SECTION V

4.1.2 PARTICULAR TECHNICAL SPECIFICATIONS

FOR

SUBSTATION AUTOMATION, CONTROL AND PROTECTION

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4.1.2 Substation Automation, Control and Protection.

4.1.2.1 Substation Automation and Control

4.1.2.1.1 General

The sections below cover the technical requirements for the systems of control, protection, metering and signalling of the sub-stations. The control and relay boards shall include all equipment as specified in Scope of Works, needed for complete installations. Any computer solution proposed shall be based on hardware and software well proven in HV installations. All data storage media shall be checked for internal faults and virus before delivery.

The supplied and installed instruments, relays, switches and other equipment shall properly match the equipment to which it shall be connected, and which is included in the sections dealing with the different types of switchgear for transformers, transmission lines and other items.

The complete and detailed scheme of control, protection, alarms, etc., shall be proposed by the Contractor for each individual sub-station project. In this detailed planning the Contractor shall carefully consider the future extension of the plants. The Bidder shall guarantee the availability of spares in 10 years from cessation of normal production. This shall be demonstrated in the bid

The control, metering and protection equipment can be placed in common panels but not as integrated functions. The panels shall not be unnecessarily crowded but have space for moderate extensions.

All control functions and status indications shall be clearly arranged in a mimic diagram. The bay control unit shall have a mimic diagram for all the equipment in the bay. The equipment shall be on a modular basis connected to terminals inside the panels and easy to replace.

For indoor MV switchgear the control and protection can be located in the instrument compartment in the switchboard.

All data and parameters specified to the individual distributed control units, shall be stored in a non-volatile memory so no local logic or information will be lost due to power supply failure.

The Contractor’s scope shall comprise the design, manufacture, factory testing, packing, transport, insurance, unloading, storage on Site, construction works and erection, corrosion protection, site testing, submission of documentation, commissioning, training of KPLC’s personnel and warranty of the system.

4.1.2.1.2 Overview of Substation Automation SAS

This Substation Automation System (SAS) comprises full station and bay protection as well as control, monitoring and communication functions and provides all functions required for the safe and reliable operation of the substations.

It shall enable local station control via a Personal Computer (PC) by means of a human machine interface (HMI) and control software package, which shall contain an extensive range of system control and data acquisition (SCADA) functions. It shall include communication gateway, inter-bay bus, intelligent electronic devices (IED) for bay control and protection.

The communication gateway shall secure the information flow with Regional Control Centres. The inter-bay bus shall provide independent station-to-bay and bay-to-bay data exchange. The bay level intelligent electronic devices (IED) for protection and control shall provide the direct connection to the switchgear without the need of interposing components and perform control, protection, and monitoring functions.

In order to meet the requirements of this specification the detailed design of the SA is in the scope of contractor, subject to approval by Project Manager.
protocols outlined above.

The substation must communicate with the Regional Control Centre, from where it shall be monitored &controlled.

4.1.2.1.3 Design

The Substation Automation System (SAS) shall be suitable for operation and maintenance of the complete substation including future extensions. The offered products shall be suitable for efficient and reliable operation of outdoor or indoor substations for distribution and transmission.

The systems shall be of the state-of-the art based on IEC61850-3-2013 and IEC60870-104 for operation under industrial conditions present in high-voltage substations, follow the latest engineering practice, and ensure long-term compatibility requirements and continuity of equipment supply and the safety of the operating staff.

The offered SAS shall support remote control and monitoring from Regional Control Centre via gateways.

The system shall be designed such that personnel without any background knowledge in microprocessor-based technology are able to operate the system easily after having received some basic training.

Cubicles shall incorporate the control, monitoring and protection functions specified, self-monitoring, signaling and testing facilities, measuring as well as memory functions, event recording and disturbance recording. The basic control functions are to be derived from a modular standardized and type-tested software library.

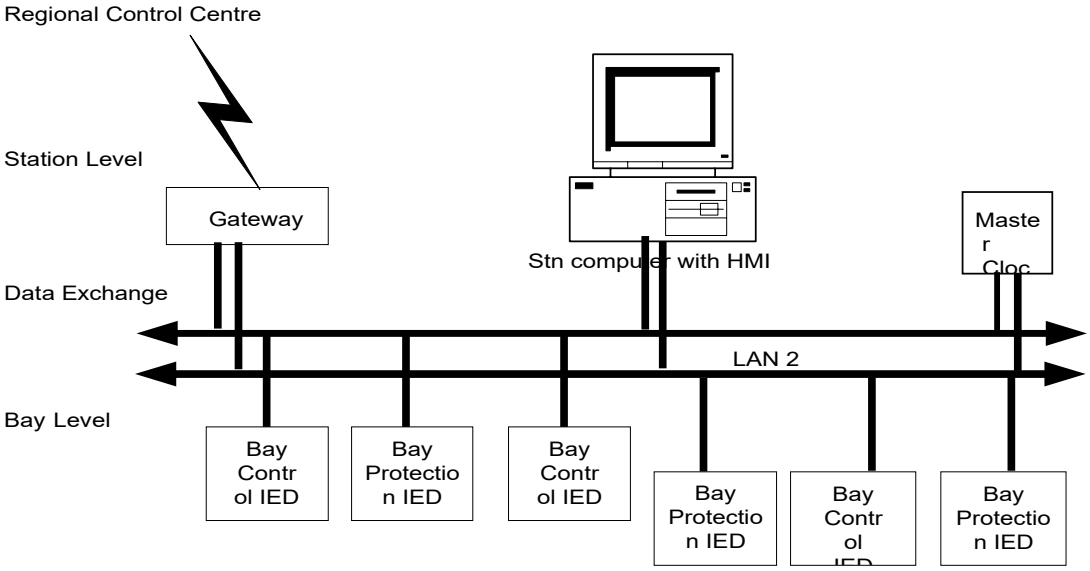
For safety and availability reasons the Substation Automation System shall be based on a decentralized architecture and on a concept of bay-oriented, distributed intelligence.

Functions shall be decentralized, object-oriented and located as close as possible to the process. The main process information of the station shall be stored in distributed databases.

4.1.2.1.4 Typical SAS Architecture for Substation

The typical SAS layout shall be structured in two levels, i.e. in a station and a bay level. The system shall accommodate control, data acquisition, alarm handling and trend analysis. The figure below illustrates the main principles. However, the Employer wants to keep a conventional back up control facility with indication at bay level (local control). i.e. control of motorised breakers and switches, status indication of all breakers and switches, analogue or digital indication of measurands (I and Imax all phases, MW and MVAr) and alarm annunciation shall be presented by discrete components.

System Architecture of Substation Automation



Layout is for 23 MVA substations and above, for 7.5 MVA Substations, redundancy is reduced

At bay level, the IEDs shall provide all bay level functions regarding control, monitoring and protection, inputs for status indication and outputs for commands. The IEDs should be directly connected to the switchgear without any need for additional interposition or transducers.

Each bay control IED shall be independent from each other and its functioning shall not be affected by any fault occurring in any of the other bay control units of the station.

The data exchange between the electronic devices on bay and station level shall take place via the inter-bay bus. The bus shall be realized using fibre-optic cables or Ethernet.

At station level, the entire station shall be controlled and supervised from the station HMI. It shall be possible to control and monitor the bay from the bay level equipment, in the event that the communication link fails. The station wide interlocking shall also be available when the station computer fails.

To provide highest reliability the station HMI and the gateways shall work completely independent meaning retrieving the process data directly from the bay level devices.
Additionally the gateway and the station HMI shall be configured fully redundant to ensure full functionality in case of single point of failure.

Clear control priorities shall prevent that operation of a single switch can be initiated at the same time from more than one of the various control levels, i.e. SCADA, station, bay level or apparatus level. The priority shall always be on the lowest enabled control level.

The station level contains the station-oriented functions, which cannot be realised at bay level, e.g. alarm list or event list related to the entire substation, gateway for the communication with remote control centres.

A dedicated master clock for the synchronization of the entire system shall be provided. This master clock should be independent of the station computer and of the gateway, and should synchronize all devices via the inter-bay bus.

The SAS shall contain the following main functional parts:
(i) Human Machine Interface (HMI) with process database
(ii) Separate gateway for remote supervisory control via SCADA
(iii) Hot Standby Gateways for stations with transformation capacity of 23MVA and above.
(iv) Master clock (GPS receiver)
(v) Collection of the relevant data concerning the substation and distribution of the data where needed
(vi) Bay and station level devices for control, monitoring and protection
(vii) Bay-oriented local control and protection panels.

The gateway/RTU shall be used, to collect, store and map signals of relays, measurement units, control units and other IEDs in the substation to The National Or Regional Control Center

The following protocols shall be supported by the gateway/RTU towards the process/substation end: IEC 61850, IEC 60870-5-101/104, IEC 60870-5-103, Modbus Serial, Modbus TCP/IP and DNP3.0.

The RTU/gateway shall be able to support hardwired signals where required.

The following protocols shall be supported by the gateway/RTU towards the control center: IEC60870-5-101/104

There are different types of switchgear and equipment in Sub Stations.
In automating an existing substation, which has old switchgear & auxiliary equipment (i.e. non IED) installed, the RTU can be connected directly to auxiliary contacts & transducers of the process via a Marshalling Cubicle with interposing relays& local transducers.

In substations with relays/IEDs, modern measuring and control units, it shall be possible to use compatible and supported, non- proprietary communication protocols, as listed above.

4.1.2.1.5 Scope of Work:

The following equipment and adaptation works are required at the station level for supervisory control and data acquisition:

- New Remote Terminal Units (RTUs)
- Interfacing Marshalling Cubicles,
- Interface terminal blocks at the existing station control and protection panels or at the station equipment itself.
- Cabling between RTUs and the points where the required data are available (either marshalling cubicles or interface terminal blocks in existing control and relay panels at the stations)
- Wiring modifications and additional de-coupling relays
- Analogue and digital transducers

The contractor shall provide the following:

- Provision of all hardware and software necessary to control and monitor the substation equipment both locally and remotely.

- Interface substation equipment to local control panels.
- Incorporate new and modified substation equipment into the SCADA/EMS System at the Central Control Centre
- At all substation sites, the Contractor shall undertake a complete survey of existing facilities to ensure that any additional control equipment provided under the scope of this package, provides at least the same level of control and functionality as similar existing equipment on site and provides a seamless interface to all the substation control points.
- The status, alarms and analogues from the new and modified circuits shall be presented to the Regional Control Centre RTU either by provision of additional transducers (Amps, Volts, MW, MVAR) or by an additional direct input CT/VT card in the RCC RTU.

4.1.2.1.6 SAS Equipment

All SAS equipment shall be of industrial type conforming to IEC 61850-3-2013 standards

4.1.2.1.6.1 The RTU Technical Specifications:

The RTU shall be programmable, with real time clock, synchronized by an external source, process Input and Output (I/O) modules, CPU, memory and data transmission equipment.

The new RTU to be supplied and installed under the project shall provide at least the following functions:

- Single command outputs, double command outputs
- Regulation command outputs e.g. Raise/lower command outputs for transformer tap changer control
- Analog setpoint transmission and output
- Single, double and multiple state digital inputs
- Analogue measured inputs
- Metering pulse inputs for acquisition of energy meter values
- Sequential event recording (ser) with time stamping of events at the rtu
- RTU time synchronization
- Self-testing and diagnostic functions for detection and reporting of any error
- Automatic re-starting function
- Database and parameter setting by menu-controlled dialogues from a local pc and remotely from the corresponding control centre with downloading function.
- Shall be designed to operate in aggressive industrial environments, complying with the highest standards, such as Electromagnetic compatibility (EMC).
- Shall support data calculation and synthesis
- For each station, a manual key type selector switch shall be provided to locally disable all control outputs at a station. The key-type selector switch shall be installed at the RTU such that it can be operated without opening the RTU panel.
- The outputs from the RTU shall be disabled by breaking the power supply connection to the control output. An auxiliary contact on this switch shall be wired to a contact input in the RTU to report the control disable switch's status to the SCADA system.
- All connections between the RTU's termination facilities and signal wiring shall be through barrier-terminal blocks with knife-switch isolation, mounted in the RTU panel or an adjacent marshalling cabinet, if not already existing in the Substation. Terminal blocks shall be screw-type, with full depth insulating barriers.

- The RTU shall report tele-indications by exception but shall also allow the SCADA system to demand - scan status data even if the data has not changed.

4.1.2.1.6.2 Signal List

The signal list shall be agreed between the KPLC and the Supplier and shall comprise the following;

- Commands for all Circuit Breakers and motorized switchgear
- Status Indications
- Alarms and Trips
- Set Point regulation
- Measurands
- Energy meter readings
- Reset by SCADA for all Master Trip Relays

The design shall include mapping of the Signal list from the supplier (as addressed & used in the HMI) to the requirements of the Regional Control Centre (supervisory level) signal requirements.

The design of the SAS system shall include the following;

- Control mode selection
- Select-before-execute principle
- Command supervision: Interlocking and blocking
- Double command Auto reclosing
- Monitoring pole discrepancy and trip function
- Transformer tap changer control
- Display of interlocking and blocking
- Breaker position indication
- Alarm annunciation
- Measurement display
- Local HMI (local guided, emergency mode)
- Data storage for at least 200 events

4.1.2.1.6.3 Select-before-execute

For safety reasons the command is always given in two stages: selection of the object and command for operation.

These two commands are realized with one contact each; only when both contacts are closed, is the final command (open or close) executed.

4.1.2.1.6.4 Station HMI

The operator station HMI shall provide basic functions for supervision and control of the substation. The operator shall give commands to the switchgear on the screen via mouse clicks on soft-keys.

The HMI shall give the operator access to alarms and events displayed on the screen. Aside from these lists on the screen, there shall be a printout of alarms or events in an event log.

An acoustic alarm shall indicate abnormalities, and all unacknowledged alarms shall be accessible from any screen selected by the operator.
SAS shall include the following displays &functions:

- Control of all switching devices
- Real time indication of status, alarms and devices
- Display of measured values, high/low limit checking.
- Indication of real and historical values

- Data Archiving
- Disturbance Monitoring and analysis
- Trend display facilities
- Protection device information
- Remote access to SAS from the Central Control Centre via the SCADA system
- Remote communications
- Indication of automatic tap changer relay status
- Manual local and remote setting of tap changer relay
- Self-check & diagnostic: These functions are essential for system operation
- Safety and easy maintenance.
- SAS Management software
- The substation master control shall be capable of automatic restart in the event of power failure
- Without loss of functionality or local database. It shall be readily possible to update the substation
- Computer software to alter or extend the SAS functionality.

Manual data setting (can be performed by the operator) using the following functions:

- Device status setting
- Analogue data setting
- Control inhibit setting
- Alarm inhibit setting
- Maintenance tag setting
- High/Low limit setting
- Protection relay parameter setting, etc.
- Also, all required signals related to the control, status indications and monitoring of the switchgear and other relevant equipment shall be provided to the SAS.
- Time Tagging

The configuration of the station HMI shall be made using the operator station in the Windows environment. The various functionalities shall be customized by easy-to-use interactive configuration tools. The configuration shall include the visual presentation of the object, adaptations needed in the process database, and adaptations of the communication configuration data.

4.1.2.1.6.5 Substation Local Area Network

Local substation communications shall use Ethernet LAN to connect the components of the SAS using open international IEC 61850 GOOSE protocol. The LAN may be of star-coupler configuration. Fiber optic can be used only in instances where the lengths are too long to be handled by Ethernet LANS. No single point of failure of the substation LAN shall result in any loss of substation control functionality.

The station controller must be able to receive and transmit information from future extensions on an IEC 61850 protocol.

4.1.2.1.6.6 Printers

- Two high performance printers shall be provided, each capable of connection to the substation LAN.
- 1 off Matrix printer Logger, for events and for operator log.
- 1 off Color Printer to print screen shots or other information

4.1.2.1.6.7 Satellite Clock

Time synchronization and event time tagging with resolution of at least 1ms shall be provided by a satellite GPS clock signal as the Master clock, the secondary clock shall be provided via the SCADA system.

4.1.2.1.6.8 Audible Alarm

One common sounder should be provided to give at least two distinct audible alarms in case of alarms/faults or events.
The sounder shall be configurable according to the event type and to the control status of the SAS (Local/Remote). An auto-silencing scheme shall be provided for the alarm and the sounder shall be controlled by distinctly labeled “Audible alarm ON/OFF” control switch.
The complete unit may be mounted in suitable relay/control panel.

4.1.2.1.6.9 Common Bay Unit

The Common Bay Unit (CBU) shall be provided for monitoring of common services. The CBU shall be located in Control/Relay Room.

4.1.2.1.6.10 Data Transmission

The SAS shall be able to communicate with the ABB type SCADA system using a variety of open protocols. The RCC shall be capable of remote access to the SAS via the SCADA system. The protocols currently supported are IEC 61850-3-2013 & IEC 60870-104.
This communication link must be via an approved communication mode complete with the terminal equipment all supplied, installed & commissioned by the Contractor.

4.1.2.1.6.11 Cyber Security

The SAS system shall have protection against malicious, accidental and hacking attempts in accordance with applicable IEC standards.

4.1.2.2 Substation Control

4.1.2.2.1 Bay Control Units

Outdoor switchgear shall have a control and relay panel in the control room with facilities for Local Control. The local control for indoor breakers can be located in the instrument cabinet. The protection and control functions can also be combined in one unit. Signals from protection equipment can alternatively be hardwired to bay control unit.

The Bay control unit shall handle position indications from Circuit Breakers, Disconnectors, Earthing switches and transformer tap changer. It shall control closing and opening of circuit breakers and receive time tag, store and display alarms and measurements.

The position indication from the on-load tap changer shall be taken from a potentiometer switch supplied and mounted on the transformer.

The alarm handling capacity must be sufficient to handle all normal alarms from the switchgear, the protection, the transformer and the tap changer.

All commands from the remote and supervisory control can be given to bay control unit, which execute the commands. Conventional interlocks should be retained.
All microprocessor based control equipment such as bay control units shall be galvanically isolated from the environments outside panels, using opto couplers or interposing relays for signals, galvanic isolated measuring transducers for measurements and relays or contactors for commands.

All data and parameters specified to the individual distributed control units, shall be stored in a non-volatile memory so no local logic or information will be lost due to power supply failure.

Editing and input of local data and parameters shall be performed locally by suitable programming equipment to be included in the supply. Preferably it should also be possible to edit any such local data at higher control level and download this information.

4.1.2.2.2 Interface with Supervisory Control and Data Facilities

In order to interface and achieve the desired functionality of the SCADA/EMS system, data concentrators in substations shall be based on standard IEC 60870-104 protocol.

The following SCADA facilities shall be available from the substation.

- Supervisory control of all circuit breakers and motorized line and bus bar isolators and remote control of on-load tap changers.
- Status Indications of all circuit breakers, isolators, positions of on-load tap changers and 'local/remote', 'Automatic/ Manual', Main/Follower mode of automatic voltage regulators where applicable. These shall be reported by exception, but system shall allow scan by demand.
- Alarms; Bay alarms, Transformer alarms, Bus bar alarms, station alarms and warning shall be collected by the SCADA.
- Measurements; bus bar voltages, frequency active & reactive power, 48 & 110 V DC voltages and line currents.
- Energy measurements, this shall be at interconnection points and feeders.

Where data concentrators will capture and process data for transmission to the control centres it is expected that the following functions shall be provided:

- Single command outputs, double command outputs for supervisory (on/off) control of circuit breakers, isolators etc. with check-before-execute function.
- Regulation command outputs e.g. raise/lower command outputs for transformer tap changer control and set point transmission with validity check before execution.
- Resetting of Lock out Trip Relays on individual circuits.
- Single and double state digital inputs. Each status (open/closed) of two state devices such as circuit breakers or isolator position should be acquired independent from each other and checked for validity. Undefined states like open and closed or neither open nor closed shall be alarmed with run-time monitoring adapted to the HV equipment operation parameters.
- Transformer tap changer position indication should be processed as coded signals, by digital measurement input modules.
- Analogue measured inputs with pre-processing including validity check, local limit supervision and measurement transmission on exception (only if a significant individually selectable change occurs).
- Measurement transmission with a resolution of at least 10 bit plus sign as this is the most economical way to increase the overall accuracy of the measurements.
- Metering pulse inputs for acquisition of energy values with internal storage to allow cyclic acquisition of meter readings.
- Sequential event recording with time stamping of events (time stamp 10ms, resolution 1 ms)
- Selectable priority levels for data acquisition to speed up the acquisition of circuit breaker status changes and important measurements.

4.1.2.2.3 Automatic Voltage Regulator

The transformer bay shall be equipped with an automatic voltage regulator acting on the on-load tap changer. The automatic voltage regulation function shall pursue to keep a constant (but adjustable) voltage on the low voltage side of the transformer by raising or lowering the tap changer (however, an appropriate hysteresis shall be included to avoid over-frequent tapping). The regulation shall be achieved either by a freestanding relay or as a function in the control system.
If connected in parallel, in order to prevent circulating current or negative reactance system: the transformers shall be regulated in a master-slave mode, where each transformer can be selected as master. If the master transformer is out of service another transformer shall take over as master.

Manual switchover to conventional tap changing (local and remote) shall be accommodated.
Necessary blocking by out of range stepping (including inappropriate difference between parallel units) and disconnected transformer shall be included. The actual tap position shall be displayed locally and remote as well as the identification of the master unit.

4.1.2.2.4 Indicating and Metering Instruments, and Transducers

Remote indication of measurands shall take place on the station controller's VDU. Where local instruments are used, they shall be of the dial type which is easily legible, with black graduations and numerals on a white background.

The instruments shall have a dimension of 96x96 mm. The error of the instruments shall be maximum 1.5% reckoned on the total length of the scale. All instruments shall be of a narrow frame type.

Preferably the measurements shall be performed directly in the SAS or in the protection relays. However, if needed, the metering transducers (converters) shall be installed in the boards and shall be suitable for connection to the potential and current transformers. The cases shall be hermetically sealed against moisture and dust. Transducer output shall be an impressed DC current of 0-10 mA output. The maximum meter reading at the receiving end shall be equivalent to 30% overload of the source value. The permitted resistive load shall be at least 1000 Ohms. The accuracy class shall be minimum 1%. The auxiliary voltage, if required (preferably not) shall be 48VDC.

The W and VAr measurements shall be of the three-element (three-wattmeter) type when connected to primary systems with grounded neutral.

W and VAr measurements for transmission lines, shall be such that the direction of the power flow is indicated by negative direction towards the substation and positive direction out of the substation. The voltage shall be measured phase-phase voltage, one reading is sufficient.

The scale on the different types of instruments shall be proposed by the Contractor and be subject to approval by the Project Manager.

Enclosures

The Contractor shall provide enclosures meeting the following requirements:

- Swing racks supported by heavy gauge hinges shall be provided so that only front access to components and wiring is required for routine maintenance and troubleshooting.

- Provisions for top and bottom cable entry. Cable entries shall be provided with protection against insect and rodents entry and sealed to prevent dust and sand contamination.

- Protection class of the enclosures shall be
  - ❖ for indoor cabinets IP52 minimum
  - ❖ for outdoor cabinets IP64 minimum.

- Suitable signal and safety ground networks within the enclosure.
- Convenience outlets at 230 V AC, shall be provided. Sockets shall be 15A British type.

4.1.2.2.5 Power Supply

At all stations where no adequate power supply exists and new RTUs and telecommunication equipment shall be installed, the Contractor shall supply, install and wire a new and complete 48V DC power supply system including a 48V DC battery, charger(s), low voltage disconnect switch,
All DC distribution equipment and cabling required for the uninterruptable supply of 48V DC power to the RTU as well as the communications equipment provided under the Contract.

The battery and charger sets shall be sized to adequately supply the loads to be connected to the battery.

The rectifier output shall be k x S
Where k = 1.5
S = sum of the following:

- input power in kVA of the largest tendered RTU
- input power to the new telecommunication equipment provided under the contract.

The battery capacity shall be $C = 1.5 \times C_n$,
where C_n is the capacity to feed the above total load for eight (8) hours.

The battery chargers shall provide normal system power and shall be capable of recharging a fully discharged battery in twelve hours while supplying normal system power. The chargers shall have 240 volt, 1 phase input power. Where duplicated chargers are to be provided, both chargers shall have an output diode in the positive pole to prevent back-feeding a failed charger.

The Contractor shall supply any hardware required to convert the 48 V battery voltage to the required internal voltages for the RTU hardware. The RTUs shall be capable of operating with ungrounded or grounded (either polarity) input power.

In RTU DC distribution, Miniature Circuit Breakers (MCBS) with alarm contact shall be used, i.e. fuses are not accepted.

4.1.2.2.6 Spare Parts

The Contractor shall furnish a list of recommended spare parts and test equipment for the purchased RTUs to maintain reliable RTU operation. The spare parts list shall be subdivided into:

- Mandatory spare parts that are necessary for two (2) years of operation. These spare parts shall be included in the contract.
- Recommended spare parts that are necessary for ten (10) years of operation.

4.1.2.2.7 Documentation

The Contractor shall provide all necessary drawings, design specifications, design details, operation and maintenance manuals. All manuals and AS-Built-Drawings shall be provided in 3 No. hardcopies and a softcopy.

The following documentation to be provided for the system in the course of the project. It shall be consistent, CAD supported and of similar look/feel:

- Control Room Layout
- Single-Line Diagram
- Block Diagram
- Circuit Diagram
- List of Apparatus
- List of Labels
- Functional Design Specification (FDS)
- Test Specification for Factory Acceptance Test (FAT)
- Logic Diagram
- List of Signals
- Operator's Manual
- Product Manuals
- Calculation for uninterrupted power supply (UPS) dimensioning (or Charger and batteries).
- Concept and contract for maintenance
- It is necessary to present the technical description and the technical data for the whole system and for any equipment and function
- Time plan for the project realization.

4.1.2.2.8 RTU Configuration & Maintenance

The RTU shall perform continuous self-diagnostics to monitor its own operational capability. Any detected fault or abnormality, which could affect its performance or operational capability, shall be indicated to the Regional Control Centre.

- A laptop computer based configuration and maintenance facility shall be provided along with all database and software interfaces required for the maintenance and configuration of the RTU,
- The laptop computer shall also be used to monitor and test the RTU's operation and communication interfaces and shall be capable of emulating the RCC.
- All equipment software licenses shall be in employers name but acquired by contractor and one time licenses (i.e. no periodic license renewal required)
- Upon completion of tests and commissioning, the following shall be provided in CDs and portable hard drives :
  - Operating system recovery disk (drivers and manuals) and installation disks
  - All installed software drivers and manuals
  - As built backup installation files, configuration files and reading software for the substation protection, metering and SCADA systems
  - 2 No. Laptops (at least core i8 8th generation), each with all substation backups

4.1.2.2.9 Testing

The Control system with Station Control Unit and Field Units shall undergo the following tests :-

a) Factory Acceptance Tests (FAT)

Systems shall pass these tests before they may be shipped to site. FATs shall be witnessed by the employer.

b) Site Acceptance Tests (SAT)

Systems shall pass these tests before they may be put into operation and before they are Taken Over

4.1.2.2.10 Training

The Contractor shall provide 2 weeks training for 4 (four) KPLC staff at the supplier's factory premises and on site during installation works and the scope of each service shall be given.

An in-depth training in the application, fault finding and maintenance of the control system shall be provided. The training must include but not be limited to the following:

- System configuration
- Programming tools
- Picture editing
- Operating system
- System maintenance
- Any other training regarded necessary by the Bidder
- Communication protocols, IEC 60870-103/104, IEC 61850-3-2013
- Protection device settings and configurations

On completion of the training, KPLC staff shall be able to modify and make changes to the configuration of the RTU to accommodate any future changes as well as interfacing & data transmission to the RCC.

4.1.2.2.11 Spare Parts and Tools

The Contractor shall furnish a list of recommended spare parts and test equipment for the purchased SAS system to maintain reliable operation. The spare parts list shall be short-term spare parts that are necessary for two (2) years of operation. These spare parts shall be included in the contract and shall comprise at least one spare module for supplied equipment and basic tools for system maintenance.

4.1.2.2.12 System Maintenance

Editing and input of local data and parameters shall be performed locally by suitable programming equipment to be included in the supply. Preferably it should also be possible to edit any such local data at higher control level and download this information. The programming equipment shall also be suitable for fault diagnostic.

- Laptop Computer for maintenance, information transfer and emergency HMI
- A Personal Computer (PC) as a service unit shall be foreseen for on-site modifications of the control and protection devices. This service unit shall be used for documentation, testing, commissioning & future maintenance work on the SAS.
- Licences for configuration of supplied equipment shall be in scope of supply.

4.1.2.3 System Protection

4.1.2.3.1 General Requirements

The protection relays to be installed for the protection of 132kV, 66kV and 11kV distribution lines, transformers and other HV/MV equipment shall be **Numerical type** and support Communication protocols including but not limited to IEC 60870-5-103/104, Modbus serial, Modbus TCP/IP, IEC 60870-5-101/104 and DNP3. Shall also support IEC 61850-9-2 GOOSE messaging.. Relays shall be of robust type, insensitive to changes of temperature, vibration, etc.

Input from the measuring transformers shall be based on 1A, 110 V AC. The relay's power supply must accept a rated operating voltage input range from 24-240 V AC/DC without the use of external resistors and without external reconnections and shall be designed to withstand the high voltage interference which is normally experienced in high voltage switching stations.

There shall be galvanic isolation on all inputs and outputs including power supply input. Isolated inputs must accept a rated operating voltage from 24-240 V AC/DC without the use of external resistors and without external reconnections.

The Contractor shall endeavour to standardise the equipment by using as few different types of instruments, relays, switches and other devices as possible.

4.1.2.3.1.1 Relay Construction and Mounting

The relays shall comply with the requirements of IEC 60255. Modular constructed equipment shall be tested as a complete assembly and details of such tests shall be agreed with the Project Manager when details of the construction are known. Constructional details shall satisfy the following requirements as appropriate:

- Relay contacts shall be suitable for making and breaking of the maximum currents which they require in normal service. The protective relays shall be provided with sufficient contacts for circuit breaker tripping. All protective relays, which initiate tripping, shall have not less than two independent pairs of contacts of which one shall operate the tripping relay or circuit breaker trip coil without the interposition of auxiliary contactors and without the use of reinforcing contactors.
- A watchdog relay must detect internal fault including low auxiliary voltage. The auxiliary 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.

- The measured service currents and/or service voltages must be visible at the front display of the relay. In order to see all values at the same time, a four-line front display must be used. It shall also be possible to select default display.

- The relay must store a record of the fault-trip values to facilitate post fault analysis including, such as currents, voltages, operating time identification of the faulted phase and faulted zone etc. The values must be available at the front display of the relay and transferable to the supervisory system. The storage must not be dependable of the auxiliary supply.

- It must be possible to do all settings both from the relay front panel and/or with a PC through connection in the front panel of the relay

- The relay must have a complete number keyboard in the front panel for settings and downloading of measured values on the front panel display

- 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 disconnector repeat relays should be of the on-latching type and a discrepancy alarm shall be provided to check correct operation of the relays following a circuit breaker or disconnector operation.

- The lockout tripping relays shall be of the latching type and shall be hand and electrically reset.

- 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 1 and main 2 where applicable. Where two protection sets cover the same fault they shall be divided into two electrically and mechanically separate parts by means of:

  i. Separated DC power supply,
  ii. separated boards,
  iii. separate current transformer cores,
  iv. separate voltage circuits,
  v. separated tripping devices,
  vi. separate tripping coils,
  vii. separated cables,
  viii. Separated relay protection channels.

- The restricted earth fault and differential functions for the transformers shall also follow the same principle for separation as outlined above.

- The Auxiliary relays for protection trip shall have operating speed of less than 7 milliseconds.
- Strict requirements shall be given on selectivity in isolation. Only the minimum possible part of the plant shall be tripped to isolate the fault or clear the abnormal conditions.

- The Contractor shall for each substation carry out the protection plan for relay settings. The plan shall be submitted to the Project Manager for approval.

- All necessary intermediate current and voltage transformers, converters and auxiliary power supply units shall form part of the supply.

- The user manuals must be user-friendly and divided into one general hardware and software description and one setting manual describing only the specified functions and necessary settings for the different types of relays

4.1.2.3.1.2 Relay Testing Facilities

Each protection relay shall be provided with facilities for the connection of relay testing equipment. The facilities shall include plugs for connecting the testing equipment and switches for disconnecting the primary circuit of the relay, short circuiting current transformer circuits (make before break) and disconnecting the tripping circuit.

Programmable relays shall be delivered with software and software licences needed for testing, setting and reconfiguration of the relays. If hardware other than laptop is required for this such shall be included in the supply. **Commissioning laptop is**

mandatory and shall be supplied by contractor with pre-installed necessary software for protection/control and SAS system.

4.1.2.3.1.3 Fault Clearing Time

The protection system plus the circuit breakers shall have fault clearing time of not more than 60 ms for voltages 132 kV and above and 100 ms for voltages below.

4.1.2.3.1.4 Trip Circuits

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. The trip circuit supervision shall be independent of the protection relays and provided to monitor each pole of each trip circuit on circuit breakers with separate mechanism per pole with the circuit breaker in both the open. The status of the trip circuit shall be indicated on the panel.

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.

4.1.2.3.1.5 Fault Recorder and Fault Locators

Fault recorders and fault locators must be integrated in the line protection relays and use the same input parameters as the main protection function. The fault locators must provide records for fault analysis in the “Standard Common Format for Transient Date Exchange (IEEE-COMTRADE)” Necessary signals from the transformers shall be included.

4.1.2.3.1.6 Supervision

An Engineering Work Station (EWS) shall be supplied and installed with a licensed software to make it possible to communicate with the relays for remote setting, supervision, control and data acquisition over the LAN network installed in each substation using the standard communication protocols which includes but not limited to Modbus TCP/IP, IEC 60870-5-101/103/104 and DNP3. The EWS will be installed with the latest windows operating system and shall be compatible with the licensed software. The Contractor shall supply, install, connect the relays and test the complete system.

The protection relays shall also communicate with the bay control units over the open protocol IEC 61850.

4.1.2.3.2 Protection Schemes and IEDs

4.1.2.3.2.1 Primary Substations - 132kV, 66kV & 33kV Line Protection Schemes

Facilities shall be provided to enable one protection (main or backup) to be taken out of service for maintenance or testing without affecting the operation of the other in any way. The facilities shall include duplicate breaker trip coils, separately MCBs DC circuits and the use of separate CT and VT windings. The protection relays shall be arranged to initiate a single set of auto-reclosing equipment. The protection relays / IEDs shall be visible from the front of the panel without having to open the panel door.

The line protection schemes shall contain the following functions:

a) Distance Protection (Main A)
b) Differential Protection (Main B - for 132kV and above)

c) Bay Control and Protection Unit (BCPU)
d) Three phase unidirectional over current and Earth fault function (Backup)
e) Sensitive Earth fault function
f) Auto reclose relay function
g) Trip circuit supervision
h) Auto reclose IN/OUT Switch
i) Breaker failure function

The distance/differential and Overcurrent & Earth protection functions shall be in separate relays/IEDs.
Protection functions (c, d, e and f) shall be incorporated in BCPU as one IED for the 66kV and 33kV Line protection.

4.1.2.3.2.2 2.5MVA 33/11kV Dist Substations – 33kV & 11kV Line Protection Schemes

33kV Overhead Line Protection

The 33kV line protection schemes for a 2.5MVA 33/11kV substation shall contain the following protection functions:

i. Distance Protection function (Main protection for long lines) or line differential for a short line
ii. Three phase Over current and Earth fault function (Back up protection)
iii. Sensitive Earth fault function
iv. Auto reclose relay function
v. Trip circuit supervision visible from the front of the panel without having to open the panel door.
vi. Auto reclose IN/OUT Switch
vii. Sensitive Earth Fault ENABLE/DISABLE switch
viii. Breaker failure function
ix. Bay Control Functions

The distance and Overcurrent & Earth protection functions shall be in one IED.
Protection functions (iii, iv, v, vii and vii) shall be incorporated the same IED

11kV OH Line Protection

i. Three phase Overcurrent & Earth fault Protection
ii. Sensitive earth fault protection
iii. Bay control functions
iv. Auto reclose function
v. Trip circuit supervision visible from the front of the panel without having to open the panel door.

4.1.2.3.2.3 Line Protection IEDs

a) Line Distance Protection IED

One complete distance relay with full scheme non-switched type for phase/earth and phase/phase faults and with up to four measuring zones. In addition to the above the numerical relays must have the following functions:

i. Ratings: AC Inputs: 110VAC, 1Amp (three phase).
ii. Power Supply Voltage shall be universal 24-240VDC
iii. The relays shall be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850
iv. The relay shall also have auto reclose function.
v. Impedance criteria.
vi. Three zones phase –phase Protection.
vii. Three zones phase –earth Protection
viii. Additional Zone 4 Protection
ix. Automatic Switch on to fault.
x. Independent settings for each zone.
xi. Distance to fault measurement.
xii. Display: On operation, the relay should display the faulted phase(s), time and zone of operation and distance to fault.
xiii. Power Swing detection: Blocking/non-blocking selectable by user.
xiv. Scheme communication logic and residual current compensating.
xv. IDMT Three Phase/Over current & Earth fault Protection.
xvi. Fuse failure supervision.
xvii. Auto- reclose logic 1phase and/or 3 phases.
xviii. Three pole tripping logic.
xix. Disturbance and event records including software for disturbance analysis.
xx. Fault record should be incorporated.
xxi. At least six (6) Binary inputs.
xxii. Mho/Quadrilateral characteristics.
xxiii. Stability against Switching inrush currents and Reverse faults.
xxiv. Clear faulted phase indication.
xxv. Clear fault identification even for boundary conditions.
xxvi. Software necessary for all above functions shall be provided.

All these functions must be integrated in a compact package and a user-friendly menu driven interface should be available to enable the setting and testing of the relays. Three sets of Installation, Commissioning and maintenance manuals and settings software shall be provided.

b) Line Differential IED

The comprehensive protection functions make it ideal for utility, industrial, marine and off-shore differential protection applications. The device features the following protection functions:

i. Ratings: AC Inputs: 110VAC, 1Amp (three phase).
ii. Power Supply Voltage shall be universal 24-240VDC
iii. The relays shall be of Numerical design and supports communication

protocols IEC 60870-5-103 and IEC 61850

iv. Three phase biased differential stage with inrush blocking dI>, dI>>
v. IDMT Three Phase/Over current & Earth fault Protection
vi. Impedance criteria.
vii. Three zones phase –phase Protection.
viii. Three zones phase –earth Protection
ix. Additional Zone 4 Protection
x. Automatic Switch on to fault.
xi. Independent settings for each zone.
xii. Unbalance protection I2>, I'2>,
xiii. Thermal overload protection T>
xiv. Circuit-breaker failure protection CBFP
xv. Programmable stages
xvi. Distance to fault measurement.
xvii. Display: On operation, the relay should display the faulted phase(s), time and zone of operation and distance to fault.
xviii. Power Swing detection: Blocking/non-blocking selectable by user.
xix. Scheme communication logic and residual current compensating.

Further the device includes a disturbance recorder and arc supervision unit. The manage communicates with other systems using common protocols, such as the Modbus RTU, Modbus TCP, Profibus DP, IEC 60870-5-103, SPA bus and DNP 3.0. In addition, each relay is expected to interface directly with a single mode optical fibre.

Note: *Relay/IEDs should come with 20m fibre patch cords to connect with optical fibre cable at the ODF where applicable.*

c) Three Phase Directional/Unidirectional Over Current & Earth Fault IED

Should incorporate the following functions:

i. Ratings: AC Inputs: 110VAC, 1Amp (Three phase).
ii. Power Supply Voltage shall be universal 24-240VDC
iii. In addition of Overcurrent and Earth fault, the relay shall also have auto reclose function
iv. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2
v. Current setting range for over current relay 0.5In-2.4In
vi. Current setting range for earth fault relay 0.05In-0.8In
vii. Quadrature connection for polarising voltage (Vn=110)
viii. Applicable on the LV side of a Dyn1 transformer
ix. High set Element, with a setting range of 1-32In
x. The phase and earth directional elements should be individually selectable.
xi. I.D.M.T characteristics according to BS142 or IEC60255 and Definite time characteristic
xii. The normal operating boundary shall be +/-90 degrees from relay characteristic angle Relay sensitivity should be 1% of rated value of current and current polarising voltage at an angle equal to the relay characteristic angle.
xiii. Time setting multiplier 0.05 - 1.0
xiv. Broken conductor protection feature
xv. Negative sequence Protection Feature
xvi. High set Element for both over current and earth fault Protection, with a setting range of 1-30In.

xvii. Thermal Protection.
xviii. Dedicated Breaker Fail Protection.
xix. Circuit Breaker Maintenance
xx. Incorporate Fault records, Event Records and disturbance records.
xxi. Configurable output relays with ability to output starting elements to control Tripping of other upstream Protection relays.

Three sets of Installation, Commissioning and maintenance manuals and settings software shall be provided.

d) <u>Sensitive Earth Fault IED.</u>

Should incorporate the following Features;

i. Ratings: AC Inputs: 1Amp
ii. Power Supply Voltage shall be Universal power supply of 24- 240VDC
iii. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2
iv. Current setting range for earth fault relay 0.005In-0.8In
v. I.D.M.T characteristics according to BS142 or IEC60255 and Definite time delay characteristic; setting range, 0- 30 Seconds.
vi. Circuit Breaker Maintenance
vii. Fault records, Event Records and disturbance records.
viii. Drop off /pickup ratio >90%
ix. Low transient overreach < 10%

Three sets of Installation, Commissioning and maintenance manuals and settings software shall be provided.

e) <u>Auto reclose function</u>

i. The autoreclose function shall be enabled in the distance relay and in the overcurrent and earth fault relay, and there shall be no need of independent autoreclose relay for 66kV lines and below.
ii. Selectable 1 - 3 autoreclose shots
iii. Independent set dead time for each shot
iv. Autoreclose inhibit after manual close
v. Separate input for over current high set element and I.D.M.T element
vi. Autoreclose inhibition for over current high set element.

For 33kV lines, the Three Phase Overcurrent, Earth fault & Autoreclose functions shall be combined in one IEDs (BCPU)

f) <u>Bay Control Protection Unit (BCPU)</u>

The relay shall have the following functions and features: -

i. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2
ii. Power Supply Voltage shall be Universal power supply of 24- 240VDC is preferred.
iii. The relay shall be suitable for flush mounting
iv. The relay will have a large LCD screen measuring at least 7cm x 7cm where a mimic of the switchgear arrangement and status of the switchgear for the bay shall be displayed.
v. The position of the switchgear i.e. Circuit Breaker and Disconnectors shall be indicated.
vi. The switchgear close and open push key buttons with symbols and colour codes as per the IEC standards shall be provided on the relay as well as switchgear selection key.

vii. A Local/Remote key selector switch shall be provided on the relay and the selected status of the selector switch indicated by means of an LED.

viii. The Relay offered shall have at least the following protection functions; -

- Three Phase Overcurrent & Earth Fault
- Sensitive Earth fault
- Broken Conductor detection
- Auto reclose function
- Circuit breaker maintenance
- Circuit breaker Failure protection
- Under and over frequency protection as well as rate of change of frequency protection
- Over/under voltage protection
- Synch Check Function

ix. The Relay shall measure and display (Metering) on the LCD screen following power system parameters; Current (I), Voltage (V), Active Power (P), Reactive Power (Q), Frequency (HZ) and power factor (P.F).

x. The relay shall store at least twenty (20) fault records, Fifty (50) events and ten

xi. (10) disturbance records. The disturbance record shall have capacity to monitor Eight (8) analogue and ten (10) digital channels.

xii. It shall be possible to display instantaneous measurands on the screen alongside the bay mimic.

xiii. The unit shall have an L.E.D to indicate relay healthy status (green colour) and relay faulty status (red colour). A separate Red L.E.D to indicate operation (Trip) of the protection functions.

xiv. The relay shall have at least Eight (8) programmable LEDs for displaying Protection function operations and other alarms.

xv. The template for writing the alarm labels shall be provided with the relay

xvi. The relay shall have at least twelve (12) binary inputs

xvii. The Relay shall have at least six (6) output relays

xviii. The relay shall be provided with IEC 61850-8-1 Communication protocol, and the corresponding communication port.

xix. The Relay terminals shall be of screw type terminals large enough to accommodate at least 2x2.5mm2 cable and shall be located at the back of the relay.

xx. Front Serial RS232 or USB or Ethernet Port for relay communication with a laptop computer for relay configuration and parameter settings and download of fault records, events records and disturbance record for analysis.

Note:

- *All the protection functions shall meet the requirements of each function as included in this specification.*
- *Earth Fault and Sensitive Earth Fault Protection elements shall be separate to allow independent settings to be applied.*
- *Earth Fault and Sensitive earth fault shall have separate CT inputs.*
- *Detailed specifications for three phase overcurrent, earth fault and sensitive earth fault functions are included elsewhere in these specifications.*

g) Under Frequency relay

Where required, in 33kV bus bar, each Bus bar shall be equipped with a separate under frequency relay for load shedding of all outgoing feeders. Each feeder trip circuit from the under-frequency relay shall be equipped with a clearly marked isolating link.

The relay shall be numeric having two independently time delayed settings in the range 50- 47Hz with a resolution of 0.1Hz. The rate of change of frequency function shall be included.

h) Busbar Protection relay for 66kV and above Voltages

Bus bar protection schemes shall be provided at bus bars for voltages from 66kV and above. Low impedance schemes will be acceptable provided full bus bar protection coverage to include single phase and phase to phase faults can be achieved. The type of tripping criteria has to be fully described and preference will be given to systems with at least two (2) criteria checks before tripping.

Bus bar Protection relay shall have the following minimum and functional features:

i. Power Supply Voltage shall be 24-240VDC universal.
ii. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2
iii. AC Inputs of 110VAC and 1Amps (In) 50Hz three phase per circuit.
iv. It should be able to carry 4xIn current continuously
v. Shall have extensive self-supervision and diagnostic facilities.
vi. Incorporate a check feature
vii. Incorporate continuous supervision for CT secondary circuits against any possible open circuit and if it occurs, shall render the relevant zone of protection inoperative and initiate alarm
viii. Be of phase segregated and triple pole type and provide independent zones of protection for each bus
ix. Provide 100% stability up to 50kA fault level and shall have immunity against system transients.
x. Be of high impedance, biased differential type and have operate and restraint characteristics with typical tripping time: 10 to 20ms
xi. The HMI should graphically display the bus bar configuration and the bus bar image and shall permit read out of a minimum of the following information:
xii. Phase currents (and optionally, phase voltages) in each bay
xiii. Differential currents in each Bus bar zone and each phase on line as well as at the time of fault.
xiv. Alarm conditions and Trip conditions
xv. State of all the inputs and outputs setting values
xvi. Positions of the breakers in each bay
xvii. Resetting of output relays
xviii. Shall include Protection Enable / Disable feature
xix. It shall have sufficient number of programmable opto coupler binary inputs (Min of 10 No. per bay) and output relays with heavy duty & signaling contacts (Min of 10 No. per bay)
xx. It shall include a Disturbance Recorder function
xxi. It shall include an Event Recorder function
xxii. The Disturbance Recorder and Event Recorder buffer memory shall be of non-volatile type and shall not require the use of batteries.
xxiii. Programmable LED indications.
xxiv. The relay shall have front and rear communication ports for settings/configuration

and integrating with the local station automation or to a station monitoring system.

xxv. One of the protocols offered for the communication port shall include IEC 61850.

xxvi. Time synchronization via IRIG-B and SNTP.

xxvii. Be supplied along with all suitable Original Customized licensed software & communication cable for local and remote communications, analysis of fault etc.

xxviii. The bus bar protection relay shall have built-in Breaker Failure feature.

xxix. The relay shall have CT supervision function.

xxx. There shall be trip command lockout with manual reset (local and remote by binary input.)

i) <u>Breaker Fail Protection relay for 66kV and above Voltages</u>

Where an independent Circuit Breaker fail (CBF) protection relay is required shall be of the numerical design and shall have following minimum features and functions: -

i. Power Supply Voltage shall be 24-240VDC universal

ii. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2

iii. AC Inputs of 1-Amps (In) 50Hz three phase per circuit.

iv. Relay should be able to carry 4xIn continuously.

v. Shall have extensive self-supervision and diagnostic facilities.

vi. Detection shall incorporate current check feature and a timing element.

vii. The current check function shall comply with IEC 60255-151 and timing element IEC 60810-1.

viii. The relay shall have programmable initiating inputs and tripping outputs.

ix. It shall have sufficient number of programmable opt-coupler binary inputs (Min of 10 No.) and output relays with high speed heavy duty & signaling contacts (Min of 10 No.)

x. The HMI should permit read out of a minimum of the following information:

xi. Phase currents

xii. Alarm conditions and Trip conditions

xiii. State of all the inputs and outputs setting values

xiv. Resetting of output relays

xv. Shall include Protection Enable / Disable feature

xvi. It shall include a Disturbance Records, event record function

xvii. The Disturbance Recorder and Event Recorder buffer memory shall be of non-volatile type and shall not require the use of batteries.

xviii. Programmable LED indications.

xix. The relay shall have front and rear communication ports for settings/configuration and integrating with the local station automation or to a station monitoring system. One of the protocols offered for the communication port shall include international standard protocol IEC 61850. Time synchronization via IRIG-B and SNTP.

xx. Be supplied along with all suitable Original Customized licensed software & communication cable for local and remote communications, analysis of fault etc.

The breaker fail protection shall only isolate the bus bar to which the faulty breaker is connected i.e. the station shall, as far as possible, remain in operation after a breaker failure. The bus bar protection can be used for selection of breakers to be tripped.

4.1.2.3.2.4 11kV Line Protection IEDs

The main protection for 11kV lines shall be three phase Overcurrent & Earth fault, Sensitive earth fault and auto reclose function combined in one IED/BCPU.

a) <u>Bay Control & Protection Unit (BCPU)</u>

The relay shall have the following functions and features: -

i. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2
ii. Power Supply Voltage shall be Universal power supply of 24- 240VDC is preferred.
iii. The relay shall be suitable for flush mounting
iv. The relay will have a large LCD screen measuring at least 7cm x 7cm where a mimic of the switchgear arrangement and status of the switchgear for the bay shall be displayed.
v. The position of the Circuit Breaker, i.e. racked-in or withdrawn shall be indicated.
vi. Circuit Breaker close and open push key buttons with symbols and colour codes as per the IEC standards shall be provided on the relay as well as switchgear selection key.
vii. A Local/Remote key selector switch shall be provided on the relay and the selected status of the selector switch indicated by means of an LED.
viii. The Relay offered shall have at least the following protection functions; -
ix. Three Phase Overcurrent & Earth Fault
x. Sensitive Earth fault
xi. Broken Conductor detection
xii. Autoreclose function
xiii. Circuit breaker maintenance
xiv. Circuit breaker Failure protection
xv. Under and over frequency protection as well as rate of change of frequency protection
xvi. Over/under voltage protection
xvii. Synch Check Function
xviii. The Relay shall measure and display (Metering) on the LCD screen following power system parameters; Current (I), Voltage (V), Active Power (P), Reactive Power (Q), Frequency (HZ) and power factor (P.F).
xix. The relay shall store at least twenty (20) fault records, Fifty (50) events and ten (10) disturbance records. The disturbance record shall have capacity to monitor Eight (8) analogue and ten (10) digital channels.
xx. It shall be possible to display instantaneous measurands on the screen alongside the bay mimic.
xxi. The unit shall have an L.E.D to indicate IED healthy status (green colour) and relay faulty status (red colour). A separate Red L.E.D to indicate operation (Trip) of the protection functions.
xxii. The relay shall have at least Eight (8) programmable LEDs for displaying Protection function operations and other alarms.
xxiii. The template for writing the alarm labels shall be provided with the relay
xxiv. The relay shall have at least twelve (12) binary inputs
xxv. The Relay shall have at least six (6) output relays
xxvi. The relay shall be provided with IEC 61850-8-1 Communication protocol, and the corresponding communication port.
xxvii. The Relay terminals shall be of screw type terminals large enough to accommodate at least 2x2.5mm2 cable and shall be located at the back of the relay.
xxviii. Front Serial RS232 or USB or Ethernet Port for relay communication with a laptop computer for relay configuration and parameter settings and download of fault records, events records and disturbance record for analysis.

Note:

- *All the protection functions shall meet the requirements of each function as included in this specification.*
- *Earth Fault and Sensitive Earth Fault Protection elements shall be separate to allow independent settings to be applied.*
- *Earth Fault and Sensitive earth fault shall have separate CT inputs.*
- *Detailed specifications for three phase overcurrent, earth fault and sensitive earth fault functions are included elsewhere in these specifications.*

b) Sensitive Earth Fault Function.

Should incorporate the following Features;

i. Current setting range for earth fault relay 0.005In-0.8In
ii. I.D.M.T characteristics according to BS142 or IEC60255 and Definite time delay characteristic; setting range, 0- 30 Seconds.
iii. Drop off /pickup ratio >90%
iv. Low transient overreach < 10%

c) Auto reclose function

i. The autoreclose function shall be enabled in the BCPU relay, and there shall be no need of independent autoreclose relay for 11kV lines and below.
ii. Selectable 1 - 3 autoreclose shots
iii. Independent set dead time for each shot
iv. Autoreclose inhibit after manual close
v. Separate input for over current high set element and I.D.M.T element
vi. Autoreclose inhibition for over current high set element.

For 11kV lines, the Three Phase Overcurrent, Earth fault, Sensitive Earth Fault & Autoreclose functions shall be combined in one IEDs (BCPU)

d) Under frequency relay

Where required, in 11kV bus bar, each Bus bar shall be equipped with a separate under frequency relay for load shedding of all outgoing feeders. Each feeder trip circuit from the under-frequency relay shall be equipped with a clearly marked isolating link.

The relay shall be numeric having two independently time delayed settings in the range 50- 47Hz with a resolution of 0.1Hz. The rate of change of frequency function shall be included.

e) Other Functions

The 11kV line protection shall also incorporate;

i. Auxiliary relay to indicate/lockout circuit breaker for low SF6 gas pressure
ii. Trip circuit supervision relay that is visible from front of panel without having to open any panel compartment door.
iii. Front panel mounted **Auto reclose IN/OUT** switch.
iv. Front panel mounted **Sensitive Earth Fault ENABLE/DISABLE** switch.

4.1.2.3.2.5 Power Transformer Protection Schemes

a) <u>Transformers of 7.5MVA, 33/11KV ratings and above</u>

b)

The transformer protection schemes shall incorporate the following protection functions:

(i) Biased differential protection relay for two winding Transformer.
(ii) HV & LV restricted earth Fault relay. This should include stabilising resistor and voltage dependent resistor (metrosil)
(iii) HV Three-Phase Directional/Unidirectional Over Current & Earth fault Protection
(iv) LV Three-Phase Directional/Unidirectional Over Current & Earth fault Protection
(v) Auxiliary relays with annunciator for the following transformer mechanical protection functions
- Tx Buchholz gas Alarm
- Tx Buchholz surge Trip
- OLTC Oil Surge Trip
- Pressure Relief Valve Trip
- Winding temperature Alarm
- Winding temperature trip
- Oil temperature alarm
- Oil temperature trip
- Tx oil level low Alarm
- OLTC oil level low Alarm

(vi) Standby Earth Fault Protection.
(vii) HV & LV Master trip
(viii) Trip circuit supervision relay for HV & LV breaker visible from front of panel without opening relay compartment door.
(ix) Breaker Fail Protection function
(x) Bay Control Function

c) <u>Transformers of 2.5MVA, 33/11KV Ratings</u>

The transformer protection schemes shall incorporate the following protection functions:

(i) HV & LV restricted earth Fault relay. This should include stabilising resistor and voltage dependent resistor (metrosil)
(ii) HV Three-Phase Directional/Unidirectional Over Current & Earth fault Protection
(iii) LV Three-Phase Directional/Unidirectional Over Current & Earth fault Protection
(iv) Auxiliary relays with annunciator for the following transformer mechanical protection functions
- Tx Buchholz gas Alarm
- Tx Buchholz surge Trip
- Pressure Relief Valve Trip
- Winding temperature Alarm
- Winding temperature trip
- Oil temperature alarm
- Oil temperature trip
- Tx oil level low Alarm

(v) Standby Earth Fault Protection.
(vi) HV & LV Master trip
(vii) Trip circuit supervision relay for HV & LV breaker visible from front of panel without opening relay compartment door.
(viii) Bay Control Function

4.1.2.3.2.6 Power Transformer Protection IEDs

a) Biased differential Protection IED for a two winding transformer.

Overall differential protection equipped with over current stabilising for external faults and insensitive to in-rush current. The operating time of the protection shall be less than 20ms. This is considered Main transformer protection.

This should incorporate the following features:

i. Ratings: AC Inputs: 1Amp
ii. Power Supply Voltage shall be 24-240VDC universal.
iii. Relay Must be of Numerical design and supports communication protocols IEC 60870- 5-103a-104 and IEC 61850-9-2
iv. Pick up setting range, 0.1 to 0.5In
v. Should incorporate a high-set Element with a setting range of up to 20In.
vi. Magnetising current inrush restraint
vii. Integral CT ratio compensation (0.1-2) and vector group compensation
viii. Measurement and indication on the MMI, of phase, differential and bias currents
ix. Storage of Fault records and Event records; the Fault flags should be accessible on the relay LCD screen without opening the relay cover.
x. Over fluxing restraint
xi. Over fluxing protection with Alarm and Trip functions
xii. 5th harmonic restraint feature on the differential Element.
xiii. Appropriate Dual Bias characteristic to ensure relay stability for heavy through faults
xiv. Should incorporate a disturbance recorder feature.
xv. Red L.E.D to indicate Tripping
xvi. Relay Self diagnostic and Alarm feature
xvii. Ability to Latch output contacts to prevent TX re-energizing before carrying out investigations.

b) Three-Phase Directional/Unidirectional Over Current & Earth fault IED

Should incorporate the following Features;

i. Ratings: AC Inputs: 1Amp
ii. Power Supply Voltage shall be 24-240VDC universal.
iii. Relay Must be of Numerical design and supports communication protocols IEC 60870- 5-103a-104 and IEC 61850-9-2
iv. Relay must be of Numerical Type
v. Current setting range for over current relay 0.5In-2.4In
vi. Current setting range for earth fault relay 0.05In-0.8In
vii. I.D.M.T. characteristics according to BS142 or IEC 60255 i.e. SI, VI, EI, LTI, including definite time for the high-set Elements.
viii. Time setting multiplier 0.05 - 1.0
ix. Broken conductor protection feature
x. Negative sequence Protection Feature
xi. High-set Element for both over current and earth fault
xii. Protection, with a setting range of 1-30In.
xiii. Thermal Protection
xiv. Dedicated Breaker Fail Protection.
xv. Circuit Breaker Maintenance
xvi. Fault records, Event Records and disturbance records.
xvii. Configurable output relays with ability to output starting elements to control Tripping of other upstream Protection relays.
xviii. Drop off /pickup ratio >90%
xix. Low transient overreach < 10%

c) <u>Bay Control & Protection Unit (BCPU)</u>

The relay shall have the following functions and features: -

i. Relay must be of Numerical design and supports communication protocols IEC 60870-5-103 and IEC 61850-9-2
ii. Power Supply Voltage shall be Universal power supply of 24- 240VDC is preferred.
iii. The relay shall be suitable for flush mounting
iv. The relay will have a large LCD screen measuring at least 7cm x 7cm where a mimic of the switchgear arrangement and status of the switchgear for the bay shall be displayed.
v. The position of the Circuit Breaker, i.e. racked-in or withdrawn shall be indicated.
vi. Circuit Breaker close and open push key buttons with symbols and colour codes as per the IEC standards shall be provided on the relay as well as switchgear selection key.
vii. A Local/Remote key selector switch shall be provided on the relay and the selected status of the selector switch indicated by means of an LED.
viii. The Relay offered shall have at least the following protection functions; -
ix. Three Phase Overcurrent & Earth Fault
x. Sensitive Earth fault
xi. Broken Conductor detection
xii. Autoreclose function
xiii. Circuit breaker maintenance
xiv. Circuit breaker Failure protection
xv. Under and over frequency protection as well as rate of change of frequency protection
xvi. Over/under voltage protection
xvii. Synch Check Function
xviii. The Relay shall measure and display (Metering) on the LCD screen following power system parameters; Current (I), Voltage (V), Active Power (P), Reactive Power (Q), Frequency (HZ) and power factor (P.F).
xix. The relay shall store at least twenty (20) fault records, Fifty (50) events and ten (10) disturbance records. The disturbance record shall have capacity to monitor Eight (8) analogue and ten (10) digital channels.
xx. It shall be possible to display instantaneous measurands on the screen alongside the bay mimic.
xxi. The unit shall have an L.E.D to indicate IED healthy status (green colour) and relay faulty status (red colour). A separate Red L.E.D to indicate operation (Trip) of the protection functions.
xxii. The relay shall have at least Eight (8) programmable LEDs for displaying Protection function operations and other alarms.
xxiii. The template for writing the alarm labels shall be provided with the relay
xxiv. The relay shall have at least twelve (12) binary inputs
xxv. The Relay shall have at least six (6) output relays
xxvi. The relay shall be provided with IEC 61850-8-1 Communication protocol, and the corresponding communication port.
xxvii. The Relay terminals shall be of screw type terminals large enough to accommodate at least 2x2.5mm2 cable and shall be located at the back of the relay.
xxviii. Front Serial RS232 or USB or Ethernet Port for relay communication with a laptop computer for relay configuration and parameter settings and download of fault records, events records and disturbance record for analysis.

Note:

- *All the protection functions shall meet the requirements of each function as included in this specification.*
- *Earth Fault and Sensitive Earth Fault Protection elements shall be separate to allow independent settings to be applied.*
- *Earth Fault and Sensitive earth fault shall have separate CT inputs.*
- *Detailed specifications for three phase overcurrent, earth fault and sensitive earth fault functions are included elsewhere in these specifications.*

d) Restricted Earth Fault IED

The relay shall be used for protection of one winding of a power transformer and shall have following minimum functions and features: -

i. Relay must be of Numerical type and supports communication protocols IEC 60870-5- 103-104 and IEC 61850-9-2
ii. Ratings: AC Inputs: 1Amp
iii. Power Supply Voltage shall be 110vdv or 24-240VDC universal supply
iv. The Relay shall operate on high impedance principle.
v. The relay shall be suitable for flush mounting on panel front.
vi. The relay shall be of an independent relay and not a function in the differential relay.
vii. Relay shall reject harmonics produced by the system particularly third harmonics.
viii. Stabilizing resistor and voltage dependent resistor (metrosil) of suitable rating shall be offered with the Relay based on maximum through Fault of 40kA.
ix. The relay current setting range shall be 0.05- 0.8 x rated current (In) as a minimum and an operating time < 25ms at 5 times the setting.
x. The relay shall have at least four (4) LEDs for relay status indication and for trip and alarms annunciation as a minimum and two (2) binary inputs as a minimum
xi. The relay shall have four (4) Binary Outputs as a minimum with LCD screen where the settings and measurands can be read
xii. The relay's REF operate current shall be displayed on the LCD screen and keypad for manual programming of settings and data access
xiii. The relay shall have serial RS232, USB or Ethernet Front Port for relay configuration and programming of parameter settings and data download using a laptop computer.
xiv. The relay shall have an event recorder with capacity to store the last fifty (50) events
xv. The relay shall have fault recorder with capacity to store the last ten (10) fault records
xvi. The relay shall have a disturbance record with capacity to store the last four (4) disturbance records
xvii. The relay terminals shall be screw type terminals large enough to accommodate at least 4mm2 cable and shall be located at the back of the relay
xviii. Relay must be of Numerical type
xix. Relay should reject harmonics produced by C.T saturation
xx. The offer should include the associated stabilising resistor and voltage dependent resistor (metrosil)
xxi. Current setting range 0.05-0.8In
xxii. Operating time < 25ms at 5 times the setting

Note: *Restricted earth fault and differential protection functions shall be provided in separate IEDs.*

e) Stabilizing resistor

Each REF relay shall be supplied with an adjustable stabilizing resistor. For dimensioning of the stabilizing resistor consider maximum through fault phase–earth current of 25kA.
Restricted earth fault and differential protection functions shall be provided in separate units

f) Voltage dependent Resistor (Metrosil)

Each REF relay shall be supplied with a voltage dependent resistor (VDR) or Metrosil to limit voltage across the REF high impedance circuit.
The basis for the rated voltage of the VDR is the maximum phase-earth through fault of 25 kA.

Note: *The Stabilizing resistor and the Voltage dependent resistor shall preferably be housed in a box with terminals that allow connection of the REF relay to the resistor and VDR in the box. Several terminals will be provided to allow selection of required stabilizing resistor. The single box will be suitable for panel mounting.*

The Protection Functions Offered shall satisfy the detailed specifications as included elsewhere in this specification for each of the protection and control functions.

4.1.2.3.2.7 Breaker Backup Protection

The breaker backup protection shall only isolate the bus-bar to which the faulty breaker is connected. I.e. the station shall, as far as possible, remain in operation by a breaker failure. The bus-bar protection can be used for selection of breakers to be tripped.

4.1.2.3.2.8 Synchronizing Equipment

Circuit breakers and the secondary side transformer circuit breakers at 66 kV and above shall have check synchronism (controlled closure) equipment.

Closure of the circuit breaker shall only be possible when the phase angle, slip and voltage difference between the measured voltages are within pre-set ranges. Permitted phase angle difference shall be adjustable in the range of 5 to 100 degrees, the slip shall be adjustable in the range of 0.05 to 0.5% and the voltage difference shall be adjustable from 2 to 20%.

4.1.2.3.2.9 Relay Test Equipment

The relay test equipment shall be a portable three phase unit with facilities for testing of over current relays, negative sequence relays, differential relays, earth fault relays both directional and non-directional as well as auto reclosing equipment. All sources of test units shall be integrated in the unit Digital display for volt and amps shall have 1% accuracy whereas the digital timer shall have a resolution not less than 1ms. It shall be possible to connect the unit to a personal computer and necessary software for data recording and data handling shall be included.

4.1.2.3.2.10 Relay Settings

The Contractor based on network and equipment requirements shall provide the protection setting.
The Contractor, prior to making all commissioning tests, shall apply the settings to the equipment.

4.1.2.4 Metering

All metering equipment shall meet the requirements in IEC 60687 and IEC 61036.

Meters shall be designed for 110V+15/25 %, 50 (47-53) Hz and 1/5 A secondary voltage/current from measuring transformers. Auxiliary supply for the meters shall be 110V, 50 Hz from the voltage transformers, or 110 VDC from the DC supply system. Secondary current 1 or 5 A from current transformers shall be decided on a later stage for each individual meter.

4.1.2.4.1 Meters for Outgoing 33kV and 11kV lines

Electronic meters for active power, reactive power (Wh and VArh) and data recording units shall be provided for each outgoing feeder for registration of power irrespective of the direction of power flow. The Wh meters and recorders shall be of class 0.5 and class 0.5 for the VArh. The scale on the different type of instruments shall be proposed by the Contractor and be subject to approval by the Project Manager. The meters shall be able to communicate with the control system with pulses and on an IEC 61850 protocol.
The energy meters for all the circuits shall be housed in one modular metering panel whose front door is a transparent glass.

4.1.2.5 LV cables and Cable Racks

4.1.2.5.1 General

This chapter covers the technical requirements of the external cables and appurtenance, cable laying, supply and erection of cable racks, etc., for all installations described under these Specifications except for the cables included in Domestic Installations (light, small power, etc.), which is described under Civil Works.

The supply and installation of the internal cables between the various parts of equipment shall be included in the Chapter in which the relevant equipment is specified.

The cable trenches including trench covers as well as conduits and cable racks shall be furnished and installed by the Contractor. Other necessary materials and equipment for laying, fixing, terminating, etc. of the cables shall also be provided by the Contractor.

For calculation of the length of cables, cable racks, etc., the Bidder shall use the measurements computed from the Drawings. No alteration in the lump sum prices shall be made due to possible rearrangement of any installation, changes in the building constructions, or any other reason, which may influence the quantity of cables and appurtenances to be supplied.

If, however, a considerable change in location of a switchyard should be made, the price shall be reduced or increased proportionally to the amount of reduction or increase in the distance between the switchyard and the control building.

The cables shall be delivered in full lengths, and consequently no joints are permitted. All accessories shall be provided, such as potheads, galvanised and painted steel supports, clamps, etc.

4.1.2.5.2 Technical Requirements

4.1.2.5.2.1 *Cables*

The design, manufacture, rating and testing of all cables shall comply with the provisions and requirements of the applicable IEC recommendations, supplemented by recognised national standards if necessary.

40 °C maximum design ambient temperature shall be applied for all cables internally in the switchyard, between the switchyard equipment and the control building and inside the control building.

All cables shall be of termite proof design, e.g. by brass tape or equal approved techniques.

Wherever the risk of inductively transferred disturbances during abnormal (short-circuit, earth fault) conditions as well as during normal conditions exists, the cables shall be screened.

In order to have a minimum number of types of cables, all cables shall be standardised as much as possible as regards cross-sections, number of cores and marking of cores.

The phase colour identification code to be applied shall be made known to the Contractor shortly after the award of the Contract.

For the three-phase low-voltage system, four wire grounded neutral system shall be used.

The low voltage power cables (AC and DC) and all cables for control, measuring, etc., shall be PVC insulated and PVC-sheathed with an earthed concentric copper screen. The conductors shall be of electrolytic copper.

All cables shall be steel wire armoured.

Further requirements are stated in General Specification of Works, "Wiring and Terminal Blocks".

4.1.2.5.3 Cable Laying

The main guidelines and general requirements for the cable laying are stated in General Specification of Works, Cable Laying and Routing.

Medium-voltage, low-voltage power cables and control and measuring cables shall be segregated from each other throughout the plant.

The cables shall be laid in an orderly manner and crossings in the same plane shall be avoided.

All cables shall be laid on cable racks where they are not running in cable ducts or trenches, or in protecting tubes.

The cable racks shall be designed to allow the laying of the cable from the side(s) without pulling through. All racks and fixing devices shall be hot-dip galvanised.

The Contractor shall supply trenches and conduits of concrete.

The last section of a cable on the switchyard may be laid in a conduit or a pipe, they shall be laid in such a way that cables easily can be exchanged without digging.

4.1.2.5.4 Diagrams and Calculations

The Contractor shall deliver cabling plans and diagrams showing each cable connection.

Drawings for the cable racks, fixing features, etc., shall also be provided by the Contractor.

All dimensioning calculations shall be submitted to the Project Manager for approval.

The Bidder shall in his Bid give detailed information about the different types of cables proposed.

4.1.2.5.5 Tests

Factory tests and site tests shall be performed in accordance with the applicable IEC recommendation.

Type test certificates shall be submitted on request.

4.1.2.6 Earthing (Grounding) System

4.1.2.6.1 General

This chapter covers technical requirements of the earth electrode systems and the earthing conductors for the connection of metallic parts, of lightning arresters and of the system neutrals, designed to protect persons and material and to allow for the correct service, operation and maintenance of the installations.

The substation earthing system shall be designed principally according to ANSI/IEEE 80 - 1986 Guide to Safety in AC Substation Grounding.

The earthing system shall consist of the earth electrode system in the ground under the switchyard, and of the earthing conductors, over-ground and in the buildings.

The Contractor shall design the complete earthing system. He shall measure and verify the specific earth resistance at all places where earthing electrodes will possibly be buried, he shall make drawings of the earthing electrode grids, calculate the resulting earth electrode resistance, and supply all information about the planned earthing electrode systems. He shall also make drawings of the earthing conductors, over ground and in the buildings and make the necessary calculations for the dimensioning of the earthing conductor systems. All the above shall be submitted to the Project Manager for approval.

For Biding purposes the earth resistivity shall be taken as 2500 ohm-metres.

The contractor shall be responsible for providing and installing the underground earthing system of the switchyard and for the connecting of all related equipment to this earthing system and shall furnish all required materials for this purpose. The earthing system shall earth operational electric systems of any type and voltage such as transformer neutrals, lightning arresters, secondaries of instrument transformers, etc.

Moreover, the Contractor shall take the necessary measures and furnish the required material for the safe earthing of:

- All steel structures, metal parts and overhead ground wires of the switchyard.

- All fences of the station, whereby for outer fences special care shall be taken to avoid injurious step and touch voltages for personnel standing outside and inside these fences.
- All metal parts, even if these do not constitute a conducting part of an electric system of the plants, such as machinery, operating desks, piping, sewers, rails, metal tanks, lighting, fixtures, cable racks, etc.
- All operational electric systems such as power and instrument transformers, lightning arresters etc.

All connections between equipment and the earthing network shall be exposed (not embedded) and easily accessible for checking of the transition points. Bare conductors, as part of the earthing system, embedded directly in the concrete will not be accepted. Similarly, bolted connection of metallic constructions, do not form an acceptable earthing connection.

The layout drawings, the detailed calculations for the earthing system and the relevant data, which the Contractor will use as basis for his design, shall be submitted to the Project Manager for approval. The Contractor shall also be responsible for performing all measurements and final checking of the whole of the earthing system.

Further requirements related to the earthing system are specified in Particular Specifications.

4.1.2.6.2 Technical Requirements, General

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

More specifically and independent of (or in addition to) the regulations and 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
- A low earthing impedance for the transformer neutrals and a sufficiently low neutral conductor impedance
- Limitation of the induced, or capacitive transformed, voltages on low voltage, low current and electronic cables, circuits, panels and other equipment.
- That short circuit, earth fault and double earth faults currents will flow through the earthing systems and not through other conducting parts or building constructions to a hazardous extent.

The maximum resistance of the earth electrode grid in the switchyard and under the control building shall be 0.5 ohm during the dry period. In addition, the earth electrode system as well as all other earthing systems shall be designed and constructed for the operating voltages, the design short circuit capacities and the corresponding short circuit and earth fault currents which are specified in General Specification of Works, and in the other Sections of these Specifications for the respective voltage systems.

The overall resistance between the earthing grid system and the surrounding soil shall be in the range of 10 ohms. If necessary, additional earthing rods shall be applied to achieve the specified value.

The dimensioning shall be co-ordinated with the relay protection scheme of the various parts of the plant. In any case, however, the earthing conductors shall be

dimensioned for carrying the earth fault current and double earth fault currents of the various parts of the plant for at least 1 (one) second without any harm to the conductors or connections.

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

Buried connection shall be made by compressed clamps or by approved welding process. No bolted clamps may be used underground surface. Connections above earth shall be screwed and shall be easily accessible for control. All connections shall be protected against corrosion.

4.1.2.6.3 Earthing System under the Control Building

The conductors shall be of electrolytic copper with dimensions at least 30 x 3 mm for flat bar or at least 95mm^2 stranded wire. Copper-weld with approximately the same conductivity may be used.

Risers shall be copper stranded wire at least 95 mm^2.

The conductors shall be placed on the ground after the excavation is completed and just before the concreting starts. Care must be taken that the earth wire is in good contact with the soil and preferably 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 brazing or welding. 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 brazed or welded to the conductors.

The risers shall be placed in the concrete shuttering, and led out of the shuttering at appropriate places approximately 30 cm 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.

4.1.2.6.4 Earthing System of the Switchyard

The conductors shall be of electrolytic copper with dimensions at least 30 x 3 mm for the flat bar or at least 120mm^2 stranded wire. Copper-weld with approximately the same conductivity may be used.

The risers shall be of at least 95mm^2 stranded copper wire or equivalent copper-weld.

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.

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 voltage between the fence and the ground.

Trenches for the earthing grid shall be excavated in the ground to reach soil of good conductivity and a layer of at least 25 cm of the same material shall be placed over the conductor. The conductor shall at no place be less than 80 cm below the ground level.

Where advantageous for achieving low resistance to ground, vertical copper-weld earthing rods may also be used, in addition to the horizontal grid.

Connecting terminals for the screwed connections between the risers and the on-ground earthing conductors shall be placed in easily accessible locations.

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

4.1.2.6.5 Earthing Conductors

In the control building 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 dimensions of at least 95 mm² for or stranded conductor.

All the risers from the earthing electrode systems shall be connected to these main buses by disconnecting screw 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 shall be earthed, shall be of electrolytic copper with adequate dimensions for each item to be earthed.

Each item shall be directly connected to an earthing 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.

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

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

Earthing switches and lightning arresters shall have a riser directly connected to the current carrying part in addition to a riser connected to the structure. All outdoor earthing conductors shall be insulated with spacers or conduits against contact with galvanised steel structures.

4.1.2.7 Site and Commissioning Tests

4.1.2.7.1 General

Tests as described below shall be used as a guideline and may be changed or varied after written agreement from the Project Manager, due to changes of design manufacturing of construction techniques.

4.1.2.7.2 Test of Wiring

a. Insulation Resistance Test at 2.5 kV a.c. for one minute shall be carried out on all A.C and DC. Protection, control, alarm and indication circuit to ensure that wiring is in satisfactory condition. Ocular inspection shall be made on cable glands, cable jointing, fuse or circuit breaker ratings and small panel items, such as indicating lamps.

b. Static equipment which may be damaged by the application of test voltages shall have the appropriate terminals disconnected.

c. Inter-relay, inter-unit and cubicle wiring carried out at site is to be checked to the appropriate circuit and/or wiring diagram. This may be done by using bells or buzzers. D.C. supplied from the station battery may also be used. Where it is found necessary during re-commissioning work to effect site modification to the secondary wiring, site copies of the appropriate schematic and wiring diagrams shall be suitably marked as agreed with the Project Manager before the circuit is commissioned.

d. Loop resistance measurements are to be done and on all current transformer circuits. Separate values are required for current transformer and lead resistances and all measurements are to be recorded on lead resistance diagrams.

e. Pilot cable impedance and phase angle measurements shall be made when pilot cable is to be used with unit type protection. The Contractor providing the pilot cables shall measure these values.

4.1.2.7.3 Test of Relays

a. All relays are to be examined to ensure that they are in proper working conditions and correctly adjusted, correctly labelled and that the relay case, cover, glass and gaskets are in good order.

a. Secondary injection shall be carried out on all a.c. relays, using voltage and current of sinusoidal waveform and rated power frequency. For circulating current protection employing high impedance voltage setting test shall be across the relay and stabilising resistance. The operation setting for the type of protection is to be established by secondary injection, where it is not possible to ascertain this value.

4.1.2.7.4 Test of DC. Circuits

Tests are to be carried out to prove the correctness of all DC. Polarities, the operating levels of DC. Relays and the correct functioning of DC. Relay schemes, selection and control switching, indications and alarm.

4.1.2.7.5 Test of Instruments

Instruments and instrument transformer circuits shall be checked for polarity of direction and for calibration including any interposing transformers or transducers. These checks shall be made on all current transformer ratios where applicable.

4.1.2.7.6 Tests on Conductors, Insulators and Accessories

None required.

4.1.2.7.7 Tests on the Switchyard on Site

All electrical equipment and installations shall be tested for correct connections of the high-voltage circuits and shall be subjected to a complete operation test to check the correct operation thereof in terms of the operational requirements specified in these specifications.

The resistance to earth of the earthing system of the switchyard shall be measured. The earthing systems shall be checked for conductivity and reliable connections.

4.1.2.7.8 On Load Test

On load tests are required, but due to the hazards inherent they shall be carried out under the direct supervision of the Project Manager and/or the Employer. The following tests are required:

a. an operation and stability test shall be carried out for on-load commissioning.

b. test for restraint shall be carried out to prove the characteristic of protective and measuring systems with directional characteristics.

c. on-load checks shall be made after the protective gear has been placed in service to ensure that all connections and test links have been replaced and test leads removed, as well as to confirm the integrity of the current transformer circuits. Where necessary, voltage readings shall be taken at the terminals on each relay to ensure that loop connections between the relays are complete. Special attention shall be paid to broken delta voltages and residual current circuits were zero voltage or current respectively may not be proof of the completeness of the circuit.