply the closing coils of motor starters, the output voltage of the transformers shall not fall below 85 per cent of the rated output voltage during pick-up of the closing coils when the input voltage is 415 V.
16.18. CABLELING DESIGN

16.18.1. SCHEDULE AND DIAGRAMS

The Contractor shall prepare, and submit to the Project Manager, cable schedules and termination diagrams for all of the Plant included in the Contract.

16.18.2. CABLE SCHEDULES

Cable schedules shall be in approved format, showing for each cable:

- Cable identification number;
- "From/to" information, showing the location of the two cable ends in separate columns by cubicle designation or device description with, where applicable, the device number as shown on the circuit diagrams;
- Brief description of route, listing cable trays, trenches, etc., by identification number or letter;
- Details of cable (type, conductor size, number of cores, route length in metres); and
- Type and size of cable glands.

Applications shall be restricted to low signal and solid state circuits, and pairs shall be individually screened where required by the application.

Conductors shall be adequately rated for the duty and shall have a minimum of seven strands. The minimum cross-sectional area shall be 0.5 mm$^2$.

If untinned conductors are supplied, crimp on terminal lugs shall be used.

16.18.3. COMMUNICATION-TYPE CABLES

Communication-type cables shall be twisted pair, single tinned copper conductors, insulated, bedded, aluminium foil screened, served and overall sheathed cables conforming where appropriate to IEC 60189 and BS 4808. Polythene insulation and sheathing may be used subject to the approval of the Employer.

The insulated conductors shall be uniformly twisted together in pairs with a right-hand lay. The direction of stranding shall alternate for successive layers, the first layer being right-hand.

Where fillers are necessary for satisfactory laying up of cable pairs, they shall be PVC free and halogen free.

The cables shall be made of the following standard numbers of pairs: 2, 6, 10, 20 or 50.

The identification of the manufacturer and the year of manufacture shall be printed on a plastic type tag beneath the sheath at not more than 1 m intervals.

The overall sheath shall be PVC free and halogen free and shall be coloured black.
16.18.4. CABLE TERMINATION

16.18.4.1. GENERAL

The termination of each end of each cable shall, unless otherwise specified, include the following:

- Fixing the cable by an approved gland (or clamp for bottom entry into floor mounted indoor cubicles);
- Fitting an approved lug to each core (except spare cores);
- Fitting an approved phase or polarity identification to each power cable core and identification ferrule to each control, indication, protection and alarm cable core;
- Connections to equipment terminals (except spare cores); and
- Fitting two approved cable identification tags to each cable end, one within the equipment enclosure and the other clearly visible outside the enclosure.

16.18.4.2. TERMINATION OF AUXILIARY POWER CABLES

Where possible, phase identification of multicore power cables shall be self-coloured cores. For cables where the cable cores are not self-coloured, the phase identification shall be provided by insulated non-flammable heat shrinkable tubing coloured red, white, blue or black as appropriate.

The Contractor shall ensure that a.c. cables are correctly phased and that polarity of d.c. cables is correct. Incorrect connections of power and control cables shall be rectified by the Contractor.

16.18.4.3. TERMINATION OF MULTICORE CONTROL CABLES

At both ends of each control cable all cable cores, except spare cores, shall be terminated on terminals. Each core shall be left sufficiently long and neatly looped to allow a fresh termination to be made should the original termination device break off. Where not enclosed in ducting the unsheathed portion of the cable shall be laced neatly with an approved non-flammable cabling strapping.

Spare cable cores need not be terminated but shall be left sufficiently long to reach the most remote terminal strip in the enclosure. Spare cores shall be loomed together and left neatly in the cable ducting inside the enclosure.

The Contractor shall provide and fit approved non-flammable wire-marking ferrules on each core of all multicore control cables. Spare cores shall be identified with the letter “S” followed by the cable number.

Where a separately mounted device to be connected cannot accommodate the specified cable or is not fitted with compliant terminals, the Contractor shall provide a junction box, complete with an approved type terminal block, adjacent to the device. The connection between the junction box and the device shall be made in PVC sheathed flexible steel conduit or screened flexible cord with a suitable cable gland.

Cable cores in multicore control cables shall be terminated using crimp-on cable lugs of the insulated type.

16.18.4.4. TERMINATION OF COMMUNICATION-TYPE CABLES

Where communication-type cables are terminated on stud type terminals the cable cores shall be terminated using crimp-on cable lugs or solder type cable lugs of approved make.
Communication-type cables terminating on pin type terminals shall be wire wrap terminations complying with IEC 60352.

16.18.4.5. TERMINATION OF CABLE SCREENS

Unless otherwise specified, the screens of screened cable shall be earthed at one end only. This shall generally be the end at which the signal originates. Shielded control and instrumentation cable shall be earthed at the end furthest from the main control/instrumentation equipment. For shielded cable using separate electrostatic and electromagnetic shields, the electrostatic shield shall be earthed at the end furthest from the main control/instrumentation equipment and the electromagnetic shield shall be earthed at both ends.

Earthing of copper screens shall be by means of wrapping three or more turns of 1.0 mm² stranded copper earthing conductor over the exposed screen and making an effective soldered joint with the screen. The earth conductor shall be terminated at the equipment by means of crimp-on terminal lugs. All earthing conductors shall be insulated.

16.19. INSTALLATION OF CABLES

16.19.1. GENERAL

All cables shall generally be installed on cable ladders except where preformed cable trenches or ducts have been provided or cables are buried direct in the ground.

In locations where available space restricts the installation of cable ladders, cables may be clamped to perforated cable trays or to horizontal ‘Unistrut’ channels, fixed direct to the wall. For vertical runs three methods shall be employed for the principal cable routes as follows:

- Open cable ladders with cables strapped to the ladder with ties;
- Cables clamped to ‘Unistrut’ type P1000 or P3300 channels with ‘Unistrut’ cable clamps or trefoil cable clamps; and
- Perforated cable trays. This method is limited to short complicated runs with many directional changes and tee-offs.

Cables may also be fixed direct to the surface of walls subject to the provision of mechanical protection in accordance with Sub-Clause S14.22.3.10 Power cables shall be spaced at least 20 mm from the wall.

Cables may be supported by running in galvanised steel conduits or pipes fixed direct to the surface. These steel conduits or pipes shall be purely for the provision of mechanical support to the cable and the cable sheath shall not be removed from cables within such conduits. Conduits shall be fixed in position with saddles at spacings of not more than 1 200 mm.

Cable installation facilities shall be fixed to concrete with expanding type masonry anchors. Explosion driven fasteners shall not be used. Holes shall not be drilled through reinforcing bars in columns and beams nor within 30 mm of such bars. The Contractor shall provide a suitable detection instrument to verify the bar locations prior to drilling.
16.19.2. DETAILED REQUIREMENTS

16.19.2.1. GENERAL

Cables shall be installed in accordance with IEE Regulations for the Electrical Equipment of Buildings and in accordance with the following additional requirements:

- Cables shall be installed in a neat and workmanlike manner free from kinks and unnecessary bends. The Contractor shall provide all necessary terminals, cable glands, ties, cleats, cable boxes and terminating facilities for the plant to which cables are to be connected and shall supply and install all facilities for the purpose of supporting cables.
- Particular care shall be taken that the cable sheath is not damaged during installation. Any cable damaged during installation shall be replaced by the Contractor.

16.19.3. SEPARATION OF ROUTES

All cables and supports shall be kept clear of process or service pipes, walkways and operating spaces.

Unless otherwise approved by the Project Manager power cables and control cables shall be separated physically.

16.19.4. SINGLE-CORE POWER CABLES

Single-core power cables shall be fixed at intervals not exceeding 2 400 mm for vertical runs and horizontal runs on cable ladders, and 600 mm for horizontal runs on ‘Unistrut’ channel, and at either side of bends or risers and before terminations.

Single-core power cables forming part of a 3-phase circuit shall, unless otherwise specified, be held in trefoil touching formation by cable ties and/or cable cleats at intervals not exceeding 600 mm for straight runs and not exceeding 300 mm in curves.

Cable cleats for single-core cables in trefoil formation shall be fixed direct to supporting steelwork or direct to concrete walls. The distance between the wall and the surface of the nearest cable shall not be less than 20 mm. The supports shall be capable of withstanding the extreme forces when the cables are carrying the maximum possible short-circuit fault current. Cable ladders shall not form part of the supporting steelwork for the purpose of fixing cleats.

Spacing between groups of trefoil cables or other adjacent power cables shall be equal to the width of the trefoil groups, or 150 mm, whichever is the less.

16.19.5. MULTICORE POWER CABLES

Multicore power cables shall be installed in one basic layer, spaced at least one cable diameter apart and fixed as follows:

- On horizontal ladders at intervals not exceeding 2 400 mm; and
- On vertical ladders or clamped to ‘Unistrut’ channels at intervals not exceeding 600 mm, or 20 times the outside diameter of the cable, whichever is the least.

16.19.6. CONTROL, INDICATION, PROTECTION AND ALARM CABLES

Control, indication, protection and alarm cables shall be installed as follows:
• On horizontal ladders, fixing is required for take-off points and elsewhere as necessary to ensure a neat secure formation;
• On vertical cable ladders, cables may be bunched in groups and fixed to cable ladders with cable ties at intervals not exceeding 300 mm. The overall height of the bunch shall not exceed 75 mm; and
• Where clamped to ‘Unistrut’ channel, cables may be bunched in groups and fixed to the ‘Unistrut’ channel with clamps at intervals not exceeding 300 mm. The overall height of the bunch shall not exceed 75 mm.

16.19.7. CONTROL AND POWER CABLES ON ONE LADDER

Where the number of power and control cables installed in the one area does not warrant the installation of separate cable ladders, both types of cable may be installed on the one cable ladder or side by side on the one set of ‘Unistrut’ channels. In such cases control, indication, protection and alarm cables may be bunched as described above, but power cables shall be spaced at least one cable diameter away from the control, indication, protection and alarm cables and from other power cables and be installed in one basic layer only.

16.19.8. BENDING RADIUS

The bending radius of cables both during installation and the final set shall not be less than those recommended by the manufacturer for the individual cable types and in no case be less than eight times the outside diameter of the cable.

16.19.9. SUPPORT OF CABLES

All cables shall be provided with supports located as close as is practicable to the point of termination of the cables. Cables run on perforated cable trays shall be fixed with profile shaped saddles at spacings between 150 mm and 300 mm as required to ensure a neat installation without sagging between saddles. Cables leaving cable ladders over the side rail shall be fixed to the ladder at the point from where they start to lift. Where cables drop over a ladder rung, the sharp edge shall be fitted with a smooth radius drop-out fitting.

16.19.10. CABLE PROTECTION

In all locations within 1 800 mm of the floor and in any other locations where cables may be exposed to mechanical damage, the Contractor shall provide and install substantial sheet steel guards to protect the cables, or alternatively shall enclose the cables in steel pipes or conduits. Cables shall not be installed in a common trench with pipework unless suitably protected and segregated from the pipework by one of the methods described above. Where cables on ladders pass under or adjacent to pipes containing fluids they shall be provided with covers to divert any leaking fluid.

16.19.11. SEALING OF OPENINGS

Where cables, including cables in ducts, trays or trenches, pass through a concrete wall, floor or ceiling or enter or leave pipes the space between the concrete or pipe and the cables shall be sealed with a fireproof sealing mixture of three-to-one by volume of granulated vermiculite and cement mixed with water to form a stiff mix, or other fireproof sealing approved by the Project Manager. Cabling through concrete floors into bottom entry cubicles is included in this requirement.

Cable pipes and ducts entering buildings and pits shall be first fireproofed with the seal described above then sealed with plastic weatherproof compound.
Cable trenches entering buildings and openings between building interiors and external cable pits shall, at the point of entry, have the fireproof seal overlaid with a weatherproof compound on the external side.

The seals around the cables shall be trimmed as required to give a neat appearance, and match-painted by the Contractor when forming part of painted concrete surfaces.

16.19.12. CLEANING OF PIPES

The Contractor shall ensure that embedded or buried pipes for installation of cables are satisfactory for the purpose and shall rod the pipes throughout with a mandrel, 3 mm less than the inside bore of the pipe, followed by a wire brush. The pipes shall then be inspected and the ends of pipes shall be plugged with properly prepared and shaped timber plugs until the installation is commenced.

16.19.13. REMOVAL AND CUTTING OF TRENCH COVERS

Formed cable trenches for installation of cables shall be fitted with covers. Before commencing installation of cables the Contractor shall mark the covers to show their position on such trenches and where appropriate take those covers into safe keeping.

Immediately after cabling is completed the covers shall be replaced. During periods when installation is temporarily suspended, the trenches shall be made safe by replacing the covers or by other approved means.

Where necessary to permit the passage of cables, the covers shall be cut by the Contractor and lined in an approved way to prevent chafing of the cables.

When galvanised trench covers are cut, the exposed steel surfaces shall be protected in accordance with Sub-Clause R2.4 of the Standard Technical Requirements.


Cables to be laid underground shall be drawn into pipes or ducts where appropriate.

In all other places cables shall be laid direct in the ground at the following minimum depths:

- Cables 0.6/1 kV, 600 mm under roadways and 500 mm other locations.
- Cables above 1 kV rating, 700 mm at all locations.

Before any bedding sand is placed in the trench the excavation shall be submitted to the Project Manager for approval. The lowest cables in a trench shall be laid in a 50 mm bed of sand. Sand shall then be added until the top of the uppermost cable is covered to a depth of 50 mm. Particular attention shall be paid to maintaining cable spacings appropriate to the design cable rating.

Concrete or clay brick protective covering for cables shall be placed on top of the bedding and shall comprise either of the following:

- Pre-cast concrete slabs of minimum thickness 38 mm and compressive strength 15 MPa minimum
- Concrete slabs cast on site of 100 mm minimum thickness
- Clay bricks laid close together lengthwise for cables rated 1 kV or lower and crosswise for cables rated above 1 kV.
A yellow polythene tape approximately 150 mm wide by 0.25 mm thick of continuous length and marked "ELECTRICITY CABLE" in 50 mm high black letters at intervals not exceeding 600 mm shall be buried approximately 100 mm above the cable slabs.

Before backfilling is commenced the works shall be submitted to the Project Manager for inspection. Backfilling shall be carried out using soil from the excavation. It shall be placed in layers not exceeding 300 mm loose depth. Each layer shall be compacted by hand or power ramming until dense firm consolidation is obtained. Surplus soil shall be disposed of in approved disposal areas on the Site as specified elsewhere in the Employer’s Requirements.

Cable marker posts for direct-laid cables shall be supplied and placed at intervals of 30 m to indicate the position of the buried cables and at every position where the cable changes direction. The marker shall be set in the ground to a depth of approximately 350 mm, directly over the buried cable.

16.20. CABLE INSTALLATION MATERIALS

16.20.1. CABLE IDENTIFICATION TAGS

The Contractor shall provide and firmly attach stainless steel or non-ferrous identification tags 50 mm long x 12 mm wide to each cable. The tag shall be fixed longitudinally along the cable by binding with 1.00 mm or larger diameter copper or approved non-corrodible wire through end holes in the tag.

Each identification tag shall be stamped indelibly with the appropriate cable number in accordance with the cable schedules, the letters and figures being not less than 5 mm high.

16.20.2. CABLE GLANDS

Cable glands shall be of the weatherproof compression type, and for outdoor locations shall be of non-ferrous metal. Cable glands for cables with an overall diameter over 20 mm shall be of metal. For single core cable, glands and locknuts shall not be made of ferrous metal.

16.20.3. CABLE LADDERS AND CABLE TRAYS

16.20.3.1. GENERAL

Unless otherwise approved, cable ladders and trays shall be of the open type as specified in this Sub-Clause.

16.20.3.2. CABLE LADDERS

Cable ladder systems shall be of an established design, complete with horizontal bends, tees, inside and outside risers and all the necessary accessories including splices, support brackets, hangers, clamps, etc. Double hanger rods or single centre rail supports are acceptable. If designs other than standard known commercial types are proposed the Contractor shall show the adequacy of the design strength.

Cable ladders, and accessories shall be preferably manufactured from aluminium. If manufactured from steel they shall be hot-dipped galvanised after forming and shall have rungs at a spacing not greater than 300 mm. Cable ladder rungs shall have slotted holes suitable for fixing cables with cable ties. The side rails of the cable ladders, and all bends, risers, tees and similar fittings shall have a rolled or double return top edge of at least 10 mm diameter (or width).

The loading of cable ladders shall in no case exceed the manufacturer's recommended design load.
The span deflection of cable ladders shall not exceed the ratio of 1 in 200.

16.20.3.3. **PERFORATED CABLE TRAYS**

Perforated cable trays shall be hot-dipped galvanised trays with returned edges not less than 12 mm high, made from not less than 1.5 mm thick sheet steel. Trays shall be installed with the returned edges against the wall or ceiling surface.

Cable saddles shall be fixed to the perforated cable trays with screws and nylon-type nuts inserted from the cable side into the slotted holes.

16.20.3.4. **MASONRY ANCHORS**

Masonry anchors shall be of the expanding corrosion-proof type. The Contractor shall supply full details of the proposed masonry anchors, complete with typical pull-out values, for approval.

16.20.3.5. **CABLE TIES**

Unless otherwise approved, the following type of cable ties shall be used:

- For multicore cables, nylon cable ties with a minimum tensile strength of 530 N, similar to Burndy type TF-7D.
- For single core power cables protected by HRC fuses:
  - For holding in trefoil formation, stainless steel ties complete with stainless steel buckles, 12.5 mm wide with a minimum tensile strength of 2 kN.
  - For fixing to cable ladders, nylon ties in accordance with paragraph a. of this Sub-Clause.
  - For single-core power cables not protected by fuses, for holding in trefoil formation, stainless steel ties complete with stainless steel buckles, not less than 12.5 mm wide with a minimum tensile strength of 4 kN.

The Contractor shall submit evidence that the proposed ties have the required strength.

16.20.3.6. **TREFOIL CABLE CLEATS**

Trefoil cable cleats shall be of non-magnetic material, fitting the contours of the cable and securely anchoring the cable into position. The cleats shall be capable of withstanding bursting forces of 4 kN due to fault current in the cable.

16.20.3.7. **CABLE MARKER POSTS AND CABLE JOINTS MARKER POSTS**

Cable marker posts shall be reinforced concrete posts 600 mm long x 100 mm diameter with recessed lettering in letters not less than 50 mm high (text to be advised by the Project Manager). The posts shall be set in the ground to a depth of approximately 350 mm directly over the buried cable.

Cable joint marker posts shall be reinforced concrete posts 700 x 150 x 75 mm with recessed lettering identifying the project (text to be advised by the Project Manager) with embedded brass plate 100 x 100 x 3 mm, engraved with the following lettering and information:

- Joint number.
- Voltage rating and type of cable.

The cable joint marker posts shall be set in the ground to a depth of approximately 350 mm directly above the cable joint.
16.20.3.8. SUPPORTING STEEL WORK

All supporting steelwork shall be of adequate strength and hot-dipped galvanised after manufacture.

16.20.3.9. CONDUIT

Metallic conduit and fittings shall be hot-dipped galvanised.

Steel conduit shall be rigid screwed steel conduit with metric thread to IEC 60423. Joining of conduit by means of welding is not permitted.

Steel conduit fittings shall be made of malleable cast iron, except that flush wall boxes may be made of sheet steel.

PVC conduit shall be heavy duty conduit to IEC 60614.

The Contractor shall satisfy the Project Manager that all metallic conduit is adequately protected against any corrosion which may arise due to wet conditions or otherwise.

Where wiring is to be concealed from view, the conduits shall be installed above suspended ceilings, embedded in concrete or chased in brick walls. The chasing of concrete walls and floors is not acceptable. Conduit chased in brick walls shall be covered by at least 10 mm of plaster.

The embedded conduits shall be hot-dipped galvanised steel screwed conduit. The wall boxes to take switches and wall sockets shall be of a type suitable for the equipment proposed to be installed. Galvanised iron draw wires of 1.6 mm, diameter shall be left in all conduits. The embedded conduits shall be checked and cleared if necessary prior to or immediately after removal of formwork.

Junction boxes and draw-in boxes in concrete walls and ceilings shall be installed with the face of the box flush with the formed surface of the concrete unless otherwise approved by the Project Manager. In brick walls the bricks shall be cut neatly and the junction boxes shall be installed so as not to protrude beyond the finished surface. Each flush wall box shall be installed with its side horizontal and vertical to within two degrees of arc. Where two or more flush boxes are adjacent to each other the distance between them shall be not less than required for the satisfactory installation of the flush plates.

Neither plain nor inspection type elbows and tees shall be used in the concealed conduit installation.

Conduits shall be installed to allow safe and easy drawing in of cables. Where conduits are bent, the inside radius of the bend shall not be less than six (6) times the nominal size of the conduit. No more than two consecutive 90° bends or a multiple number of bends adding up to a total of 180° shall be installed between two conduit ends. Where more than the above numbers of bends are required an intermediate flush draw-in box shall be provided. Conduit runs in excess of 10 m shall also be provided with draw-in boxes.

Conduit exposed to view shall run parallel to the structural lines.

Where surface mounted conduit crosses an expansion joint approved expansion fittings shall be provided.

Where embedded conduits run across expansion or contraction joints in concrete, a 1 m section of flexible steel conduit equal to “Sealtite Anoconda Metal Hose”, complete with connectors, shall be inserted across the joint. In addition the flexible conduit shall be taped with 2 layers of half lapped bitumen impregnated paper tape bedded in a bituminous undercoat. An alternative arrangement
using expansion/deflection couplings will also be acceptable subject to the approval of the Project Manager.

All screwed joints in embedded conduit shall be made watertight by sealing with a plastic weatherproof compound. Conduits shall be electrically continuous between conduit ends. All ends of conduits shall be reamed with a conical reamer and all burrs and sharp edges shall be removed to prevent damage to the wire insulation. All damage to the galvanising coat, including exposed screw threads shall be painted in accordance with R2.4.5.

All joints in PVC conduit shall be made waterproof by use of suitable adhesive compounds. Suitable moulded thread attachments shall be used for entry into equipment. Flexible expansion couplings shall be used to allow movement due to temperature variations.

The Contractor shall ensure that all embedded conduits and associated fittings are not damaged or displaced during the placing of concrete or the installation of reinforcing bars and embedded metal work and that the embedded conduits are kept clean of the ingress of concrete or mortar. To this end all embedded conduits shall be fitted with temporary caps.

Connections between embedded conduits and exposed conduits or cable troughs shall be made in an approved manner and in such a way that metallic and electric continuity is not impaired.

All surface mounted conduits shall be fixed in position with stand-off saddles and screws, spacing the conduit approximately 5 mm off the surface, at spacings not more than 1.20 m for steel conduit and 0.80 m for PVC conduit.

The ends of conduits shall either terminate in a metal box or be screwed directly into a fitting.

16.20.3.10. CABLE TRUNKING

Cable trunking shall be hot-dipped galvanised steel trunking not less than 1.5 mm thick, complete with removable cover and cable retaining clips.

The cable trunking system shall be an established system complete with fishplates, bends, risers and other associated fittings.

All trunking shall be spaced off the surface using 5 mm PVC spacers, and fixed at least every 1.50 m.

There shall be no sharp projections into the cable trunk, only the heads of mushroom head screws shall be permitted inside the cable trunk.

16.21. SIGNAL INTERFACE REQUIREMENTS

Where the control system has protection, control, indication and alarm inputs from and outputs to equipment provided by another Sub-Contractor / Supplier the following shall apply:

- The Sub-Contractor / Suppliers shall mutually agree the types and quantities of IO required.
- The Control System Sub-Contractor / Supplier (1) shall provide capacity in the control system for the required IO plus 10% spare of each type, with a minimum of one spare of each IO used, and shall provide interface equipment which has physical capacity for the required IO plus spares.
• The Second Sub-Contractor / Supplier (2) shall provide for installation of the interface equipment within the equipment it is providing. If it is not possible Sub-Contractor / Supplier (2) may provide a standalone control system cabinet or cubicle.

• Sub-Contractor / Supplier (1) shall supply to Sub-Contractor / Supplier (2) the control system interface equipment.

• Sub-Contractor / Supplier (2) shall mount the control system interface equipment in its cubicle or equivalent facility.

• Sub-Contractor / Supplier (2) shall provide sufficient isolatable terminals for the required IO (plus 10% spares) for connection to the interface equipment.

• Sub-Contractor / Supplier (2) shall wire its IO to the isolatable terminals. The isolatable terminals shall have the isolator OPEN and any current circuits shorted out.

• When the equipment is on site, Sub-Contractor / Supplier (1) shall connect the IO from the isolatable terminals to the interface equipment, and shall provide and connect the power supply for the interface equipment.

• Sub-Contractor / Supplier (2) shall prove its IO from the devices to the isolatable terminals.

• Sub-Contractor / Supplier (1) shall prove the IO from the isolatable terminals to the corresponding control system data points.

16.22. INSULATING OIL

Mineral insulating oil for transformers shall comply with the latest edition of IEC Publication 60296.

Ester insulating fluid for transformers shall be an ester oil, either a natural vegetable oil enhanced by anti-oxidants, classified as tri-ester, or synthetic ester oil, classified as tetra-ester, otherwise to meet the requirements of the latest edition of IEC 61099.

The Contractor shall state the type and grade of oil proposed. The oil shall be of a type which is available from normal local commercial sources.

The transformers shall be supplied with the first filling of oil.

Care shall be taken to prevent contamination of oil during transport, handling and storage.

The electrical insulating properties of the oil, offered as minimum values, shall be submitted to the Project Manager for approval of the insulating oil. The following properties shall be stated to IEC and ISO Publications test specifications: breakdown voltage, kinematic viscosity at 40°C and 100°C, acidity neutralisation value, dissipation factor at 20°C, DC resistivity at 20°C, water content, and fire point.

To reduce the susceptibility of the insulation oil to oxidation, sealed transformers shall be provided where the transformer rating permits this construction.

Testing and handling equipment for the mineral oil or ester oil shall be provided with sealing covers on all oil openings. The equipment shall be clearly labelled for its exclusive use with the particular type of insulating oil for which it was supplied.
17. MECHANICAL REQUIREMENTS

17.1. S18.1 FABRICATION AND WELDING

17.1.1. STANDARDS

The design, fabrication, testing and inspection of welded fabrication shall be in accordance with the following respective standards:

i. Category A

For general steel structural components to AISC Specification for the Design, Fabrication and Erection of Structural Steel for Buildings.

ii. Category C

For aluminium components to Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

17.1.2. GENERAL REQUIREMENTS FOR FABRICATION

The following requirements shall apply to all fabrication of components in Categories A, B and C:

i. Plates and sections shall be free of all surface marks or damage exceeding 1 mm deep.

ii. Weld root gaps for partial penetration welds shall not exceed 1.5mm. The dimensions of weld preparations, root gaps and plate alignment shall be to tolerances specified on the relevant drawings. All weld preparations shall be subject to examination for material flaws.

iii. Before welding, the weld preparation and plate surface on either side of the preparation shall be completely cleaned to base metal including complete removal of any surface coating by abrasive blasting to ensure satisfactory weld.

iv. Weld procedure and welder qualification tests shall be carried out in accordance with the appropriate standards. Where the standard does not specifically require weld procedure and/or welder qualification tests, the Project Manager may require the Contractor to submit details of the proposed weld procedure and of the qualifications of the proposed operator. The Project Manager may at his discretion require that weld procedure and/or welder qualification tests be conducted in such cases. The Project Manager reserves the right to call for further qualification tests and to withdraw approval of any welder whose work is unsatisfactory.

v. Weld procedure and welder qualification tests shall be carried out under conditions identical to the production conditions, including preheat, electrode treatment, interpass temperature, degree of restraint and stress relief.
vi. The dimensions of fillet welds shall be not less than nominated on the relevant drawings. Undercut not exceeding 1 mm deep shall be removed by grinding; undercut exceeding 1 mm deep shall be filled by welding.

vii. The surface of welds shall be smooth and free of sharp contour changes. The Contractor shall grind the surface of any weld as necessary to avoid affecting the interpretation of non-destructive examination.

viii. Arc strikes on the plate surface shall be avoided. Accidental arc strikes shall be ground out and the area crack-detected.

ix. Welded-on fabrication aids shall be kept to a minimum. They shall be attached only by approved welders using approved procedures and shall be removed by flame cutting not less than 1.5 mm above the parent plate surface and then by subsequent grinding and crack-detecting of the weld area.

x. Butt welds shall be free from underfilling and from reinforcement greater than one-tenth the face width of the weld. All undercut shall be filled by welding.

xi. Wherever practicable, welding shall be carried out in the downhand position.

xii. Weld splatter shall be removed where appropriate. Machined surfaces and tapped holes shall be adequately protected from splatter during welding.

xiii. Joints not completely protected from the weather or in a corrosive environment shall be seal welded. Unless otherwise approved, welds between dissimilar metals shall be performed at the Contractor’s premises.

xiv. Electrodes shall be stored and dried before use strictly in accordance with the electrode manufacturer’s recommendations and welding code requirements.

xv. Preheat and interpass temperatures shall be applied in accordance with the electrode and steel manufacturer’s recommendation and with the weld procedure tests. Measurements shall be by temple sticks or surface pyrometer on the opposite side of the plate surface from that to which heating is being applied.

17.1.3. FURTHER REQUIREMENTS FOR CATEGORY A COMPONENTS

The following further requirements shall apply to components in Category A:

i. All plate material and sections shall be identified by heat number at all phases of fabrication and erection. They shall be checked ultrasonically for internal defects in accordance with BS EN 10160.

ii. As far as practicable all shop-welded fabrications shall be stress relieved.

iii. As far as practicable, all welds shall be full penetration, back-gouged and of a configuration which lends itself to radiographic or ultrasonic examination.
17.1.4. **STAINLESS STEELS**

Stainless steels used on components subject to total or frequent immersion in water shall have sulphur content less than 0.03 per cent.

17.1.5. **CASTINGS AND PATTERNS**

All steel castings shall be heat-treated in accordance with the relevant standard. All iron castings shall be mild annealed in a suitable annealing furnace to relieve casting strain before being machined.

The Contractor shall retain all patterns required for the production of the Plant at least until the end of the guarantee period.

17.1.6. **THREADFASTENERS**

Bolts, nuts, studs, screws and washers shall be to the ISO metric system.

Steel bolts shall be forged unless otherwise approved.

Steel fasteners greater than 8 mm diameter and with coarse threads shall be hot-dip galvanised in accordance with ISO 1461.

Steel fasteners with fine threads and those with coarse threads less than 8 mm in diameter shall be of stainless steel or electroplated with zinc to BS EN 12329 and BS EN 12330. With the exception of some fasteners on the turbine, fasteners in contact with water shall be of stainless steel. Fasteners used in proprietary items shall be subject to the approval of the Project Manager.

All parts shall be spot-faced or machined for nuts or bolts except in the case of clearance bolts in structural steelwork.

Tapped holes shall not be used in sheet metal less than 6 mm thick.

Fasteners of less than 6 mm diameter shall not be used except if specifically approved by the Project Manager.

Threaded fasteners of more than 8 mm diameter shall have hexagon or socket hexagon heads.

All threaded fasteners shall be locked in an approved manner. Direct welding of bolts or nuts will not be accepted.

Bolts and studs greater than 50 mm diameter shall be arranged for tightening by hydraulic tensioning devices.

17.1.7. **LUBRICATION**

The Contractor shall submit, for the approval of the Project Manager, a complete list of the lubricants recommended for each moving equipment; this list shall give the type and grade of each lubricant in sufficient detail to permit the correct lubricant to be supplied by local commercial sources.

The Contractor shall as far as possible standardise on lubricant types used in similar types of Plant so as to minimise the number of types required.
All lubricating oils and greases added to the Plant prior to delivery to the Site shall be of a type and grade approved by the Project Manager. Where flushing oil is required it shall be of a type and grade compatible with the final oil to be used and shall be to the approval of the Project Manager.

All lubricating oil and greases added prior to delivery to the Site and all flushing oils shall be provided by the Contractor. The first fill, for erected plant, of all required grease and oil shall be provided by the Contractor.

The Contractor shall nominate a minimum number of standard size grease nipples from BS 1486 which shall be used for all Plant.
18. **BID DRAWINGS**

18.1.1. **GENERAL**

The drawings provided in this Section and listed below are solely for the purpose of Bid Information and Bid preparation only. The drawings present typical details in respect of the Project Facilities and Plant requirements.

18.1.2. **BID DRAWINGS LIST**

**PROJECT AREA AND ADMINISTRATIVE DISTRICTS MAP**

Drawing Number and Title;

1. 5083020-MAP-001 Lot 3A and Lot 3B Project Area Overview and 132/33kV Substation Locations

**SUBSTATION LAYOUTS AND SINGLE LINE DIAGRAMS**

**DRAWING NUMBER AND TITLE:**

1. 5083020-NRK-001 LOT 3A 132kV/33kV Narok Substation SLD Layout Drawing.
2. 5083020-BMK-001 LOT 3A 132kV/33kV Bomet Substations SLD Layout Drawing.