SECTION - VI

PARTICULAR TECHNICAL SPECIFICATIONS
SUBSTATIONS
CONTROL, PROTECTION

TABLE OF CONTENTS

4.1.2 Control, protection and cabling – Substations

4.1.2.1 Control Protection and Metering

4.1.2.1.1 General

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

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

The complete and detailed scheme of control, protection, alarms, etc., shall be proposed by the Contractor for each individual sub-station project. In this detailed planning the Contractor shall carefully consider the future extension of the plants.

The control, metering and protection equipment can be placed in common panels but not as integrated functions. The panels shall not be unnecessarily crowded but have space for moderate extensions. All control functions and status indications shall be clearly arranged in a mimic diagram. The bay control unit shall have a mimic diagram for all the equipment in the bay. The equipment shall be on a modular basis connected to terminals inside the panels and easy to replace. For indoor MV switchgear the control and protection can be located in the instrument compartment in the switchboard.

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

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 Control Centres. 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 KENYA POWER.

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

4.1.2.1.2 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.

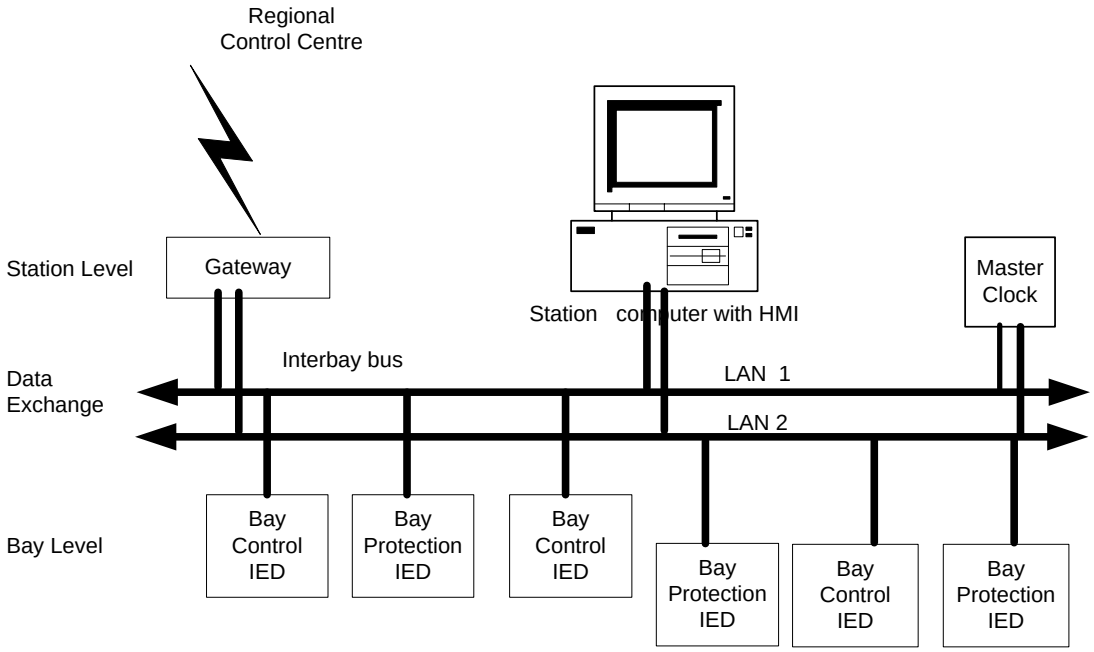
The typical SA layout shall be structured in two levels, i.e. in a station and a bay level.

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 form 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.

4.1.2.1.2.1 Signal List

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

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

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 supervision:
  Interlocking and blocking
  Double command
- 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

4.1.2.1.2.2 Select-before-execute

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

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

4.1.2.1.2.3 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.

4.1.2.1.2.4 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 isachieved.

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 HMIshall 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.
-

4.1.2.1.2.5 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 CBUshall be located in Control/Relay Room.

4.1.2.1.3 Control Stations

4.1.2.1.2.1 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.

4.1.2.1.2.2 Interface with Supervisory Control and Data Facilities

In order to interface and achieve the desired functionality of the SCADA/EMS system, data concentrators in substations shall be based on standard IEC 60870-5-101 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 sates 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.

4.1.2.1.4 Automatic Voltage Regulator

The transformer bay shall be equipped with an automatic voltage regulator 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.

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.

4.1.2.1.5 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 0-10 mA output. The maximum meter reading at the receiving end shall be equivalent to 30% overload of the source value. The permitted resistive load shall be at least 1000 ohms. The accuracy class shall be minimum 1%. The auxiliary voltage, if required (preferably not) shall be 110 V or 30 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.

4.1.2.2 Factory Acceptance Test

The Control system with Station Control Unit and Field 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 must include but not be limited to the following:

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

4.1.2.4 Spare Parts and Tools

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

- short-term spare parts that are necessary for two (2) years of operation. These spare parts shall be included in the contract and shall comprise at least one spare module for supplied equipment and basic tools for system maintenance.
- long-term spare parts that are necessary for ten (10) years of operation.

4.1.2.5 System Maintenance

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

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

4.1.2.6 Protection

4.1.2.6.1 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 input range from 24-240 V AC/DC without the use of external resistors and without external reconnections and shall be designed to withstand the high voltage interference which is normally experienced in high voltage switching stations.

There shall be galvanic isolation on all inputs and outputs including power supply input. Isolated 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.

4.1.2.6.2 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: The protective relays shall be provided with sufficient contacts for circuit breaker tripping. All protective relays, which initiate tripping, shall have not less than two independent pairs of contacts of which one shall operate the tripping relay or circuit breaker trip coil without the interposition of auxiliary contactors and without the use of reinforcing contactors.

A watchdog relay must detect internal fault including low auxiliary voltage. The auxiliary voltage supply to each discriminative relay unit shall be continuously monitored and an alarm shall be given whenever the voltage exceeds the limits for reliable protection operation.

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

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

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

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

Wherever practicable the design of the relay schemes shall be based on the "fail-safe" principle. For example, care shall be taken to ensure that loss of DC supply or an open circuit does not cause incorrect opening or closing of circuit breaker. Circuit breaker or disconnector repeat relays should be of the on-latching type and a discrepancy alarm shall be provided to check correct operation of the relays following a circuit breaker or disconnector operation.

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

In order to achieve a high degree of security in function, the protection system of each high voltage main component (lines, power transformers, shunt reactors, etc.) shall consist of two separated protection sets, main 1 and main 2 where applicable. Where two protection sets cover the same fault they shall be divided into two electrically and mechanically separate parts by means of:

- 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.

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

The Auxiliary relays for protection trip shall have operating speed of less than 7 millisecond.
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 users manuals must be user-friendly and divided into one general hardware and software description and one setting manual describing only the specified functions and necessary settings for the different types of relays

4.1.2.6.3 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 for this such shall be included in the supply.

4.1.2.6.4 Fault Clearing Time

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

4.1.2.6.5 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.

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.

4.1.2.6.6 Fault Recorder and Fault Locators

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

4.1.2.6.7 Supervision

The supply shall include hardware and software for remote setting, supervision and data acquisition of the protection relays, fault locators and fault recorders. The software will be installed on a central PC with 'windows XP and windows 7' operating system. This PC will be shared with other Contractors. The centrally installed software shall make it possible to contact the relays over the telephone network via modems installed in each substation. The Contractor shall supply and install the modems, connect the relays and test the complete chain of control.

The protection relays shall also communicate with the bay control units over the open protocol IEC 870-5-103.

4.1.2.6.8 Protection of HV system

4.1.2.6.2.1 33 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
(vii) Breaker maintenance
(viii) Breaker failure

<u>Distance Protection</u>
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 must be integrated in a compact package and a user-friendly menu driven interface should be available to enable the setting and testing of the relays.

Three 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 0.5In-2.4In
- Current setting range for earth fault relay 0.05In-0.8In
- Quadrature connection for polarising voltage (Vn=110)
- Applicable on the LV side of a Dyn1 transformer
- High set Element, with a setting range of 1-32In
- 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.

4.1.2.6.2.2 Transformer Protection 132-33/11 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 two winding transformer.
Overall differential protection equipped with over current stabilising for external faults and insensitive to in-rush current. The operating time of the protection shall be less than 20ms. This is considered main 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.

4.1.2.6.2.3 Transformer Protection 132-33/11 kV Transformers (LV 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.

4.1.2.6.2.4 Feeder Protection 33-11 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

4.1.2.6.2.5 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.

4.1.2.6.2.6 Busbar Protection 33 kV and above.

Busbar protection schemes shall be provided at busbars for voltages 66 kV and above. 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 must be of the numeric type with full discrimination between the busbars even with closed bus coupler. It shall have CT supervision,

4.1.2.6.2.7 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.

4.1.2.6.2.8 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.

4.1.2.6.9 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%.

4.1.2.6.10 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.

4.1.2.6.11 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.

4.1.2.7 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.

4.1.2.7.1 Meters for Outgoing 33, and 11kV lines

Electronic meters for active power, reactive power (Wh and VArh) and data recording units shall be provided for each outgoing feeder for registration of power irrespective of the direction of power flow. The Wh meters and recorders shall be of class 0.5 and class 0.5 for the VArh. The scale on the different type of instruments shall be proposed by the Contractor and be subject to approval by the

Project Manager. The meters shall be able to communicate with the control system with pulses and on an IEC 60870-5-103 protocol.

4.1.2.8 LV cables and Cable Racks

4.1.2.8.1 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.

4.1.2.8.2 Technical Requirements

4.1.2.8.2.1 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 ^{o}C maximum design ambient temperature shall be applied for all cables internally in the switchyard, between the switchyard equipment and the control building and inside the control building.

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

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

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

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

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

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

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

4.1.2.8.3 Cable Laying

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

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

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

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

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

The Contractor shall supply trenches and conduits of concrete.

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

4.1.2.8.4 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.

4.1.2.8.5 Tests

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

Type test certificates shall be submitted on request.

4.1.2.9 Earthing (Grounding) System

4.1.2.9.1 General

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

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

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

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

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

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

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

- All steel structures, metal parts and overhead ground wires of the switchyard.
- All fences of the station, whereby for outer fences special care shall be taken to avoid injurious step and touch voltages for personnel standing outside and inside these fences.

- All metal parts, even if these do not constitute a conducting part of an electric system of the plants, such as machinery, operating desks, piping, sewers, rails, metal tanks, lighting, fixtures, cable racks, etc.
- All operational electric systems such as power and instrument transformers, lightning arresters etc.

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

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

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

4.1.2.9.2 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, additional earthing rods shall be applied to achieve the specified value.

The dimensioning shall be co-ordinated with the relay protection scheme of the various parts of the plant. In any case, however, the earthing conductors shall be dimensioned for carrying the earth fault current and double earth fault currents of the various parts of the plant for at least 1 (one) second without any harm to the conductors or connections.

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

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

4.1.2.9.3 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 10 m. At all crossings the conductors shall be interconnected by brazing or welding. The grid shall also be connected to the concrete reinforcement at several places as well as to the earthing grid of the switchyard area. Vertical risers shall be brazed or welded to the conductors.

The risers shall be placed in the concrete shuttering, and led out of the shuttering at appropriate places approximately 30 cm above the floors. Care shall be taken to protect the risers against damage during shuttering and concreting.

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

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

4.1.2.9.4 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 20 m.

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

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

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

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

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

4.1.2.9.5 Earthing Conductors

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

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

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

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

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

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

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

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

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

outdoor earthing conductors shall be insulated with spacers or conduits against contact with galvanised steel structures.

4.1.2.10 Site and Commissioning Tests

4.1.2.10.1 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.

4.1.2.10.2 Test of Wiring

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

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

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

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

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

4.1.2.10.3 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.

4.1.2.10.4 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.

4.1.2.10.5 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.

4.1.2.10.6 Tests on Conductors, Insulators and Accessories

None required.

4.1.2.10.7 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.

4.1.2.10.8 On Load Test

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

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

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

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