

SECTION - VI

**PARTICULAR TECHNICAL SPECIFICATIONS
SUBSTATION
CONTROL, PROTECTION and
COMMUNICATION**

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4.1.2 Control, protection and cabling

4.1.2.1 Control Protection and Metering

4.1.2.1.1 General

The sections cover the technical requirements for the systems of control, protection, metering and signalling of the Juja Road substation. 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. In the 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.

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 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.

Overview of Substation Automation SAS

This Substation Automation System (SA) 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, interbay bus, intelligent electronic devices (IED) for bay control and protection.

The communication gateway shall secure the information flow with Regional ControlCentres. The interbay 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 within the manufacturer's responsibility, but subject to approval by KPLC.

This specification covers the design, manufacture, inspection, training and testing at the manufacturer's works and at site, delivery to site, installation and commissioning.

Design of SAS

The Substation Automation System (SA) 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, IEC60870-5-101,103,104 for operation under electrical conditions present in high-voltage substations, follow the latest engineering practice, ensure long-term compatibility requirements and continuity of equipment supply and the safety of the operating staff.

The offered SA 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, signalling 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.

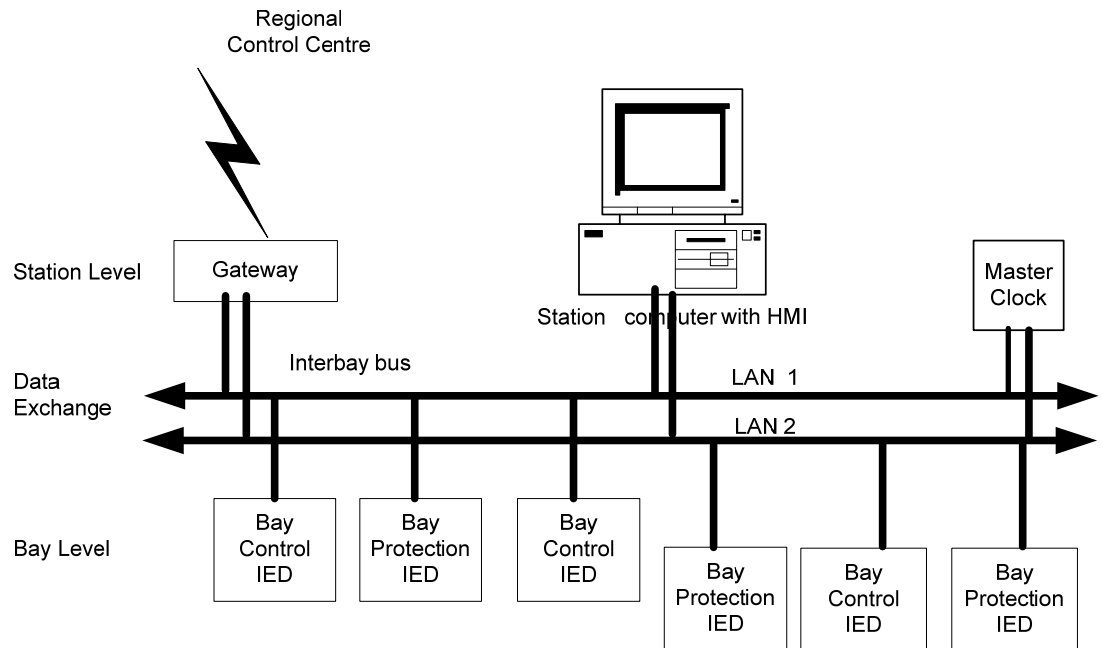
The typical SA layout shall be structured in two levels, i.e. in a station and a bay level.

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 I_{\max} all phases, MW and MVA_r) and alarm annunciation shall be presented by discrete components.

The control of high and medium voltage circuit breakers, isolating switches and tap changers shall take place in a hierarchy with four levels as described in Project Specific Data Section. From each level one may block access from higher levels:

The control units shall take auxiliary voltage from the station battery and be equipped with self-supervision systems giving alarm by internal faults.

The system shall be fail-safe keeping all equipment in the last status by loss of communication to higher systems.



System Architecture of Substation Automation

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 interbay 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 interbay bus.

The SA shall contain the following main functional parts:

- Human Machine Interface (HMI) with process database
- Separate gateway for remote supervisory control via SCADA
- Master clock (e.g. GPS receiver)
- Collection of the relevant data concerning the substation and distribution of the data where needed
- Bay and station level devices for control, monitoring and protection
- Bay-oriented local control panels.

- *Signal List*

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

- Commands for all CBs and motorized switchgear
- Status Indications
- Alarms
- Set Point Regulation
- Measurands
- Accumulators

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 SCMS SA system shall include the following;

- Control mode selection
- Select-before-execute principle
- Command
Interlocking and supervision:
Double command and blocking
- Autoreclosing
- 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

- *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.

- *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.

SCMS 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 SCS 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.
- 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 SCS.

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.

- *SCMS Equipment*

Substation Computer

- The substation computer coordinates the operation of the SCS. The functionality shall include:
 - Alarm Grouping

- Event Logging
 - SCS 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 SCS functionality. The Tenderer shall state how this is achieved.

Substation Local Area Network

Local substation communications shall use Ethernet LAN to connect the components of the SCS using IEC 61850 protocols. The LAN may be of star-coupler configuration. Fibre 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 protocols.

Operator Workstation

- The Operator workstations / HMIs shall consist of high performance computer and monitor with computer desk. It shall be fully integrated into the SCS on the substation LAN. The proposed HMI shall be based on the latest PC technology available on the market at the time of offering.
- The operator desk and chair shall be of high quality construction, appropriate to continuous use by the operator.

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 Colour Printer to print screen shots or other information

Satellite Clock

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

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 SCS (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.
-

Data Transmission

-
- The SCS 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 SCS via the SCADA system. The protocols currently supported are IEC 60870-5-101 & IEC 60870-5-104.
- This communication link must be via an approved communication mode complete with the terminal equipment all supplied, installed & commissioned by the Contractor.

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.

- **Control Stations**

- *Distributed 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 galvanic ally 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.

- *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 60870-5-101/104 protocol. The following SCADA facilities shall be available from the substation.

- Supervisory control of all circuit breakers and motorized line and bus bar isolators. 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, 30, 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.
- 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.

The Contractor shall as part of his supply fill in I/O lists for each substation in the format to be specified by the employer. The I/O lists will comprise the name tag, address tag (fitted to the SCADA Contractor's system of addressing the information), ASDU type in accordance with the agreed interoperability list and other information as required.

4.1.2.1.2 Automatic Voltage Regulator

The transformer bay shall be equipped with an automatic voltage regulator relay acting on the on line 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.

The voltage relay shall be equipped with functionality for parallel operation of several transformers.

If connected in parallel the transformers shall be regulated in a master-slave circulating current or negative reactance system where each transformer can be selected as master. If the master is tripped 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.

4.1.2.1.3 Protocols

The Station Controller shall be set up for communication with the Control Centre interface with protocol IEC 60870-5-104, redundant with main and back-up interface. Switching between the two must be allowed for at any time by changing software parameters.

An international open and defined User Convention must be used (e.g. "Norwegian User Convention or similar) and the Contractor shall inform on which convention he intends to use.

Internally between bay controllers and station controller the Contractor may use an open (not proprietary) protocol of his own choice or the IEC 61850 protocol for sub stations internal communication. The particular solution shall be described in the bid.

However, the station controller must be able to receive and transmit information on IEC 60870-5-104 protocol.

4.1.2.1.4 Communication

All communication between bay units and between bay units and station controller/workstation shall be on a bus structure, preferably by fibre optic cable.

4.1.2.1.5 Indicating and Metering Instruments and Metering Transducers (if used)

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 96 x 96 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 SCS 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 4-20 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) will be 110 V DC.

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.

4.1.2.1.6 Programming and Fault Finding

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.

4.1.2.2 Factory Acceptance Test

The Control system with Station Control Unit and Bay Units shall undergo a factory acceptance test where the total system is connected and all measurements and controls are simulated.

4.1.2.3 Training

An in-depth training in the application, fault finding and maintenance of the control system shall be provided. The training shall include:

- System configuration
- Programming tools
- Picture editing
- Operating system
- System maintenance
- Diagnostics and fault finding/correction
- Any other training regarded necessary by the Bidder

4.1.2.4 **Protection**

4.1.2.4.1 **General Requirements**

The protection relays to be installed for the protection of transmission lines, transformers and other HV/MV equipment shall be numeric 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 from 110 V 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 opto 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.

4.1.2.4.2 **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: Where contacts of the protective relays are not sufficient for circuit breaker tripping, auxiliary trip relays shall be provided in order to prevent damage to relay output contacts. Operating time for such tripping relays shall not significantly affect the overall fault clearing time.

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 shall 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 shall 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 shall 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 disconnecter 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 disconnecter 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 two protection sets cover the same fault they shall be divided into two electrically and mechanically separate parts by means of:

- separated DC power supply
- separated boards
- separate current transformer cores
- separate voltage circuits
- separated tripping devices
- separate tripping coils
- separated cables
- separated relay protection channels

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

4.1.2.4.3 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 such shall be included in the supply.

4.1.2.4.4 Fault Clearing Time

The protection system plus the circuit breakers shall have fault clearing time of not more than 100 ms for voltages 132 kV and above and 150 ms for voltages below.

4.1.2.4.5 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.

Trip circuit supervision relays shall supervise the Trip coils both when the circuit breaker is open and when the circuit breaker is closed.

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.

4.1.2.4.6 Fault Recorder and Fault Locators

Fault recorders and fault locators shall 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 Data Exchange (IEEE-COMTRADE)" Necessary signals from the transformers shall be included.

Distance to fault shall be displayed in Kilometres (Km), on the relay LCD screen together with the fault data.

4.1.2.4.7 Supervision

The supply shall include hardware and software for local setting, supervision and data acquisition of the protection relays, fault locators and fault recorders. The software shall be installed on engineering lap top type PC with "windows NT" operating system.

The protection relays shall also communicate with the bay control units over the open protocol IEC 870-5-102 or IEC 61850.

4.1.2.4.8 Protection of HV system

4.1.2.4.2.1 132 kV and 66 kV Transmission Line Protection

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 fused 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 line protection schemes shall contain the following protection relays:

- (i) Distance Protection Relay
- (ii) Three phase directional over current and Earth fault relay
- (iii) Sensitive Earth fault relay
- (iv) Auto reclose Relay
- (v) Trip circuit supervision visible from the front of the panel without having to open the panel door.
- (vi) Autoreclose IN/Out switch

Distance Protection

One complete distance relays of 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 characteristics:

- Ratings: AC Inputs: 110V, 1Amp (three phase).
- Power Supply Voltage: 110VDC. (Universal power supply of 30-300VDC is preferred).
- The relays shall be of Numeric design.
- Impedance criteria.
- Three zones phase –phase Protection.
- Three zones phase –earth Protection
- Additional Zone 4 Protection
- Automatic Switch on to fault.
- Independent settings for each zone.
- Distance to fault measurement.
- Display: On operation, the relay should display the faulted phase(s), time and zone of operation and distance to fault.
- Power Swing detection: Blocking/non blocking selectable by user.
- Scheme communication logic and residual current compensating.
- IDMT Three Phase/Over current & Earth fault Protection.
- Fuse failure supervision.
- Auto- reclose logic 1 and/or 3 phases.
- Three pole tripping logic.
- Disturbance and event records including software for disturbance analysis.
- Fault record should be incorporated.
- At least six (6) Binary inputs.
- Mho/Quadrilateral characteristics.
- Stability against Switching inrush currents and Reverse faults.
- Clear faulted phase indication.
- Clear fault identification even for boundary conditions.
- Software necessary for all above functions shall be provided.
- Three sets of Installation, Commissioning and maintenance manuals shall be provided.

All these functions shall be integrated in a compact package. A user-friendly menu driven interface shall be for included for setting and testing of the relays.

Three phase numeric directional over current and earth fault relay

Should incorporate the following features:

- Relay must be of Numerical design.
- Current setting range for over current relay $0.5I_n-2.4I_n$
- Current setting range for earth fault relay $0.05I_n-0.8I_n$
- Quadrate connection for polarising voltage ($V_n=110$)
- Applicable on the LV side of a Dyn1 transformer
- High set Element, with a setting range of $1-32I_n$
- The phase and earth directional elements should be individually selectable.
- I.D.M.T characteristics according to BS 142 or IEC 60255 and Definite time characteristic
- 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.
- Time setting multiplier 0.05 - 1.0

- Broken conductor protection feature
- Negative sequence Protection Feature
- Highset Element for both over current and earth fault Protection, with a setting range of 1-30In.
- Thermal Protection.
- Dedicated Breaker Fail Protection.
- Circuit Breaker Maintenance
- Incorporate Fault records, Event Records and disturbance records.
- Configurable output relays with ability to output starting elements to control Tripping of other upstream Protection relays.
- Must provide all technical and operations manuals and configurations and settings software.

Sensitive Earth Fault Relay.

Should incorporate the following Features;

- Relay must be of Numerical Type
- Current setting range for earth fault relay 0.005In-0.8In
- Definite time delay characteristic; setting range, 0- 30 Seconds.
- Circuit Breaker Maintenance
- Fault records, Event Records and disturbance records.
- Drop off /pickup ratio >90%
- Low transient overreach < 10%

Autoreclose relay

- Selectable 1 - 3 autoreclose shots
- Independent set dead time for each shot
- Autoreclose inhibit after manual close
- Separate input for over current high set element and I.D.M.T element
- Autoreclose inhibition for over current high set element.

4.1.2.4.2.2 Transformer Protection 132/66/11 kV Transformers (HV side)

The protection contains the following protection relays on the HV side:

- (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 Over current and Earth fault Protection Relay
- (iv) Auxiliary relays with annunciator for the following transformer functions
 - Tx Buchholz gas
 - Tx Buchholz surge
 - OLTC Buchholz gas
 - OLTC gas relay
 - Pressure relief
 - Winding temperature Alarm
 - Winding temperature trip
 - Oil temperature alarm
 - Oil temperature trip
 - Tx oil level low
 - OLTC oil level low
- (v) Standby earth fault relay.
- (vi) HV Master trip
- (vii) Trip circuit supervision relay for HV breaker

Biased differential protection for a three 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 1 transformer protection

This should incorporate the following features:

- Relay Must be of Numerical design
- Pick up setting range, 0.1 to 0.5In
- Should incorporate a high-set Element with a setting range of up to 20In.
- Magnetising current inrush restraint
- Integral CT ratio compensation (0.1-2) and vector group compensation
- Measurement and indication on the MMI, of phase, differential and bias currents
- Storage of Fault records and Event records; the Fault flags should be accessible on the relay LCD screen without opening the relay cover.
- Overfluxing restraint
- Overfluxing protection with Alarm and Trip functions
- 5th harmonic restraint feature on the differential Element.
- Appropriate Dual Bias characteristic to ensure relay stability for heavy through faults
- Should incorporate a disturbance recorder feature.
- Red L.E.D to indicate Tripping
- Relay Self diagnostic and Alarm feature
- Ability to Latch output contacts to prevent TX re-energizing before carrying out investigations.

Three phase numeric IDMTL over current and earth fault relay

Should incorporate the following Features;

- Relay must be of Numerical Type
- Current setting range for over current relay 0.5In-2.4In
- Current setting range for earth fault relay 0.05In-0.8In
- 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.
- Time setting multiplier 0.05 - 1.0
- Broken conductor protection feature
- Negative sequence Protection Feature
- Highset Element for both over current and earth fault
- Protection, with a setting range of 1-30In.
- Thermal Protection
- Dedicated Breaker Fail Protection.
- Circuit Breaker Maintenance
- Fault records, Event Records and disturbance records.
- Configurable output relays with ability to output starting elements to control Tripping of other upstream Protection relays.
- Drop off /pickup ratio >90%
- Low transient overreach < 10%

Restricted Earth fault relay

- Relay must be of Numerical type
- Relay should reject harmonics produced by C.T saturation
- The offer should include the associated stabilising resistor and voltage dependent resistor (metrosil)
- Current setting range 0.05-0.8In
- Operating time < 25ms at 5 times the setting

Restricted earth fault and differential protection functions shall be provided in separate units.

LV side protection defined below.

4.1.2.4.2.3 Transformer Protection 132/66/11 kV Transformers (11 kV side)

The protection shall be as follows:

- (i) Three phase over current and earth fault relay
- (ii) Three phase directional over current and earth fault relay
- (iii) LV Master trip relay
- (iv) Trip circuit supervision visible from front of panel without opening relay compartment door.

The characteristics of the relays shall be as above.

4.1.2.4.2.4 Feeder Protection 11 kV Transformers (LV side)

The functions below can be combined in one unit. The characteristics are as above.

- (i) Feeder protection relay to include the following protection functions
 1. Three phase over current and earth fault
 2. Sensitive earth fault
 3. Autoreclose function
- (ii) Auxiliary relay to indicate/lockout circuit breaker for low SF6 gas pressure
- (iii) Trip circuit supervision visible from front of panel without having to open any panel compartment door.
- (iv) Autoreclose IN/OUT switch
- (v) Sensitive Earth Fault (SEF) isolation link or switch

4.1.2.4.2.5 Under Frequency Relay

Each busbar shall be equipped with a separate under frequency relay for load shedding of all outgoing breakers. Each trip circuit 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 0.1 Hz.

4.1.2.4.2.6 Busbar Protection 132 kV and 66 kV

Busbar protection schemes shall be provided at busbars for the 132 kV and the 66 kV bus bars. Low impedance schemes will be acceptable provided full busbar 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 more than two criteria checks before tripping. The busbar protection relays shall be of the numeric type with full discrimination between the busbars even with closed bus coupler. It shall have CT supervision.

4.1.2.4.2.7 Breaker Backup Protection

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

4.1.2.4.2.8 *Bypass Trip Logic, Bus Coupler*

Where bus coupler is specified or already installed, the trip signals of any bypassed circuit breaker shall be instantaneously transferred to the bus coupler.

Electrical interlocks shall be provided to ensure that only one circuit can be put on bypass at any one time. This is only possible through the reserve busbars.

The bus coupler protection shall in addition to possible bypass consist of a 3-pole IDMTL overcurrent relay and one IDMTL earth fault relay, all with standard inverse characteristics as well as breaker failure back-up protection.

4.1.2.4.9 **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 preset 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%.

4.1.2.4.10 **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 1 ms. It shall be possible to connect the unit to a personal computer and necessary software for data recording and data handling shall be included.

4.1.2.4.11 **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.

4.1.2.5 **Metering**

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

Meters shall be designed for 110 V+15/25 %, 50 (47-53) Hz and 1/5 A secondary voltage/current from measuring transformers. Auxiliary supply for the meters shall be 110 V, 50 Hz from the voltage transformers, or 110 V DC 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.

4.1.2.5.1 **Meters for Outgoing 132, 66, 11kV lines and HV side of transformers**

Electronic meters for active power, reactive power (Wh and VARh) and data recording units shall be provided for each outgoing and incoming line and for the HV side of all transformers 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 60870-5-103 protocol.

4.1.2.6 **SCADA EMS and Telecommunication**

Overview of existing equipment associated with the Juja Road SS upgrade project.

4.1.2.6.1 **General SCADA EMS**

Currently Juja Road Substation is monitored and controlled via an existing RTU (Remote Terminal Unit), located on the first floor of the substation building, and is an integral part of KPLC'S SCADA EMS system. This RTU is connected both to the NCC Network Manager and to the Backup Coast RCC (Regional Control Centre) located at Rabai based on IEC 60870-5-104 protocol using Fibre Optic Cables and SDH Terminals. The Juja Road Substation is the largest RTU in the KPLC SCADA system and consists of the main RTU cubicle, plus several cubicles containing process interface materials such as transducers, interposing relays etc, and cable marshalling cubicles.

4.1.2.6.2 **General Telecommunications**

Various communication media and equipment whether based on Fibre Optic Cables, or Power Line Carrier (PLC), etc converge at Juja Road substation, which forms the link to the NCC (National Control Centre) with the rest of the power network, and are mainly used for voice communication on a private network, transmission of SCADA data, Line protection signalling, and Ripple control signalling for load management.

Power Line Carrier (PLC)

There are several PLC Equipments linking Juja Road with other stations on 132 kV and 66 kV lines. Most of these PLC equipments are several decades old and are virtually obsolete and are to be decommissioned under this contract. There are however a small number which are fairly new and will be retained, and relocated to the new substation building.

SDH Fibre Optic FOX515 Equipment

The existing FOX 515 Terminal and the associated FOC connections forms part of the backbone of the KPLC private telecoms network linking the NCC, and all other stations in the power system either via FOC or PLC. Together with two similar terminals located at the NCC, and two others at Dandora substation form an STM-4 ring. See *KPLC SDH Network drawing*.

PAX (Private Telephone Exchange)

An old PAX type SOPHO DCS 255 currently forms the main voice communication link between the NCC and the rest of the network, and together with three newer units type SOPHO iS3030 SSW800 located at the three Regional Control Centres (Lessos, Kiganjo and Rabai) form the backbone of the KPLC Private Telephone Network, and provides such services as.

- Dispatcher Consoles at both the NCC, and the Nairobi Area Control Centre (NACC) via cables, and facilitates monitoring traffic on trunk Lines, handling and outgoing calls from either of the two Controller positions; Intrusion / Force Down facility on trunk lines
- Tie Lines to the NCC PAX (ECS-FX)
- Two-wire Telephone Subscriber connections
- 4-Wire E & MTrunk Lines via PLC, FOX515 and Microwave Radio.

- 2-Mbit telephone Trunk connections to the existing three SOPHO iS3030 SSW800 located at Lessos, Kiganjo and Rabai via the FOX515 network.

ODF'S (Optical Distribution Frames)

There are currently ODF'S located in the Relay/PLC Room, on which several Optical Fibre Cables are terminated.

Ripple Injection Control

The station is also the location of one of several Ripple Control Injection points used for load management. The Central Controller for Ripple Control is also located here.

48 VDC Supply System (Batteries/Charger/Distribution Board)

There exists an old 48 VDC Supply System located at the present Juja Road Substation building. This system normally supplies all the SCADA, Telecommunications and Ripple Control Equipment located in the building.

The system is also linked to the 48 VDC System located on the ground floor of the NCC building. While the two systems are normally operated independently, the link provides a facility that enables using any one of the two systems to supply equipments at both locations at the same time should the need arise. Both systems are therefore sized to carry the combined 48 VDC load at both locations.

4.1.2.7 SCADA EMS Requirements

Complete integration of the new Juja Road Substation into the existing KPLC SCADA/EMS system via **IEC 60870-5-104** communication protocol between the station SCMS (Station Control and Monitoring System) and the Network Manager at the NCC and the Backup at Coast RCC.

Data base update, and testing each and every signal to the process as currently defined in the SCADA EMS Data Base, etc. is in scope of supply.

4.1.2.8 Digital PLC Requirements

The PLC equipment should in general comply with the following standards

Functional requirements according to IEC 60495(1993) and any subsequent revisions

Electromagnetic compatibility according to EN 61000-6-2 (2001), IEC 61000-6-2 (2006), IEC 61000-6-4 (2006), and IEC TS 61000-6-5 (2001)

Mechanical requirements according to IEC 60721-3-3 (2002) class 3M1 and IEC 60721-3-2 (1997) class 2M1. Detailed specifications are listed in the table below.

The new equipment shall be fully software programmable, have the facility to integrate a Tele-protection interfaces operating within the speech band, and above all else interface in every way with the existing and new equipment.

Also see the attached Technical Schedule which has to be completed by the bidder.

4.1.2.8.1 Detailed PLC specifications

Specification	Specified Requirement
	The PLC equipment shall comply with the standard IEC60495, second edition 1993
<i>Safety:</i>	Conform to IEC60950-1.
<i>For EMC and EMI:</i>	Comply with IEC60255-5, IEC61000-4-4/-5/-6/-12/-16, IEC60255-22-1
<i>Design:</i>	The PLC shall be of modular design and allow for easy upgrading. It shall not use fans or similar artificial cooling under normal operating conditions. The PLC equipment shall support DPLC (Digital PLC) and APLC (Analogue PLC) mode of operation in the same platform, software programmable via PC.
<i>Modulation:</i>	Modulation shall be SSB (Single-Side-Band) for APLC operation, and MCM (Multi-Carrier-Modulation) with Trellis Coding for DPLC mode of operation. Modulation and coding shall be implemented as software functions in DSP (Digital Signal Processing) technology
<i>Transmission Mode:</i>	Transmission mode shall be 2-wire frequency duplex
<i>Nominal Carrier Frequency Range :</i>	40 kHz to 500 kHz, programmable
<i>Frequency Stability:</i>	Equal to or better than +/- 1 ppm over the stated temperature operating range
<i>Nominal bandwidth for TX/RX :</i>	Programmable from 4 kHz to 32 kHz, in steps of 4 kHz, and shall be configurable for adjacent and non adjacent operations.
<i>Transmitter Output Power:</i>	Shall be user programmable 40, or 80 Watts (PEP)
<i>Output Impedance:</i>	Shall be programmable 75 / 125 ohms unbalanced and 150 ohms balanced as an option)
<i>Return Loss within TX Band:</i>	> 10 dB
<i>Tapping Loss:</i>	< 1.5 dB, according to IEC60495.
<i>RX Selectivity:</i>	> 65 dB at 300 Hz from the band edges.
<i>AGC Range:</i>	40 dB minimum.

<p><i>Programmable:</i></p>	<p>The PLC shall be programmable via PC with HMI(Human Machine Interface), based on MS-Windows The PLC system shall facilitate the programming and monitoring of the remote terminal from the local terminal using the standard HMI</p>
<p><i>Speech and AF Signal transmission:</i></p>	<p>The PLC shall be configurable for providing up to 3 analogue AF (audio frequency) channels with 4 kHz gross bandwidth each. The useful frequency band shall range from 300 Hz to 3720 Hz for each AF channel</p>
<p><i>SpeechLowPass Filter:</i></p>	<p>Shall be programmable in steps for commonly used data rates, ranging from 2 kHz to 3,4 kHz in steps of 200 Hz</p>
<p><i>Speech Interface:</i></p>	<p>Shall be configurable as 4-wire E&M, 2-wire FXO or 2-wire FXS It shall be possible to configure 3 analogue speech channels in 8 kHz or in 12 kHz RF-transmission bandwidth. Inter-channel crosstalk shall be compliant with IEC60495 A compandor according to ITU-T G.162 shall be configurable via HMI for each speech channel. Control inputs shall be provided for compandor switching (on/off) by the PAX</p>
<p><i>Data Modems:</i></p>	<p>The frequency band above speech shall be available for the transmission of narrowband modem signals from internal or external modems. The level of the AF - input/output ports shall be in accordance with IEC60495</p>
<p><i>Digital Filters:</i></p>	<p>Digital transit filters, programmable with respect to bandwidth and centre frequency in steps of 60 Hz, shall be available for each AF channel for local extraction , insertion and transit connection of selected teleoperation frequency bands.</p>

<p><i>Channel Equalization:</i></p>	<p>An equalizer shall be available for each AF channel for equalizing amplitude distortions of up to +/-12 dB Equalization of the channel frequency response in both directions shall be possible from one(either) end.</p>
<p><i>Narrowband Data Transmission:</i></p>	<p>The PLC shall provide – as software options - integrated modems for narrowband data transmission Transmission speed, channel centre-frequencies and the spectral bandwidth shall be programmable in steps for commonly used data rates, ranging from 100 bit/s to 9'600 bit/s in bandwidths of 240 to 3'400 Hz respectively. The narrowband modems shall be designed for low delay and short recovery times following a link disturbance. In a 4 kHz channel, it shall be possible to transmit up to 4 x 2'400 bit/s, or 2 x 4'800 bit/s, or 1 x 9'600 bit/s. Data transmission above 2 kHz band-limited speech shall be possible at 2 x 2'400bit/s or 1 x 4'800 bit/s</p>
<p><i>Broadband Data Transmission:</i></p>	<p>The PLC shall provide – as software option – an integrated modem for broadband/high speed data transmission. Transmission speed and spectral bandwidth shall be programmable via PC The speed and transmission bandwidth shall be programmable for up to 28.8 kbit/s in 4 kHz spectral bandwidth, up to 128 kbit/s in 16 kHz bandwidth, and up to 256 kbit/s in 32 kHz bandwidth. The data rates shall be selectable in steps, compliant with commonly used standardized data rates. The system shall support automatic transmission speed adaptation in at least 3 user defined steps, self adapting to the prevailing line condition (noise and interference)</p>

	<p>The broadband modem shall provide a facility for automatic detection and suppression of narrowband interference.</p>
<i>Data Multiplexing:</i>	<p>The PLC equipment shall provide an internal multiplexer for the time division multiplexing of up to 8 serial data channels that can be allocated individually to the internal modems</p>
<i>Data Interfaces:</i>	<p>Data ports shall be compliant with V.24/V.28, RS-232 and/or V.11/X.21/X.24</p> <p>The internal multiplexer shall provide data flow control for the asynchronous ports and speed adaptation for the synchronous ports according to the prevailing aggregate data rate and HV power line condition.</p> <p>All data ports shall be electrically isolated from ground and against each other.</p> <p>Point-point and point-multipoint operation with channel-sharing shall be possible.</p> <p>An Ethernet port shall be available as an option, for equipment configuration via LAN, or for general IP forwarding.</p>
<i>Tele-protection Interface</i>	<p>The PLC shall have a facility for an integrated teleprotection interface that operates within the speech band or within the spectral bandwidth of of the broadband modem, i.e teleprotection shall not require the allocation of extra / separate bandwidth.. The Tele-protection shall conform to IEC60834-1, 1999.</p> <p>Up to 2 integrated, independent teleprotection systems shall be configurable, each operating in it's respective channel for single or dual channel PLC configurations.</p> <p>Each Tele-protection system shall facilitate the transmission of up to 4 independent and simultaneous commands, programmable individually for blocking, permissive, or direct</p>

	tripping applications.
	The teleprotection shall be software-programmable via PC HMI with GUI, and shall incorporate a cyclic periodic automatic self initiating test loop.

4.1.2.8.2 PLC Tele-protection Interface on existing ETL600

The Tele-protection shall conform to IEC60834-1, 1999.

Up to 2 integrated, independent teleprotection systems shall be configurable, each operating in its respective channel for single- or dual channel PLC configurations.

Each teleprotection system shall support the transmission of up to 4 independent and simultaneous commands, programmable individually for blocking, permissive or direct tripping.

The transmission of the command signals shall be accomplished within the speech bandwidth or within the spectral bandwidth of the broadband modem, i.e. the teleprotection shall not require the allocation of extra / separate bandwidth.

During transmission of protection commands, other services like speech and data shall be temporarily interrupted in order to transmit the protection signal at increased power (command signal boosting).

The nominal transmission time shall be < 11 ms, < 12 ms, < 13 ms for blocking, permissive and direct tripping respectively.

The required SNR for a dependability of < 1E-03 shall be no more than 4, 3 and 0 dB for blocking, permissive- and direct tripping respectively in Tac = 15 ms, 20 ms and 40 ms.

The unwanted commands probability (security) shall for any SNR conditions worst case) be no higher than 1E-04, 1E-06, 1E-09 for blocking, permissive and direct tripping, respectively.

Electrically isolated opto-coupler inputs, solid-state outputs and mechanical relay outputs shall be available as I/O interfaces to the protection relay.

Voltage range shall be selectable from 24 VDC to 250 VDC nominal.

Inputs and outputs shall be freely allocated to the commands or alarms (programmable via HMI).

It shall be possible to individually delay or prolong the input and output command signals via HMI, and to monitor their duration.

All transmitted and received commands shall be logged with time stamps of 1 ms resolution by the internal event-recorder, and stored in a non-volatile memory for at least 1'000 events.

The teleprotection shall provide an integrated cyclic loop test

The teleprotection shall be software-programmable via PC HMI with GUI

The Tele-protection interfaces should be freely programmable depending on application as may be required for Blocking, Permissive and Direct Tripping schemes.

The Tele-protection interfaces for existing PLC are to be supplied as extensions on the existing PLC type ETL600. The Tele-protection facility should not utilise additional bandwidth, and operate within the normal speech band. This is because

the PLC equipments involved are already being used for SCADA Data at the highest possible speeds and no additional bandwidth would be available. The Transmission Delay times should be software programmable depending on application.

Also see the Technical Schedule which has to be completed by the bidder.

4.1.2.8.3 Line Traps

The Line Traps to be supplied shall comply with the relevant IEC guidelines/regulations

They shall be supplied complete with the appropriate mounting pedestals and other accessories for mounting on either CVT'S(or Coupling Capacitors), or post insulators.

Rated inductance (mH): *0.315 mH*

- Power frequency inductance (mH):
- Rated continuous current (A): *1,250 A*
- Rated short time current (kA, sec): *31.5 kA, 1 sec*
- Blocking Band: *will depend on chosen Carrier Frequency*

4.1.2.8.4 Line Matching Units (LMU's)

Phase/Phase Coupling

- Type: High Pass (f1 – selectable; f2 = 500 kHz)
- Impedance Line Side: 240/320 Ω (selectable)
- Equipment side: 75/125 Ω (selectable)
- Carrier power rating: up to 1'000 watts PEP

Protection against 50/60 Hz Power Frequency components and over voltage transients:

a) Drain Coil:

- Inductance: 0.2 to 0.7 mH
- Impedance at 50/60 Hz: < 1.5 Ω
- Continuous current: < 1.5 A rms
- Short-time current: < 50 A, 0.2 s

b) Surge Arrester:

- Rated voltage: 660 V
- Max, 100% impulse voltage: 3300 V peak
- Rated discharge current: 5 kA peak

Earth Switch:

- Rated current: 300 mA continuous
- Short-time current: 16 kA, 1s

Enclosure, Protection Class:

IP 65 according to IEC529, Weatherproof, tropicalised and corrosion inhibited

4.1.2.9 SDH Equipment

4.1.2.9.1 SDH FO Terminal

The new SDH Terminal is to be implemented in the overall KPLC Fibre Optic Terminal network (see attached "KPLC Fibre Optic Terminal Network"), as part of the existing STM-4 ring which includes five other units at NCC, Juja Road SS, and Dandora SS. This unit is also to be equipped with Tele-protection interfaces with the corresponding interfaces being installed on existing SDH equipments at the remote substations.

Above all the new equipment shall be fully software programmable and freely configurable and to interface in every way with the existing equipment, and be managed through the existing "FOXMAN" Management system located at the NCC.

The digital multiplex equipment shall be designed to operate in electrical high-voltage network and shall be suitable for installation in substations with harsh environment and high electromagnetic interference. It shall be highly reliable and provide secure communications for real time signals such as voice, SCADA, Tele-protection, data including IP/Ethernet and status/control signals.

The equipment offered shall already be working successfully in telecommunication networks operated by power utilities. It shall comply with the latest ITU-T recommendations and ETSI standards and be able to be interconnected with legacy multiplexers and other telecommunication equipment.

On TRANSPORT LEVEL interfaces for optical transmission on PDH 8Mbit/s, STM-1 155Mbit/s and STM-4 622Mbit/s shall be available. For connection to higher order transport equipment also Nx 2Mbit/s and STM-1 electrical interfaces shall be available.

The equipment shall be software controlled, of modular design and all modules shall form an integrated part of a 19" shelf.

The platform shall have means to cross-connect, drop and insert individual channels (64kbit/s time slots), 2Mbit/s framed (G.704) and unframed (G.703) signals. It shall also support termination and cross connection of VC 12, VC-3 and VC-4.

Equipment protection and various protection schemes shall be supported.

The new equipment should be able to accommodate the integration of Tele-protection functions as and when required.

The new terminal shall be manageable locally and also from an operation centre using an existing Network Management System (FOXMAN). It shall be possible to access the terminal over a TCP-IP network, and access over SDH OHC channel using the OSI protocol shall also be possible.

The equipment shall be capable of functioning as a terminal, in 'through connection' (transit, repeater) mode and as add-drop multiplexer. First order multiplexing (2Mbps), second order multiplexing (8Mbps) and STM-1 multiplexing shall be integrated. Conference for voice channels and point to multipoint function for data signals shall be possible. The equipment shall be of fully modular design.

4.1.2.9.2 Channel Capacity, Digital Cross section

The equipment shall be equipped with redundant, decentralised cross-connection functions. The cross-connect capacity shall be at least 40x 2Mbit/s (i.e. 1200x 64kbit/s) and non-blocking. For high-density applications the cross-connect capacity shall be upgradeable up to 128x 2Mbit/s. It shall cross-connect 64kBit/s as well as 2Mbit/s (G.703 unframed and G.704 framed) and VC12. The cross-connect shall be capable of cross-connecting the SDH overhead with any 64kBit/s timeslot on the system.

In addition the equipment shall offer an SDH cross-connect capacity of at least 4xVC-4 in the same equipment.

4.1.2.9.3 Redundant centralised functions

The equipment shall be equipped with redundant circuits for all centralised functions.

4.1.2.9.4 Power Supply

The multiplex equipment shall operate from a nominal 48Volt-DC battery with positive ground. The equipment shall work satisfactorily over battery voltage variations of + / – 15% (40.8 volts through 55.2 volts). Redundant power-supply (N+1 protection) shall be supported. The equipment shall support dual power feed i.e. that two power sources can be connected directly to the equipment (two connection points).

Furthermore an integrated power module for direct powering from 115/230VAC shall be available.

4.1.2.9.5 Safety

The equipment shall be safe to use and shall comply with EN 60950 class V1.

4.1.2.9.6 Electromagnetic Compatibility and Safety Regulations

The equipment shall comply with the EN50022 class A, EN50082, IEC 801-2, IEC 801-6 and shall be conformant with CE.

4.1.2.9.7 Ambient Conditions

Storage and transport:

- Temperature range: -25°C+70°C
- Humidity: max. 98% (no condensation)

Operation:

- Temperature range: - 5°C +55°C
- Ethernet, x DSL, ISDN: - 5°C +45°C
- Humidity: max. 95% (no condensation)

4.1.2.9.8 Mechanical Construction

The equipment shall be available as a 19" shelve to be mounted in a 19" rack or 19" cabinet. It shall be of robust design. All modules shall be integrated in the same shelf. All connectors shall be accessible from the front and comply with international specifications. The minimum cabinet depth required shall be stated.

4.1.2.9.9 Local User Terminal –

It shall be possible to connect the craft terminal to the element in the network using the TCP-IP protocol. The craft terminal shall support configuration, maintenance, and status information. It shall provide a 'windows' oriented user interface.

4.1.2.9.10 1 + 1 Path Protection

The equipment shall provide means to protect 64kBit/s channels. The protection shall be end to end from one interface (telephone or data) to the other. It shall

switch automatically from the main channel to the standby channel. It shall be configurable whether the system switches back to the main channel (reversible switching) or not (non-reversible).

If a path has switched to its standby route because the main route is disturbed this shall be indicated with an alarm. The switching shall be done within the multiplexer without using the Network Management System.

4.1.2.9.11 1 + 1 Section Protection

The equipment shall provide means to protect STM-1 (MSP). It shall be possible to use two independent links: one as the main and the other as the standby. The system shall automatically switch to the standby connection and generate an alarm if the main connection is disturbed.

The switching shall be done within the multiplexer without using the Network Management System.

4.1.2.9.12 Network Topology

It shall be possible to integrate the new terminal as part of point to point, linear, ring, T, and meshed network.

4.1.2.9.13 Synchronisation

It shall be possible to synchronise the equipment using an external clock source, derived from a network or with an internal oscillator. The synchronisation shall be configurable and it shall be possible to distribute the synchronisation to other equipment as well. The system shall have the means of switching to select the synchronisation source as well as a means of preventing the system from creating synchronisation loops. The equipment shall be capable of selecting the source of synchronisation by means of SSM (Synchronisation Status Messaging) on 2Mbit/s PDH or SDH port or by means of a priority-based sequence.

For teleprotection event recording it shall be possible to synchronise the clock of all teleprotection interfaces with one GPS in one station. The GPS time shall be distributed over the teleprotection channel.

As part of scope the contractor shall supply and Test contractor shall supply install and test GPS for SDH synchronisation. The required master clock is Meinberg Lantime M300 or its equivalent inclusive of antenna/converter unit mounted in waterproof plastic case, mounting kit and 20 m

4.1.2.9.14 Alarms

Each module shall supervise its functions and shall have an alarm-indication LED on its front. All alarms shall be collected by the NMS (Network Management System). Each node shall be capable of collecting up to 50 external alarms.

4.1.2.9.15 Test Loops

The equipment shall provide means to loop signals on 64kBit/s level as well as on 2Mbit/s level. It shall indicate an alarm if a loop is activated.

4.1.2.9.16 Maintenance facilities

The new Element shall have a built-in Signal Generator and Analyser to analyse communication paths. It must be possible to connect the Generator and Analyser to the communication channels and terminate the signal on other Network Elements. It

shall be possible to configure circuits locally with the craft terminal and remotely from the NMS or the craft terminal. It shall be possible to loop-back signals locally and remotely using the craft terminal or the NMS.

4.1.2.9.17 Transport Level Requirements

SDH Modules

The interface shall be designed for use on single mode fibre (conforming to ITU-T G.652 or G.655). The interface card shall be based on SFP technology and use LC/PC connectors.

The following main functions shall be supported:

- Prepared for SFP's (small-factor pluggable units) for short, medium, long and extra-long optical communications (1310nm and 1550nm)
- Termination of the OS-, RS-, MS- and VC-4 layer
- Extraction and insertion of the SOH communications information
- Through connections of VC-12, VC-3 and VC-4
- Support MSP (Multiplex Section Protection)

The following maintenance functions shall be supported:

- Status indications
- Loops
- Restart after ALS
- TTI monitoring
- BIP Error Insertion

The following SDH interfaces shall be available:

- STM-4: (622Mbit/s) optical 2-port interface
- STM-1 (155Mbit/s) optical 1-port or 4-port interface
- STM-1 (155Mbit/s) electrical 1-port interface

PDH Modules

An 8Mbit/s module for optical communication on 1310nm or on 1550nm shall be available. Each module shall provide at least 4x 2Mbit/s (G.703) electrical ports and have an integrated switch matrix to convert the incoming optical signal directly into electrical G.703 signals.

Modules for direct connection to following USER SIGNALS shall be available as plug-in modules for the equipment:

- Analogue subscriber interface: subscriber and exchange side
- 4-wire E&M voice interface
- G.703, 64kbit/s data Interface
- X.24/V.11 (RS-422), Nx 64kbit/s data interface
- V.24/V.28 (RS-232), data interface
- V.35, Nx 64kbit/s data interface
- RS485 data interface
- Programmable data interface V.24,/V.28, V.35, X.24/V.11
- Alarm collection interface
- Tele-protection command interface
- Binary signal (status and control) interface

- 2Mbit/s electrical interface for unframed signals acc. to ITU-T G.703 and framed signals acc. to G.703 and G.704.
- LAN interface 10/100BaseT electrical interface RJ45, IP/Ethernet
- LAN Interface for 100BaseFX and 1000BaseLX/SX, IP/Ethernet

On TRANSPORT LEVEL the equipment shall support the following connection ports:

- Up to 2 STM-4 SDH optical ports per module
- Up to four STM-1 SDH optical ports for medium and long distances, with automatic laser shut down programmable on each interface.
- Up to four STM-1 SDH electrical ports
- Up to eight 8Mbit/s optical ports
- Up to sixteen 2Mbit/s HDSL ports

All optical ports shall support SFPs (small-factor pluggable unit) for short, medium, long and extra-long optical communication. ALS (Automatic Laser Shut-down) shall be fully supported.

4.1.2.9.18 User Signal Interfaces

The equipment shall provide the following user interfaces in addition to other standard user interfaces.

Tele-protection requirement

The Tele-protection and communication system has to ensure the easy and secure function of the Tele-protection. The following features have to be provided:

- At least an 8 bit command addressing for Tele-protection signal shall be provided to prevent tripping if the signal is inadvertently re-routed through the telecommunication network.
- An automatic and periodic loop test (<100s) has to be provided for a signal delay measurement.
- A switch-over of the Tele-protection command in less than 10 ms has to be guaranteed
- The configuration of the Tele-protection has to be integrated into the communication configuration tool in order to ensure an easy maintenance

4-Wire Interface (VF interface)

This module shall provide connections for voice channels with a bandwidth of 300 Hz - 3.4 kHz and 2 signaling channels (M => E, M' => E') per voice channel. Each voice channel shall be configurable to operate with or without CAS. With CAS it shall use the "a" and "b" bits for the two signaling channels.

The level shall be software adjustable within the following range:

- Input: +7.5 to -16dBr
- Output: +7.0 to -16dBr

Modules where each voice channel can be individually configured with 1+1 path protection shall be available.

Analogue Subscriber Interface (FXS)

A module with at least 10 subscriber ports or more shall be available. The ringing generator shall be integrated on the subscriber module. The ringing frequency shall be adjustable for 20Hz, 25Hz, and 50Hz.

The following main functions shall be supported:

Downstream signaling: Ringing, Metering, Polarity reversal, Reduced battery, No battery
Upstream signaling: On/off-hook, Pulse and DTMF dialing, Flash impulse, Earth key
General: Constant current line feeding, Line test, Permanent line checks, CLIP (On-hook VF transmission), Metering after on-hook

Exchange Interface (FOX)

This module shall provide at least 10 ports for connection to the ports for remote analogue subscribers of a telephone exchange (PAX, PABX). It shall provide the following functions:

- Pulse dialing, tone dialing (DTMF), earth key function, metering function(12 kHz or 16 kHz), flash impulse, polarity reversal, indication of busy lines

The following parameters shall be configurable by software:

- Input voice level -5 .. +4dBr, output voice level -7.5 .. -1dBr
- metering pulse enable/disable, signaling bit definition,
- loop back of voice to the telephone

Party line Telephone System (Engineering Order Wire)

An engineering order wire (EOW) facility shall be provided at each multiplexer. Following options shall be available:

- The EOW shall be configured as a party line and use in band DTMF signaling to call another EOW-Terminal. The Terminal shall have an integrated DTMF decoder allowing to program a subscriber call number (1..4 digits), and two group call numbers (1..4 digits each).
- EOW based on Voice over IP (VoIP). The EOW traffic shall be routed over the management channel.

Data Interfaces

Following interfaces shall be available:

- V.24/V.28, V.11/X.24, V.35

Following bit rates shall be supported:

- Synchronous and asynchronous: 0.6 ... 38.4kbit/s
- Synchronous: 48, 56, Nx 64kbit/s (n = 1 ... 31)

Following options shall be available:

- 1+1 path protection, Sub rate multiplexing, Point-Multipoint, Performance Monitoring

64 kbit/s Co-directional Interface

This module shall comply with the ITU-T G.703 part 1.2.1 for co-directional data transfer. A module shall have at least 8 interfaces. Modules where each interface can be individually configured with 1+1 path protection shall be available.

IP/Ethernet Interface

Ethernet module shall comply with the following specification:

- Ethernet electrical connection: 10/100BaseT
- Ethernet optical connection: 100Base-FX and 1000Base-LX/SX
- Switching: bypass mode for IEEE Std 802.3 frame or based on port or VLAN tag ID
- WAN capacity: 63x VC-12 or 3x VC-3
- Logical WAN ports (LWP): minimum 8

- Framing: According General Framing Procedure (GFP) ITU-T G.7041
- Capacity: Virtual Concatenation (VCAT) acc. ITU-T G.707
- Protection: Link Capacity Adjustment Scheme (LCAS) acc. ITU-T G.7042

Additionally a module with an integrated Ethernet Router shall be available with following function:

- \ Ethernet connection: Minimum 10BaseT
- Routing Protocols: Static IP route, OSPF2 V2
- WAN protocols: PPP
- WAN capacity: Nx 64kbit/s (n=1 to31)
- WAN-ports: > 30

A module with Power over Ethernet shall be available as an option to power e.g. camera, telephone set (Voice over IP).

Module to Transmit Protection Commands

This module shall support the following features related to the protection commands:

- Transmit 4 protection commands bi-directionally
- Accept protection command signals in the range of 24VDC ... 250VDC
- All inputs and outputs shall be isolated and with EMC immunity for harsh environment.
- Security and Dependability shall be selectable and programmable.

It shall also be able to drop and insert commands, transfer commands as a transit station and to realize AND- and OR-combinations between commands. The module shall support T-node configurations.

The teleprotection module shall provide

- an integrated non-volatile event-recorder, which shall synchronized either internally or by Global Positioning System (GPS)
- A command counter, which counts trip commands.

The teleprotection module shall further support:

- Signal delay measurement
- 1+1 protection, switching shall be done within less than 4ms (typical value)
- Periodically automatically initiated loop-tests (e.g. every 60s).
- Command addressing: This function shall be used to prevent tripping if the signal is inadvertently re-routed through the telecommunication network

Under no circumstances will the module cause trip-commands in case of power supply failure or when equipment is put into or taken out of service.

2 Mbit/s Interface according to ITU-T G.703 and G.704

This module shall comply with the ITU-T G.703 / G.704 recommendations and also allow transparent 2Mbit/s signals complying with G.703.

The module shall have at least 4x 2Mbit/s interfaces, each of which may be individually activated. It shall be possible to have up to 126 x 2Mbit/s interface modules in a multiplexer.

Features:

- Impedance of 120 ohms and 75 ohms
- Supporting CRC-4 multi-frame according to ITU-T G.704 (enabled and disabled by software).
- The CAS signaling according to ITU-T G.704 table 9 shall be activated optionally.
- 2Mbit/s loop-back of the incoming signal as well as the loop-back of the internal signals.

The interface shall be able to extract the 2.048MHz clock for synchronization of the multiplex equipment.

4.1.2.9.19 Tele-protection Interface on existing SDH Terminals

Tele-protection interfaces to be installed on existing SDH Fibre Optic Terminals both at Juja Road and at the corresponding remote substations where the various 132 kV and 66 kV Lines originating from Juja Road terminate.

Four duplex channels should be provided for each 132 kV line, while two channels should be provided for each 66 kV protected line. The channels should be freely software programmable depending on application. Similarly, transmission delay times should also be software programmable depending on application. The Interfaces shall have same specifications as specified above.

4.1.2.10 Private Automatic Exchange - PAX

The new PAX must be fully integrated into the existing KPLC private telephony network consisting of more than twenty exchanges, but *in particular must interface in every way and provide the same facilities as the existing units type SOPHO iS3030 SSW 810 at the Regional Control Centres located at Lessos, Kiganjo and Rabai*. See the attached drawing "PKLC PAX Network".

Table1.above gives a summary of the required facilities.

Also see the attached Technical Schedule which has to be completed by the bidder.

4.1.2.11 Optical Distribution Frames (ODF)

Refer to Technical Schedule Sheets

4.1.2.12 Underground Fiber Optic Cables

Refer to Technical Schedule Sheets

4.1.2.13 Decommissioning and Disposals

All necessary decommissioning of existing equipment that shall be moved to the new switch gear and control building or will be obsolete shall be included in the scope of works.

Obsolete equipment shall be moved to a site within Juja Road site agreed with KPLC.

4.1.2.14 **LV cables and Cable Racks**

4.1.2.14.1 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. No price adjustment shall be made for deviations of less than 25 metres.

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.

4.1.2.14.2 Technical Requirements

4.1.2.14.2.1 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 is the 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.

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

4.1.2.14.3 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. The cables shall be laid in such a way that cables easily can be exchanged without digging.

4.1.2.14.4 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.

4.1.2.14.5 Tests

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

Type test certificates shall be submitted on request.

4.1.2.15 Earthing (Grounding) System

4.1.2.15.1 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 - 2000 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.

4.1.2.15.2 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 between 10 and 20 ohms. If necessary, earthing rods shall be installed 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 the earthing conductors shall be dimensioned to carry 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 under ground surface. Connections above earth shall be screwed and shall be easily accessible for control. All connections shall be protected against corrosion.

4.1.2.15.3 Earthing Electrode 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 95mm² stranded wire. Copper-weld with approximately the same conductivity may be used.

Risers shall be copper stranded wire at least 95 mm².

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 6 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.

4.1.2.15.4 Earthing Electrode 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 95 mm² stranded wire. Copper-weld with approximately the same conductivity may be used.

The risers shall be of at least 95 mm² 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 6 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.

4.1.2.15.5 Earthing Conductors

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

The conductor for the main earthing buses shall be of electrolytic copper with dimensions at least 150 mm² for flat bar or stranded conductor.

All the risers from the earthing electrode systems shall be connected to the 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. The low current earthing conductors shall not be mixed (radial system) 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.

4.1.2.15.6 Lightning protection system

As part of the protecting system of Juja Road Substation a lightning protection system shall be designed and installed. The design shall be submitted to The Project Manager for approval.

Existing systems may be reused and integrated in the new protective system.

Necessary new towers with lightning rods shall be installed to cover the substation. The connections to the earthing grid shall be completed with shielded wires.

4.1.2.16 Site and Commissioning Tests

4.1.2.16.1 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.

4.1.2.16.2 Test of Wiring

- a. Insulation Resistance Test at 2.5 kV a.c. for one minute shall if possible be carried out on all ac and dc protection, control, alarm and indication circuit to ensure that wiring is in satisfactory condition. Visual inspection shall be made on cable glands, cable jointing, fuse or circuit breaker ratings and small panel items, such as indicating diode 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.

4.1.2.16.3 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.

4.1.2.16.4 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.

4.1.2.16.5 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.

4.1.2.16.6 Tests on Conductors, Insulators and Accessories

None required.

4.1.2.16.7 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.

4.1.2.16.8 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. 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.