

SECTION-9

PROTECTION SYSTEM

9.0 SCOPE

This section of the specification covers the design, manufacture, assembly, testing at manufacturer's works, supply, storage at site, erection, testing and commissioning, handing over to owner & guaranty for two years from handing over, complete with all accessories, equipment, wiring & cubicles for making the system complete & guarantee for trouble free & safe operation of Protection system for Vishnugad Pipalkoti Hydro - Electric Project.

9.1 STANDARDS

9.1.1 The protection equipment and accessories specified herein shall operate satisfactorily in the climatic conditions specified in General Technical conditions. The performance, testing and rating of the equipments and accessories shall conform to the latest edition of the following IEC/DIN/BS/IEEE/ASA/IS publications:

Relays:

IEC 50(16)	International Electro Technical Vocabulary
IEC – 68-1	Environmental testing Part I (General & Guidance)
IEC –255	Electrical Relays
Part 3	Single Input energising quantity measuring relays with dependent or independent time
Part 5	Insulation Tests
Part 6	Measuring relays with more than one input energising quantity
Part 7	Test and measurement procedures for electromechanical all or nothing relays
Part 8	Thermal electrical relays
Part 10	Application of the IEC quality assessment system for electronic components for all or nothing relays
Part 11	Interruption to and alternating component (ripple) in DC auxiliary energising quantity of measuring relays
Part 12	Directional relays and power relays with two input energising quantities
Part 13	Biased (%) differential relays

Part 16	Impedance measuring relays
Part 21	Vibration, shock, bump & seismic tests on measuring relays & protection equipment
	Section I - Vibration Tests
	Section II - Shock & Bump tests
	Section III - Seismic tests
Part 22	Electrical Disturbance tests for measuring relays & protection equipment
	Part I 1 MHZ Burst disturbance tests
	Part II Electrostatic discharge tests
	Part III Radiated electromagnetic field disturbance tests
	Part IV Fast transient disturbance tests
IEC –255 Part 23	Electrical Relays - Contract performance
IEC – 337	Control Switches & low voltage switching devices for Control & Auxiliary Circuits
IEC 524	D.C. Resistive Volt Ratio Box
IEC 529/ DIN 40050	Degree of protection provided by enclosures (IP Code)
IEC 617/BS 3950 BS 142	Electrical Protective Systems for A.C. Plant Electrical Protection Relaysim
BS: 4227 (Part-I)	Relay Terminology
IEEE 372-1991/ ASA C 37.90 & Standard 313	Relays & Relay Systems
ASA C 5013	Electrical Relays
IS : 1885	Electro Technical vocabulary
Part-IX	Electrical Relays
Part-X	Electric Power System Protection
Part-XVIII	Switchgear and Control Protection
IS : 3231	Specification for Electrical relays for Power System Protection
IS : 3842	Application Guide for Electrical relays for AC System

Part-I	Over current relays for feeders and transformers
Part-IV	Thermal Relays
Part-V	Distance Protection relays
Part-VI	Power Relays
Part-VII	Frequency Relays
Part-VIII	Voltage Relays
Part-IX	Relays for bus bar protection

IS : 12083 Special Requirements for Protection Relays

Control Switches and Push Buttons:

IS : 6875 Control switches for voltage upto and including 1000V AC or DC

Part-I	General requirements
Part-II	Push buttons and Related control switches

IS:4064/4236 Specifications for air break switches, disconnectors, fuses etc. for voltages not exceeding 1000 V AC or DC

Part-I General requirements

Part-II Specific requirements for direct switching of individual motors.

Panel Wiring:

IS : 694 Specification for PVC insulated cables for working voltage upto and including 1000 V.

IS:1554 (Part-I) PVC insulated cables upto and including 1000 V.

IS : 5578 Guide for marking of insulated conductors

IS : 11353 Guide for Uniform System of marking and identification of conductors & apparatus terminals.

Indicating Lamps:

IS : 1901 Specifications for visual indication lamps

Miscellaneous:

IS : 1893 Criteria for Earthquake Resistant Design to Structure

IS : 2705 Current transformers

IS : 3156	Voltage transformers
IS: 5	Colour for ready mixed paints and enamels
IS: 9224 (Part II)	HRC Cartridge fuse lamps
IS: 2147	Degree of protection provided by enclosures for LV switches and control gear.
IS : 6005	Code of practice for Iron Steel

- 9.1.2 Compliance with the provisions of the specifications does not absolve the supplier from the responsibility of furnishing protection equipments & accessories of proper design, electrically and mechanically suited to meet the operating guarantees at the specified service conditions.
- 9.1.3 If there are, in the opinion of the bidder, any contradictions between the above standards and these specifications, such contradictions shall be brought to the attention of the purchaser. Where requirements contained in the latest applicable standards are more stringent than those contained herein, the applicable standard requirements shall govern.

9.2 SYSTEM PARTICULARS

- 9.2.1 The details of the equipment to be supplied under these specifications are given as under:

- a) The protection systems for the following:
 - i) Generators
 - ii) Generator Transformers
 - iii) Unit Auxiliary Transformers
 - iv) Station Service Transformers
 - v) Excitation Transformer
 - vi) Gas Insulated Switchgear (GIS)
 - vii) XLPE cables
 - viii) Pothead Yard
 - ix) Outgoing feeders/ transmission lines

The bidder shall integrate in his protection scheme, all necessary protections, signals from Generators, Gen.Transformers, UATs, SSTs, Excitation transformers, Excitation system, UABs, SABs, GIS, XLPE cables & Pothead Yard which would be supplied by others, for which potential free contacts shall be provided. These shall broadly include but not limited to:

Turbine - Generators:

- i) Turbine bearing temperatures
- ii) Generator bearings temperature
- iii) Temperature supervision system
- iv) Over speed
- v) Vibration monitoring
- vi) Governor
- vii) Generator Braking System
- viii) Emergency Stop
- ix) Starting/stopping too long

- ix) Guide vane failure
- x) MIV oil pressure
- xi) Cooling water
- xiii) Fire Protection, etc.

Generator Transformers:

- i) Buchholz Protection
- ii) Oil level low
- iii) Winding Temperature Protection
- iv) Oil Temperature Protection
- iv) Cooling system failure
- v) Pressure Relief Valve
- vi) Overload Protection
- vii) OLTC Buchholz protection (if applicable)
- viii) OLTC oil surge protection (if applicable)
- ix) Power supply fail
- x) Tap changer trouble.

UATs and SSTs:

- i) Winding temperature protection
- ii) Over-load
- iii) Multiphase faults in windings & at terminals
- iv) Earth faults
- v) Under voltage (in LT circuits, SST & UAT)
- vi) Buchholz Protection
- vii) Oil level low
- viii) Winding Temperature Protection
- ix) Oil Temperature Protection
- x) Cooling system failure
- xi) Pressure Relief Valve
- xii) Overload Protection
- xiii) OLTC Buchholtz protection (if applicable)
- xiv) OLTC oil surge protection (if applicable)
- xv) Power supply fail
- xvi) Tap Changer Trouble

Excitation system:

- i) Over current & Short circuit relay for rectifier transformer
- ii) Over current relay for excitation transformer protection
- iii) Rotor earth fault relay
- iv) Over voltage relay for protection of insulation of field winding
- v) Over temperature protection relay for excitation transformer
- vi) Earth fault protection for excitation transformer
- vii) Current asymmetry protection for fault in thyristor stacks
- viii) Cooling fan failure (main & reserve)
- ix) Loss of regulator D.C. Power
- x) Failure of thyristor firing circuit
- xi) Individual cooling fan for failure
- xii) Rectifier exit air high temperature
- xiii) Failure of AVR

- xiv) Current asymmetry & faults in one thyristor stack
- xv) Operation at min/max. excitation limit
- xvi) Over current & short circuit relay for electrical braking excitation

UAB's and SAB's:

- i. Restricted Earth Fault
- ii. Neutral Over Current
- iii. Over Current Protection

Gas Insulated Switchgear:

- i) Low/High gas pressure/density
- ii) Circuit breaker operating mechanism failure
- iii) Other abnormal conditions
 - XLPE Cables & Pothead Yard
 - 1. Thermal
 - 2. Differential
 - 3. Over Current, O/V, U/V

Feeders

- 4. Multi phase and earth faults
- 5. Over voltage conditions
- iii) Maloperation of circuit breakers

In addition to above-mentioned tripping functions, provision shall be made for other tripping orders which shall be finalized at the design stage.

The bidder is free to include in his offer any additional relays over and above the relays / protections covered in these specifications based on his experience in order to cover all the possible faults / abnormal system conditions.

The protection scheme envisaged by the purchaser has been indicated in Single Line Relaying and Metering Diagram as per Section-30: "Tender Drawings" of Part-2: Section VI: "Employer's Requirement". The bidder should check the provisions and relative locations of various CTs, PTs, isolators, disconnectors / earthing switches, LAs etc. and suggest suitable changes & additions, if any, which in his opinion will add to operational maneuverability of switching scheme or credibility of protection schemes envisaged. The bidder is however, required to furnish full justification for the changes suggested by him alongwith his offer.

- 9.2.2 The central protection monitoring system (CPMS) shall have all man/machine communication equipments such as PC, Printer, UPS of adequate capacity, Software, Cables, Connectors, Converters, lugs and other equipment for its independent operation from a separate PC which shall be located in central control/ relay room of the power house. It shall have the provision of integration with SCADA system.
- 9.2.3 All cables required for connection between protection systems and Unit control Board (UCB) shall be under the scope of supply of separate package "Power & Control Cables". However the interconnecting cables including optic fibre cables required for Protection system shall be included by the bidder in this package. All fibre optic cable used shall be armoured and should have minimum two spare fibres. The supplier shall provide all materials, labour,

supervisory staff, equipment & services necessary for accomplishing the respective work.

9.3 AUXILIARY SUPPLY

- 9.3.1 AC supply: 415/230 volts, 3 phase / single phase, 4 wire / 2 wire, 50 Hz $\pm$ 3% grounded neutral AC supply will be available at the station. The supply is subject to variation of $\pm$ 10%.
- 9.3.2 DC Supply: 220 volts DC two wire supply will be available from the station battery through the auxiliary DC board. This DC supply is subject to variation between -20% to +15 %.
- 9.3.3 The bidder shall give in his bid an estimate with feeder rating for the AC and DC power requirement for the equipment covered by this specification.

9.4 DETAILED DESCRIPTION OF THE RELAY PANELS

- 9.4.1 The panels to be provided shall have vertical front panel with equipment mounted thereon. In case of panels having width more than 800 mm, double leaf doors shall be provided. The doors shall have handles with built in lock and key facility.

Constructional Features

- 9.4.2.1 *The relay panels shall be fabricated from cold rolled steel sheet of not less than 3mm thickness for load bearing members of the panels such as base frame, side sheets, front sheet of door frames, side & bottom and 2mm for top & rear portions. The panels shall be suitably reinforced with sufficient number of steel members so as to provide level surfaces, resistance to vibration and rigidity during transportation & installation.
- 9.4.2.2 All the panels shall be of same height & depth and shall be capable of being assembled or dismantled with minimum disturbance to the adjacent panels. The bottom of the panels shall be suitable for erection on flush concrete floor and screwed to it by means of equally spaced grout bolts, projecting through the base channel members of the frame. The embedded base, foundation frames/channels and foundation bolts / fasteners etc. shall form part of the supply.
- 9.4.2.3 The panels shall be completely metal enclosed type and shall be dust, moisture & vermin-proof suitable to meet the requirements. The degree of protection of the relay panels shall not be less than IP-52 as per the relevant standard. The relay panels shall be suitable to meet the above stated requirements and other requirements as per DIN 40050.
- 9.4.2.4 All doors, removable covers and panels shall be provided with neoprene gaskets all around Ventilating louvers, if provided, shall have suitable screens and filters. The screens shall be made of either brass or GI wire mesh.
- 9.4.2.5 Design & selection of materials and workmanship of panels shall be such as to result in neat appearance, inside and outside with no welds, rivets or bolt-head visible from outside with all interior surfaces turned and visible smooth.

9.4.2.6 The cable entries shall be from the bottom of the panels. The gland plates of the panels (fitted without glands at the bottom of the panels) shall be connected to earthing of the panel/station through a flexible braided copper conductor rigidly. Necessary detailed drawings indicating details of the foundations with the necessary openings for cable entry etc. shall be supplied after award of contract but well in advance to enable the purchaser to prepare the floor plan. However, preliminary details in this regard and over-all size of equipment offered shall be furnished alongwith the tender. The purchaser will make provision for foundations with pockets and for foundation bolts. The contractor shall supply the channels for foundation bolts, pipes, nuts, lock nuts and washers, etc. The panels shall be fixed on the embedded foundation channels with intervening layers of anti-vibrations strips made of shock absorbing materials. Necessary number of cable glands suitable for armoured PVC/XLPE cables entering from the bottom shall be supplied by the contractor.

9.4.2.7 All unfinished surfaces of the steel panels and frame shall be painted with two priming coats of approved primer paint on the interior and exterior surfaces of steel, which shall be followed by applying an undercoat i.e. suitable base and binder for the finishing coat. The finishing coat shade shall be as under :-

- a. Exterior surface-stoved enamel. The colour of panels shall be finalized by the purchaser during the detailed engineering stage. The panels shall have semi-glossy finish.
- b. Interior surface-stoved enamel semi-glossy white.
- c. Base frame-stoved enamel black.

The panel shall be given a plastic covering, if necessary, for protection of the panels during transit. Sufficient quantity of finishing paint shall be supplied to enable the purchaser to restore at site that finishing paint which has been damaged during transit.

9.4.2.8 Relay panels of modular construction would also be acceptable.

9.4.3 **Mounting of Equipment**

All equipment, particularly all plug-in modules, electronic cards and elements shall be mounted such that removal and replacement can be accomplished individually without interruption of service to adjacent devices and are readily accessible without the use of special tools. Terminal marking on the equipment shall be clearly visible.

9.4.3.1 The contractor shall provide necessary cut-outs and do mounting & wiring of the equipment, to be supplied by other manufacturers for mounting in his panel in accordance with the corresponding manufacturers drawings. The Contractor shall co-ordinate with other suppliers in this regard Cut-outs, provided for future mounting of equipment shall be properly blanked off with blanking plates.

9.4.3.2 The centre lines of relays shall be not less than 450 mm from the bottom of the panel.

9.4.3.3 No equipment shall be mounted on the doors. Except as indicated at 9.4.9.6.

- 9.4.3.4 The height of panels shall be matched with the other panels to be supplied by the supplier of generating unit & CCS. The necessary coordination in this regard shall be responsibility of the EPC Contractor.
- 9.4.3.5 All equipment connections and cabling shall be designed and arranged to minimise the risk of damage which may be caused by fire. The bidder shall indicate in his offer special requirements, if any, for the type of fire protection arrangement proposed to be provided in the control room, machine hall, GIS bay and cable spreading areas.
- 9.4.4 **Panel internal wiring and other equipments & accessories**
- 9.4.4.1 The panels shall be supplied complete with inter-connecting wiring between all the electrical devices mounted & wired inside the panels and between the devices & terminal blocks for the devices to be connected to equipment outside the panels. When the panels are arranged to be located adjacent to each other, all inter-panel wiring & connections between the panels shall be furnished and the wiring shall be carried out internally. The adjacent inter-panel wiring shall be clearly indicated in the drawings furnished by the contractor.
- 9.4.4.2 All wiring shall be carried out with 1100 V grade, single core, and stranded copper conductor wires with FRLS insulation. The wiring shall be flame, vermin & rodent proof and shall have Oxygen Index of not less than 29 & Temperature Index of not less than 250 degree C.. The number & minimum size of the stranded copper conductors used for internal wiring shall be as follows :
- All circuits except the circuits for current transformers and voltage transformers: one 2.5 mm² per lead.
 - All current transformer circuits: One 6 mm² per lead.
 - Voltage transformer circuits: One 6 mm² per lead.
- 9.4.4.3 All internal wiring shall be securely supported, neatly arranged, readily accessible and connected to equipment terminals & terminal blocks. Wiring gutters, troughs shall be used for this purpose.
- 9.4.4.4 The bus wiring for auxiliary AC and DC supplies, voltage transformer circuits, annunciation circuits and other common services shall preferably be provided near the top of the panels running throughout the entire length of the panels. A.C. circuits, D.C. circuits & circuits operating at different voltages shall be grouped separately and the wiring for each of these groups shall be segregated. The D.C. feeders provided with miniature circuit breakers and voltage relays to initiate an alarm in case of tripping of the breaker. The bidder shall furnish a detailed wiring diagram of D.C. distribution scheme proposed by him for control & protection circuit for the approval of the purchaser.
- 9.4.4.5 Wire terminations shall be made with solderless crimping type and tinned copper lugs, which firmly grip the conductor. Insulated sleeves shall be provided at all the wire terminations. Engraved core identification plastic ferrules marked to correspond with panel wiring diagram shall be fitted at the other ends of each wire. The ferrules shall fit tightly on the wire and shall not fall off when the wire is disconnected from terminal blocks.

- 9.4.4.6 All the wires directly connected to trip circuit breakers shall be distinguished by the addition of red coloured unlettered ferrules. The numbers 6 and 9 shall not be included for ferrule purposes.
- 9.4.4.7 Longitudinal troughs extending throughout the full length of the panel held against the ceiling shall be provided for inter-panel wiring. Interconnections for the adjacent panels shall be brought on to a separate set of terminal blocks located near the slots of holes meant for taking the inter-connecting wires. The arrangements provided shall permit easy interconnections to adjacent panels at site and wires for this purpose shall be provided by contractor looped & punched properly inside the panel.
- 9.4.4.8 Contractor shall be solely responsible for the completeness and correctness of the internal wiring and for proper functioning of the connected equipment.
- 9.4.4.9 All the wirings between Generator Protection Panel and Unit Control Board (UCB) shall be provided and terminated by the supplier. All the wirings between Feeder Protection Panel/Busbar Protection Panel/XLPE Cable Protection Panel and Control and Metering Panel for Switchyard (located in GIS Hall and arranged from other supplier) shall also be provided and terminated by the supplier.
- 9.4.5 **Terminal Blocks**
- 9.4.5.1 All internal wiring for the external equipment shall terminate on terminal blocks, preferably vertically mounted on each panel. Terminal blocks shall be of 1100 V grade and have 10 amps. continuous rating, made of suitable moulded plastic material/ polyamide, metal parts made up of copper, complete with insulated barriers, stud type terminals, washers, nuts & lock nuts. Terminal block design shall include a white fibre marking strip with clear plastic & slip-on/clip-on terminal covers. The markings on the terminal strips shall correspond to wire number and terminal numbers on the wiring diagrams.
- 9.4.5.2 Terminal blocks for secondary leads of current transformer & voltage transformer shall be provided with test links and isolating facilities. The secondary leads of CTs shall be provided with short -circuiting and earthing facilities.
- 9.4.5.3 At least 20% spare terminals shall be provided on each panel and these spare terminals shall be uniformly distributed on all terminal blocks.
- 9.4.5.4 Unless otherwise specified, each side of the terminal blocks shall be suitable for connecting 16 mm² Aluminium cables to be arranged by the purchaser for AC/DC Power supply circuits to panels.
- 9.4.5.5 There shall be a minimum clearance of 250 mm between the first row of terminal blocks and the associated cable gland plate & / or panel side wall. The minimum clearance between rows of terminal blocks shall be of 150 mm.
- 9.4.5.6 Arrangement of terminal block assemblies and the wiring channels within the enclosure shall be such that a row of terminal blocks is run parallel and in close proximity with each side of the wiring duct to provide for convenient

attachment of internal panel wiring. The side of the terminal block opposite the wiring duct shall be reserved for the purchaser's external cable connections. All adjacent terminal blocks shall also share this field wiring corridor. All wiring shall be provided with adequate support inside the panels to hold them firmly and to enable free & flexible termination without causing strain on the terminals.

- 9.4.5.7 All necessary accessories for cable termination such as gland plates, crimp type lined copper lugs, supporting clamps & brackets, wiring troughs & gutters etc. for purchaser's cables shall be included in scope of supply of the contractor. The number, type, voltage rating & size of such cables shall be decided during detailed design stage.

9.4.6 **Test Blocks**

Switchboard type, back connected, semi-flush mounting type test blocks with suitably rated contacts shall be provided for routine checks/ testing. The current terminals shall be provided with links or other devices for shorting the terminals of current transformer leads prior to interrupting the normal circuits, without causing open circuit in the C.T. secondary. Test block covers shall be removable from the front of the panel and shall be provided with suitable lead sealing arrangement to prevent unauthorised access to the test studs.

9.4.7 **Name plates and markings**

- 9.4.7.1 All equipment mounted on front and rear side as well as inside the panels shall be provided with individual name plates with equipment designation engraved as per applicable standards. The large and bold name plates shall also be provided for circuit/feeder designation on the top of each panel on front as well as rear side,

- 9.4.7.2 All front mounted equipments inside the panel shall also be provided with individual name plates engraved at the rear with tag numbers corresponding to one shown in the panel internal wiring to facilitate easy tracing of the wiring. The name plates shall be mounted directly by the side of the respective equipment and shall not be hidden by the equipment wiring.

- 9.4.7.3 Name plates shall be made of non-rusting metal or plastic or other better material. Name plates shall be black with white engraved lettering. The name plates inscription and size of the name plates and letters shall be submitted to the purchaser for his approval.

- 9.4.7.4 All relays and other devices shall be clearly marked with manufacturer's name, type, serial number and data (for electrical parameters/particulars).

9.4.8 **Miscellaneous Accessories and Supporting Steel**

9.4.8.1 **Interior Lighting**

Each panel shall be provided with a fluorescent lighting fixture rated for 240 volts, single-phase, 50 Hz supply for the interior illumination of the panel during maintenance. The fitting shall be provided with MCB and switching of the fitting shall be controlled by the respective panel door switch.

9.4.8.2 **Convenience Outlets**

One no. 240V AC socket with switch suitable to accept 5 Amps/15 amps. round pin Indian plug shall be provided in the interior of each panel with ON-OFF switch for connection of hand lamps etc.

9.4.8.3 **Space Heaters**

Tubular space heaters suitable for single phase 240 volts AC supply shall be provided at the bottom of the panels to prevent condensation of the moisture. The space heaters shall be controlled through thermostats to maintain the desired temperature. The watt loss shall be low enough to keep the surface temperature well below the permissible limits.

9.4.8.4 **Supporting Steel**

All necessary embedded levelling steel, sills, anchor bolts, channels & other parts for supporting & fastening the panels and vibration dampers shall be supplied by the contractor. The embedded parts with detailed instructions shall be supplied in time to meet the schedule for insertion in the building structure. All trays and their supporting structure shall also be supplied.

9.4.9 **Earthing**

9.4.9.1

All panels shall be equipped with an earth bus securely fixed. The location of earth bus shall ensure no radiation interference for earth systems under various switching conditions of isolators and breakers. The material and the size of the bus bar shall be at least 25 x 6 mm copper unless specified otherwise. When several panels are mounted adjoining to each other, the earth bus shall be made continuous and necessary connectors & clamps for this purpose shall be included in the scope of supply of contractor. Provision shall be made for extending the earth bus bars to future adjoining panels on either side.

9.4.9.2

Provision shall be made for each earth bus of the end panels for connecting purchaser's earthing grid in the vicinity of the equipment at two separate points. Necessary terminal clamps and connectors for this purpose shall be included in the scope of supply of Contractor. The earth wires or screens should be clearly bonded and earthed to the gland plate. The earthing scheme shall be approved by the purchaser.

9.4.9.3

All metallic cases of relays, instruments and other panel mounted equipment including gland plates, shall be connected to the earth bus by independent copper wires of size not less than 2.5 sq. mm. The colour code of earthing wires shall be green. Earthing wire shall be connected on terminals with suitable clamp connectors and soldering shall not be permitted. The connections of the plug-in modules to earth bar have to be made before the plugs make contact.

9.4.9.4

Looping of earth connections which would result in loss of earth connection to other devices when the loop is broken, shall not be permitted. However, looping of earth connections between equipments to provide alternative paths to earth bus can be provided.

9.4.9.5

CT and VT secondary, neutral or common lead shall be earthed at one place only at the terminal blocks where they enter the panel. Such earthing shall be made through links so that earthing may be removed from one group without disturbing continuity of earthing system for other groups.

9.4.9.6 **FAULT INDICATING LAMP**

Suitable DC operated red coloured lamp indication facility shall be provided on each set of Protection Panel. The lamp shall be mounted either on top of the front door or just above the door in such a way that it shall be visible from long distance. The lamp shall be operated during any kind of the faults

inside the panel. A suitable reset push button after clearance of the fault and lamp test push button shall be provided.

9.4.9.7 **DC Supply Changeover feature**

All panels shall be equipped with automatic changeover to alternate DC supply from the 2 available DC supply sources i.e. DC1 & DC2. This arrangement shall be facilitated in such a way that in case of failure or loss of DC1(orDC2) supply, the panel shall be supplied from DC2(orDC1) supply with automatic changeover. Suitable rated diodes shall be used to avoid mixing of DC supplies or reverse current flowing. A suitable delay timer may also be used to satisfy the parallel operation criteria of any 2 DC supplies.

9.5 **PROTECTIONS**

General Protection Function

The alarm/status of each individual protection function & trip operation shall be communicated to SCADA. The numerical system shall have built in features/hardware interface to provide such inputs to SCADA for analog/digital values.

A trip coil supervision function shall for each lockout trip relay & each of the circuit breaker trip coils. It shall incorporate both the pre-close & post-close supervision of trip coils & associated trip circuits. An audible alarm shall be given in the event of operation of trip coil supervision function. It shall have a time delay on drop-off of not less than 200ms. Trip coil supervision function as a built in feature of the Generator & GT protection units is acceptable, provided it meets all other requirements specified here, including loss of DC supply

Following protection functions/relays shall be provided along with relay setting calculations of individual protection functions:

Protections for each Unit

21G	Generator Back-up Distance Protection for external faults
24	Generator Transformer Over fluxing
25	Synchronizing check relay
26 T	Transformer Oil Temp. Relay
27/ 50 G	Dead Machine
27S	U.V. relay on LT side of SST
27U	U.V. relay on LT side of UAT
27 SC	Synchronous condenser mode
27G	Under Voltage
32G	Generator Reverse /Low forward Power
40G	Loss of excitation
46G	Negative Phase Sequence Current
49S	Stator Thermal Over-load
49R	Rotor Thermal Over-load
49T	Transformer Winding temp. relay
50Z	Local Breaker Backup Protection
50ET/51ET	Instantaneous & IDMT O/C Protection for Excitation

	Transformer
50S/51S	Instantaneous & IDMT O/C Protection for SST
50U/51U	Instantaneous and IDMT O/C Protection for UAT
50IT/51IT	Instantaneous & IDMT O/C Protection for Independent Excitation system
51GT	IDMT O/C Protection for Gen. transformer
51G	Over current / Earth fault Protection of Generator in Synchronous mode
51NE1/87N	Earth fault and restricted earth fault for independent excitation transformer
51NGT	Gen. Transformer Neutral Grounding Back-Up Protection (IDMT O/C relay)
51NU	O/C & E/F /Neutral Back up Protection for UAT
51NGS	O/C & E/F Neutral Backup Protection for SST
59G	Generator Over-voltage
59NS/64S	95% & 100% Stator earth fault
59NT	Monitoring of Insulation of L.V. bushing for Gen. Transformer
60G1/60G2	Voltage Balance Scheme for VT circuit failure
63T	Buchholz Relay for Generator Transformer
64R	Rotor Earth-Fault
64RS	Restricted E/F Protection for SST
78G	Pole slipping
81 U/O	Under/Over Frequency Protection
81 SC	Under frequency protection of Generator in Synchronous mode
87G	Generator Differential Protection
87T	Generator Transformer Differential Protection
87OA	Overall Differential Protection for Gen. and Gen. Transformer
87N	REF Protection for Gen.transformer
87NBJT	Restricted E/F Protection for UAT
95G/51	Split Phase with Over current Protection for inter-turn fault
98T	Monitoring of Insulation of H.V. bushing for Gen. Transformer

Protections for GIS

87A1	Differential Current Protection for Bus Bar-A
87B1	Differential Current Protection for Bus Bar-B
87A2	Differential Current Protection for Bus Bar-A
87B2	Differential Current Protection for Bus Bar-B
50Z	Local breaker Backup Protection (for all bays)

Protections for XLPE Cables for each feeder

87-I, 87-II	Differential Protection of 400 kV XLPE cables (Main-I & II)
59	Over Voltage Protection

27	Under Voltage
49	Thermal Overload

Protections for Line/Feeder

21 L1 M-1	Line-1 Distance protection, Main-1 (Numerical)
21 L1 M-2	Line-1 Distance protection, Main-2 (Numerical)
21 L2 M-1	Line-2 Distance protection, Main-1 (Numerical)
21 L2 M-2	Line-2 Distance protection, Main-2 (Numerical)

For better reliability of distance protection, Main -1 & Main-2 relays will be of different make.

67/64L Directional O/C & EF protection

78G	Pole slipping relay
59L1	Over Voltage Protection
59L2	Over Voltage Protection
79L	Auto Reclose Relay
50Z	Local breaker Backup Protection Disturbance recorder

Auxiliary Relays

Cooling water system condition
 Generator fire protection system condition
 Transformer fire protection system condition
 Station fire protection system condition
 AC system condition
 DC system condition

9.6 GENERAL REQUIREMENTS

- 9.6.1 The protection system shall be designed and used for a fast and selective protection of generators and transformers, 420 KV SF₆ equipments, Feeders & XLPE Cables and other connected equipment / switchgear with a fast separation of the faulty part.
- 9.6.2 All protection relays shall be numerical type but where contacts of the protective relays are unable to deal directly with tripping, approved auxiliary contactors relays or auxiliary switches shall be provided. Separate contacts shall be provided for each alarm & tripping functions for SCADA system.
- 9.6.3 The numerical relays will be Siemens/Areva/ABB make unless otherwise specified or warranted. Specific approval from the owner shall be obtained in case of other makes of numerical relays.
- 9.6.4 The components of the protective system are

- a) Numerical plug in units, with data exchange via a powerful parallel bus.
 - b) Interfaces to the process (primary system, station equipment) VT, CT and tripping circuits shall be directly wired.
- 9.6.5 The protection relay shall be of plug-in modular design for the insertion into standard rack which shall be mounted on the hinged frame. The protection functions shall be sub-divided into two groups each being independent and capable of providing uninterrupted protection even in the event of one of the protection groups failing.
- 9.6.6 The single front type cubicles shall accommodate the protection relays, meters, controls & indications as specified, a variable tripping logic, supervision, signaling and inter-locks, which are fully wired and pre-tested.
- 9.6.7 The cubicles shall be of sheet steel of adequate strength (sheet thickness not less than 2.5 mm) with a glass window in the front door.
- 9.6.8 The cold rolled sheets used for the cubicles shall be completely degreased, rust removed and phosphated. Two coats of primer and two coats of finished synthetic enamel paint shall be applied, each coat followed by stoving. The interior surface shall be painted white while the colour of paint for external surface shall be subject to the approval of the purchaser.
- 9.6.9 All the numerical relays used in protection system shall comply with latest version of communication protocol IEC 61850.

9.7 MECHANICAL REQUIREMENTS

The following mechanical requirements shall apply to all protection relays

- a) Easy replacement of all plug-in modules, electronic cards and elements
- b) Interchangeability of identical units
- c) Easy maintenance and fault detection
- d) Silver or gold plated contacts of all auxiliary relays.
- e) All protection relays shall work with greatest possible reliability under all expected service conditions.
- f) The degree of protection of the relays shall be minimum IP52.
- g) All bases and frames of relays shall be earthed at the main panel bar. Connection of the plug-in modules to earth bar have to be made before the plugs makes contact.
- h) All protection relays and cubicles shall be completely wired and tested at the factory.

- i) Relays shall not be affected by mechanical shock or vibrations or by external magnetic fields.
- j) All front LED's shall be suitably marked.
- k) All the rubber/plastic parts shall be tropicalised and shall not get brittle or decay with age.

9.8 ELECTRICAL REQUIREMENTS

The following electrical requirements have to be satisfied for all relays.

- a) The protection system shall be operated with analogue and binary signals by use of completely digital processing techniques. The input transformers provide the galvanic isolation between the primary system CT and VT circuits and protection relays and also correspondingly adjust the signal levels. Separate CTs shall be used for each protective system i.e. system I & II.
- b) Complete digital measured value processing and control of analogue and binary data acquisition and digitizing of the measured values up to the trip decision for the circuit breakers, shall be provided.
- c) Complete galvanic and reliable separation of the internal processing circuits from the measurement, control and supply circuits of the primary system.
- d) The protection relays shall be insensitive to voltage transient and current transient errors, transient conditions and interference.
- e) The relays shall operate in a large frequency range, therefore also be operative during run-up and shutting down of the generator. Relays shall have adequate setting range, accuracy, resetting ratio & transient overreach.
- f) In order to achieve the highest reliability, adequate hardware & software redundancy shall be provided.
- g) Simple setting through connected personal computer with menu-guided software.
- h) The self monitoring of the hardware and software of the protection system shall be continuously and/or cyclically (mostly by software). The internal clock of the system will be time synchronized through GPS time synchronization system. The bidder shall specify the number & type of input signals of GPS.
- i) All protection relays shall be designed for redundant auxiliary DC-supply concept.
- j) The protection relays system shall be based on data exchange via internal parallel bus with digital signal processing for most functions, single conditioning, analogue and digital inputs, A/D conversion, processing and signal output.

- k) Communication and data exchange with process computer shall be provided via serial interface link.
- l) The system interface to connect a personal computer shall be available as an isolated interface.
- m) All protection relays shall be equipped for local and remote resets.
- n) The tripping outputs of each protection function shall be allocated to channels of the tripping auxiliary relay.
- o) External protection signals applied to the binary inputs of the matrix shall be processed via matrix in any desired alarm processing or tripping output.
- p) All relays shall be labeled with the following information:
 - function of relay
 - phase identification
 - main characteristics
- q) Numerical relays shall have self diagnostic feature in order to reduce down time of the relay & provide useful diagnostic information upon detection of an internal fault so as to speed up maintenance. The necessary support documentation explaining in detail the self diagnostic feature shall be furnished for the Employer's use.

9.9 Man Machine Interface

- 9.9.1 One mobile man-machine communication system (Laptop) shall be provided. The system shall contain hook up facility with numerical protections, software, cable, UPS etc. All functions that can be executed with central protection monitoring system located in control room shall be possible to realize through this mobile station.
- 9.9.2 The user interface for all the numerical relays provided by the manufacturer should be designed in such a manner that the user has scarcely to refer to the operating instructions. The functions listed below shall be ensured:
 - Extremely user friendly menu based operator program with choice of functions from the full screen & a graded series of windows.
 - Provision for creating, processing and checking sets of parameter settings off-line, i.e. while not connected to the protection device.
 - Transfer of settings of a set of parameters from/and/ to CD.
 - Provision for the user to enter commands to describe each input.
 - Entry and display of set points and other set-up parameters.
 - On-line display of input analog values;
 - Display of functioning of protection self-recording;
 - Activation and removal from service of separate protections that are integrated into terminal, as & when required
 - Listing of faults detected by self-diagnostics & messages /confirmations to guide the user and avoid errors.

9.10 CENTRAL PROTECTION MONITORING SYSTEM

9.10.1 Modern station protection monitoring system shall be based on the principle of distributed intelligence. A centralized control & monitoring center for the complete protection system shall be provided in the control/ relay room of power house. One operator station, one keyboard with mouse, printer, 2 KVA UPS, operator desk with chairs shall be provided for this purpose in the control room. The communication link between various protection panels and centralized control & monitoring center shall be realized with fibre optic cables. Provision shall be made for future extension of communication with other numerical protection devices.

- The system shall support a wide range of protection and disturbance recording devices.
- The system shall provide for local as well as remote monitoring of station operation from any location.
- The structure of the system shall be modular and facilitate expansion stages to keep pace with changing station requirements.
- The evaluation and communication system shall as far as possible comprise commercially available equipment to enable it to be integrated in the existing data processing infrastructure.
- Provision shall be made for synchronising the individual protection and disturbance recording devices in the station via the system and also for remotely changing-their setting as required by power system operating conditions.
- Provision shall be made for transferring disturbances registered by the disturbance recording devices to the system, which shall incorporate the corresponding software programs for evaluation, analysis and the graphical presentation of the results.
- The user interface shall be equipped with a graphical display and take full advantage of modern multiple windows technology. It shall provide the user with an overview of the status of the station and facilitate coordination of protection functions.
- The system shall continuously log all events and give alarm if any abnormal operating situation arises.
- All station data shall be collected, preprocessed for subsequent evaluation (statistic, trends etc) and saved on reliable mass storage media.
- The functionality of the required system can be summarized as follows:
 - Synchronization of all devices.
 - Provision for changing device setting from a control center.
 - Provision for central analysis of disturbance records.
 - Registration and processing of alarms and events-registration and processing of measurement.
 - Process image of the station showing states and measured values.
 - Testing and simple function check of the relay circuits and tripping logic.

9.10.2 Hardware

The centralized protection control & monitoring system shall be moderately and mainly based on commercially available standard equipment. The minimum system configurations to be included by the bidder in his offer are:

- Latest version
- Operating system : Latest version of MS windows,

- Minimum 2 GB RAM
- 52X DVD R/W
- Inbuilt Magneto Optic Device (MOD) for mass storage (backup)
- Hard disk minimum 500GB,
- Wireless KB & wireless mouse
- 21" colour TFT.
- USB Serial & Parallel Ports, as required
- Laser Color Printer
- Control desk for mounting MMI System, UPS, printer tables, chairs etc.

9.10.3 Software

The Central Protection Monitoring System software shall be set-up in a modular way, to fit all applications. The base software shall always be included and to that, different modules are added, depending on which protection is to be communicated with software for the transfer of disturbance recordings, evaluating software shall also be used as an expert system for automatic evaluation of the disturbances.

9.10.4 Disturbance recording visualization and evaluation program

The program shall be used for visualization of disturbance recordings. It shall handle the following formats:

- MANUFACTURER'S format. (shall be approved by the Purchaser);
- COMTRADE format. This is a standard format for disturbance recording according to IEEE.

Apart from this, a format conversion function shall also be included. This function shall convert between any of above mentioned formats.

For presentation of the recordings, the program shall use user- defined templates.

The following functions shall be included in this program among others:

- Zooming in and out;
- Change of channel size for analogue channels;
- Selection of colors;
- Selection of line shapes;
- Rulers for measurement of time difference and phase angle;
- Rulers for measurement of instantaneous and RMS values;
- Configuration of print-outs;
- Possibility to add a comment file;
- Possibility to merge up to three recordings with synchronized time;
- Individual or equal scaling of analogue channel;
- Grouping of signals;
- Handling of up to 33 analogue and 144 digital signals in one window;
- Printout on windows system printer.

9.10.5 Relay Setting and Supervision Program

With this program it shall be possible to alter all relay settings remotely, as well as switching between different setting groups, and clearing the LEDs on the relay front. Also the distance to fault, the self supervision status, the

measured values, and relay oriented event list shall be available. Before any change of settings is allowed, a password has to be entered. When the file with new settings is then downloaded to the relays, it will automatically be read back to the PC to be compared with the original file, to make sure that the communication worked correctly.

9.11 PROTECTION DEVICES

The supplier shall offer the various protections as per Clause 9.5 & 9.12 and Single line Diagram as per Section-30: "Tender Drawings" of Part-2: Section VI: "Employer's Requirement". Any other protection, if required to be necessary, should be included in the offer.

9.12 SHORT DESCRIPTION OF PROTECTION DEVICES

9.12.1 GENERATOR PROTECTIONS

Generally the Generator protection system shall be designed by using completely digital processing of the measured input-currents from the sampling and digitising of the analog input values to the release of the trip signals for the circuit breaker.

The digital techniques used in the processing of the protection functions shall guarantee the suppression of the influence of the switching currents, transients & harmonic-current components and varying degree of CT saturation.

The unit protection functions which should be provided are briefly described as under:

9.12.1.1 Generator Differential Protection (87G)

The generator differential protection shall be provided for the protective zone of the stator in the case of short-circuits, for fast, selective and sensitive protection.

The protection function shall be an instantaneous percentage-differential type with suitable biased characteristics and adjustable pick-up setting of 5 to 10% nominal current. The relay shall have a operating time of less than 30 m secs at 2 times the setting. The measurement system shall be based on 3-phase, low impedance principle. It should be possible to detect three phase and phase to phase faults.

Generator differential protection shall include only stator winding & generator terminals and shall have the following features:

- High stability for external faults and CT saturation;
- Very short operating/trip time < 20 ms at five times current settings;
- Suppression of DC-transients and harmonic components;
- Non-linear current dependent trip characteristic.

9.12.1.2 Stator Earth Fault Protection (59NS, 64S)

As shown in drg. "Single Line Relaying & Metering Diagram", generator neutral will be connected to earth through a earthing transformer, the secondary side of which is connected across a resistor. Stator earth-fault protection shall be

provided as an integrated protection module or a separate protection relay. All necessary coupling components such as injection transformer, capacitors, as required shall be provided. In case of this function being implemented as software function in computerised unit protection systems the need for a separate solid state stator earth fault protection instead of software implementation of this function shall be examined during design stage. This protection shall have the following elements.

I) 90% Stator Earth-Fault Protection (59 NS)

For faults within about 90% of the stator winding, a sensitive voltage function should be provided. This protection for detection of the neutral displacement voltage shall be equipped with a filter to eliminate all harmonics and must therefore be insensitive to phenomena other than ground faults in the stator windings (up to about 85-95% from the generator terminals). The pick up voltage of the relay shall be at 5% of max. neutral voltage and the time delay shall be adjustable within 0.3 to 5 secs.

The protected zone shall be limited to approx. 90% due to the danger of false tripping. The stator earth fault relay shall be connected to the voltage transformer in the generator neutral or the voltage transformer at the generator terminal side. In both the cases, the relay monitors neutral displacement at stator earth faults.

By means of digital filtering of the input measurement, only the fundamental frequency shall be measured. The harmonic components shall be suppressed. The protection shall be insensitive to 3rd harmonic voltage. The residual voltage measuring stage shall have a wide setting range.

II) 100% Stator Earth Fault Protection (64S)

- a) In order to cover the remaining stator winding (about 5 to 15%) and also to provide back-up coverage of the 90% protection which is a part of digital protection systems, an additional independent 100% earth-fault protection shall be provided.
- b) The relay shall generally operate on the principle of low frequency signal injection into the secondary of the earthing transformer, detecting the corresponding current if an earth fault occurs. The relay shall be set in terms of insulation resistance.
- c) Alternatively a protection based on change in magnitude / distribution of 3rd harmonic voltage caused by an earth fault shall be used. This shall have voltage check or current check unit as applicable to prevent faulty operation of the relay at generator standstill or during the machine running down period.
- d) The relay shall have a continuously adjustable time delay range of 1 to 10 secs.
- e) If the relay supplied is based on injection principle then pick up level of relay shall be 500 ohms & time delay of 2 secs (> than 3rd zone of distance relay) and if the relay supplied is based on 3rd harmonic principle the setting of the relay shall be 0.45V (should be

checked w.r.t. the 3rd harmonic voltage generated by the machine) and time delay shall be 2 secs. The voltage & current check units should be set at 80% of rated voltage & 20% of rated current respectively.

- f) Suitable Means/Arrangement for testing a simulated earth fault shall be provided.

9.12.1.3 Rotor Earth-Fault Protection (64R)

- a) A sensitive voltage function operating on bridge measuring basis with auxiliary equipment should be provided for this protection. The relay / protection function shall have two levels, one for alarm & another for trip. This protection must also be able to detect the earth fault in the rotor circuit in the standstill condition of the machine.
- b) The relay must be insensitive against harmonics and shall not be influenced by rotor capacitance to earth or any other interference.
- c) The function shall be based on DC injection principle or low frequency AC injection principle. All adaptation elements such as injection equipment, coupling capacitors, earthing resistance, etc. shall be included. Injection unit equipment should preferably be built in the relay itself. Information about the same shall be specifically given in the offer.

9.12.1.4 Generator Negative Phase Sequence Protection (46G)

- a) A generator negative phase sequence protection function / relay shall be provided in order to prevent prolonged heating of the rotor iron caused by the induced double frequency (100Hz) currents when negative phase sequence currents are present in the stator. The negative sequence current may also appear due to unbalanced single phase loads or unsymmetrical faults of the transmission line. Two different stages, one for alarm and another for trip shall be available. This function shall have an adjustable time current characteristics that must be matched with negative sequence current withstand characteristics of the generator i.e. to the $(I_2)^{2t}$. The exact value of $(I_2)^2$ shall be confirmed from the generator supplier.
- b) The first stage of the protection shall have the low setting to provide alarm and visible indication and the second set for higher unbalance to affect the tripping of the machine. Necessary provision i.e., potential free contacts etc. for the same shall be provided, for alarm communication / visible indication / trip signal, for wiring in respective circuits of computerised control systems. Requisite optical or special cables, if any, for this purpose shall be supplied by the bidder.
- c) The pick-up current and operating time should be separately adjustable for each stage.
- d) The alarm unit shall have a range covering negative phase sequence current of 5-10% of generator rated current continuously adjustable.

- e) The definite time negative phase sequence (NPS) current function shall be suitable for the protection of networks where long infrequently varying current asymmetries occur. Relatively long delays shall be provided since the temperature of the affected rotor surface is expected to rise slowly.
- f) The negative phase sequence current protection shall be delayed in order to avoid false tripping as a result of transient and particularly asymmetrical short circuits in the network. As such alarm element shall have a definite time setting of 1 to 10 secs. The alarm unit shall be set at 50% of continuous withstand capability of machine and time delay for alarm can be 3 sec. and the trip element shall have independently adjustable heat & cooling constants which shall be stated in the offer.
- g) The protection relay shall have a definite time starting contact for trip warning purposes. The pickup current and operating time should be separately adjustable.

9.12.1.5 Generator Reverse-Forward Power & Low forward Power Protection (32G)

- a) This system shall protect the generator in the event of reverse power flow (generator motoring effect).
- b) The power setting shall be approx. 0.5% - 1% of rated active power of generating unit.
- c) The relay shall have independently time delay relay with setting range of 1 to 10 secs. & 0-20 secs. respectively on pickup.
- d) As the settings required for power function may be very sensitive the function may preferably take current inputs from the metering core C.Ts. A compensation angle setting shall be possible to compensate for any CT & VT errors to facilitate accurate measurement of power. Since reverse power condition is a three phase symmetrical phenomenon, single phase measurement shall be acceptable. Under pulsating power condition to allow the relay to trip within the predetermined time delay an integrated delayed drop-off timer shall be included in the timing logic of the relay.
- e) Provision shall be made to block the operation of this relay during synchronous condenser mode.

9.12.1.6 Stator Thermal Overload Protection (49S)

The stator overload relay shall be used as an additional check of the stator winding temperature. The stator overload protection is a protection of the stator winding against excessive heating due to very high continuous overload current (thermal replica). The protection relay must match the machine characteristics with an inverse time thermal replica response defined by the generator supplier as per ASA - C50. 13 or IEC 255-8.2 for synchronous generators and defined by the generator supplier.

9.12.1.7 Generator Back-Up Distance Protection for External Faults (21 G)

- a) When a self excitation system is provided for a generator, conventional generator protections for symmetrical fault (low voltage over-current relay or single step distance relay) may fail for close-up external faults

due to the stator current decay. Accordingly, it is proposed to provide distance measuring type protection function with offset mho characteristics. It shall provide three phase two stage definite minimum time protection against all types of uncleared faults in generator, main transformer & 400 kV line.

- b) The protection shall be connected to the generator neutral side current transformers & to the line voltage transformer on the line side.
- c) The first stage / step of the protection may be provided as a back up for close-up faults. The zone covered by the distance relay should include a portion of the step-up transformer, bus bars between the generator and the transformers (step-up, excitation & unit auxiliary transformers) and a part of the excitation & unit transformers.
- d) The reach of the first zone is chosen in such a way that 70% of the transformer winding is protected besides providing protection to the generator. The first step shall have a circular operating characteristics and shall be selected to match with the characteristics of the distance protection provided on the outgoing 420 kV lines.
- e) The second stage / step of the protection shall be provided as a remote back-up and shall initiate machine shut down. It should extend as far as possible into the power system without upsetting the grading of the various protection devices. This step shall have suitable operating characteristics to make the protection insensitive to the field forcing & normal operating conditions.
- f) The time delay of this relay should be set at one step higher than time delay of the back-up protections on the outgoing 420 kV lines.
- g) It shall have an adjustable definite time delay of 0.5 to 5 secs.
- h) It shall remain inoperative during maximum load conditions and shall not initiate machine shut down. The relay shall operate for fault currents down to $0.3 I_n$.

9.12.1.8 Loss of Excitation Protection (40 G)

- a) This protection function shall protect the generator during a fault in the excitation circuit. If a generator with sufficient active load loses the field current it causes the loss of synchronism which may cause the machine to run at a speed higher than the system absorbing reactive power for the excitation from the system. Under these conditions, the stator end regions and part of the rotor get over heated. The protection function shall prevent damage to the generator due to power swings in the system. The function shall have mho characteristics lying in 3rd & 4th quadrant of impedance diagram with off set features with independently adjustable settings for off set and mho circle diameter (reach).
- b) The tripping characteristics of the protection function shall have as nearly as possible the same curve form as the generator stability characteristics.

- c) In order to obtain a rapid & effective under excitation protection, as second criteria the excitation voltage or current shall be introduced into the system. If both, stability curve & the excitation voltage criteria are satisfactory, alarm & trip shall be triggered after a time delay of 1-2 secs. The loss of synchronism with the excitation being in normal operation shall be detected by an integrator which integrates the short duration output pulses from the relay to count the short & brief power swings which, if of persistent nature, should intimate tripping.
- d) It shall have independently adjustable time setting range of .5 to 10 secs. to distinguish loss of excitation from power swings.
- e) Prevent undesirable operation during starting of the machine.

9.12.1.9 Pole Slipping Protection (78G)

- a) The loss of excitation protection should be supplemented by an out of step relay which detects slipping of all poles. This function should be connected to instrument transformers on the neutral side of the generator & to the voltage transformer on the phase side and shall disconnect the generator either after the first slip of the rotor or after the pre-determined number of allowed slips of the machine. The characteristics of this function shall consist of a lens in a R-X diagram passing through the origin which is at the generator terminals.
- b) The pole slipping protection shall operate on the principle of measuring the impedance course / curve (or polar frequency response curve) on the R-X diagram.
- c) The relay shall be capable of detecting a power swing which can lead to instability in addition to its ability to detect an actual pole slip.
- d) By varying the size of the characteristics it shall also be possible to ensure that a trip command is given to the circuit breakers in such a way that separation of the poles occurs at a controlled angle at any time.
- e) The various modes of operation and properties of the pole slipping protection are given as under :
 - i) If the source of oscillation lies within a generator/transformer unit, the machine shall be isolated from the network after the first slip.
 - ii) If the source of oscillation lies in the network outside the unit, the generator shall not be switched-off until at least several pole slips have occurred.
 - iii) The function operational criteria shall be fulfilled when the impedance enters the lens on one side and leaves on the other side, regardless of the direction.

Pole slipping protection operating on some other principle shall also be acceptable provided it has given satisfactory service. The details of power houses, where such protection is under operation shall be given in the

offer alongwith a performance certificate from utilities for its trouble free operation clearly indicating the year of installation.

9.12.1.10 Overvoltage Protection (59G)

- a) This relay shall protect the generator against dangerous overvoltages produced within the generator. At the same time, the magnetic core shall also be protected against overheating due to iron losses. Longer lasting over voltages are particularly to be expected by a failure of the automatic voltage regulator (AVR). The protection relay shall have two stages each separately adjustable. It shall be independent of frequency on a wide scale.
- b) The first stage is intended for protection against lower but long lasting over voltages.
- c) The second stage is intended for protection against higher over voltages.
- d) The relay shall have a drop-off to pick up ratio greater than 95%.
- e) The relay shall be of 3-phase type with a time delay & instantaneous stage.

9.12.1.11 Over/Under Frequency Protection (81U/O)

This protection function shall prevent the running of the generating unit from exceeding the permissible operation time at above or below the set frequencies. The relay(s) shall have one alarm and two tripping stages. The bidder should co-ordinate with generating unit supplier for time delay setting for tripping stage. The timer for alarm stage have a range of 0.5 to 5 secs with a least count of 0.5 secs. The timers for each tripping stage shall have range of 1 to 10 secs. with a least count of 0.1 sec. The relay shall have a setting range of 45-55 Hz. It shall operate on digital basis whereas the frequency setting should be adjustable in steps of the order of 0.1 Hz.

9.12.1.12 Protection against Inadvertent Energisation (Dead-Machine Protection) (27/ 50G)

- a) A three phase, high speed numerical relay shall be provided for fast protection against inadvertent energisation of the machine at standstill. The provision shall be made to block the operation of the relay during the running of the machine. The operating time of the relay shall be set much lower than the operating time of loss of excitation and the reverse power flow relay as these shall operate with delays. This protection shall be installed in switchyard panel rather than in generator panel to ensure that protection is available during maintenance period when the generator protections can be rendered inoperative by switching-off of the D.C. supply to the panel. This may be reviewed during detailed design stage & suitable changes if required shall be affected in relay panels for location of this relay.
- b) The protection shall consist of 3 high speed overcurrent relays of range (0.2-20 I_n) to initiate instantaneous tripping if generator terminal voltage is below set value.

- c) Shall have under voltage relays of range (0.2-1 U_n) to permit operation of overcurrent relays when voltage is low.
- d) Shall have timers with adjustable range of 0-60 sec. to avoid operation of protection for nearby fault when the machine is in service.

9.12.1.13 Voltage Balance Relay or Voltage Transformers Circuit Fuse Failure Protection (60G1, 60G2)

The intended function of this relay is to block the operation of relays which can mal operate due to PT fuse failure or MCB operation in primary side or secondary side or any interruption in the reference voltage circuits. The relay shall be triple pole, voltage balance or equivalent type. The relay shall have variable tripping and reset delay. The relay shall have sufficient contacts to block the possible faulty operation of those relays which are voltage dependent AVR etc. & give alarm.

9.12.1.14 Protection of Generator in Synchronous Condenser Mode

In addition to the aforesaid protections intended for protection of the generator in the generating mode, necessary protections which shall be activated when the unit is transferred/operating to/in the synchronous condenser mode, the following protections shall be included:

a) Over Current/Earth Fault Protection

A suitable relay which shall cause the tripping of the machine in case of over current/earth fault during the machine being operated in synchronous condenser mode will be initiated by 51GT.

b) Under Frequency Protection (81 SC)

The protection is intended to trip out the synchronous condenser in the event of system under frequency / feeding line getting disconnected from the other end due to fault etc. The relay shall have under frequency setting range from 45 Hz to 50 Hz. Two stage under frequency protection with timer shall be provided so that the machine can be tripped off under low frequency conditions.

The requirement of above protections shall be subject to confirmation during detailed design stage. The prices for these protections shall be quoted separately by the bidder.

c) Under Voltage Protection (27SC)

This protection function shall be used as a backup protection in case of voltage reduction during parallel operation. It shall be a 3-phase type with a time delayed stage, frequency independent within range 0.5 to 1.2 rated frequency.

9.12.1.15 Split Phase with Overcurrent Protection (95 G/51) for inter-turn faults

Each generator has been provided with current transformers mounted on neutral side of terminals for split phase protection. Bidder shall provide a set of suitable relays for split phase protection of each Generator.

9.12.2 PROTECTIONS FOR GENERATOR TRANSFORMERS

9.12.2.1 Transformer Differential Protection (87 T)

- a) This relay/function shall be provided for protecting the generator transformer. The measurement system shall have 3-phase features and it should be possible to detect three phase and phase to phase faults.
- b) Biased differential function having bias windings shall be offered. The function shall have an adjustable pick-up. Range of adjustable pick-up and percentage biasing provided for the relay shall be indicated in the offer.
- c) The function shall be stable during magnetising inrush & under normal overfluxing conditions. The relays shall have second harmonic or other inrush proof features. Magnetising inrush proof feature shall not be achieved through any intentional time delay by use of timers to block relay operation or using disc operated relays.
- d) The function shall have high stability for external faults and the provision for preventing CT saturation.
- e) Interposing current transformers or built in provisions shall be provided for ratio & phase angle corrections.
- f) The relay shall display differential & bias currents.
- g) The relay shall have trip test facility. The relay shall have operating time less than 30 milli secs at 5 times of setting.
- h) The relay shall have an additional high set instantaneous element for rapid clearance of heavy faults (which shall not operate during inrush). This element shall have current adoptive measuring characteristics to ensure fast operation for internal faults with saturated CT's.
- i) The relay shall include HV side of UATs, SSTs & Excitation Transformer in its zone of Protection. Bidder shall also furnish his views along with the bid regarding operational feasibility/requirements of such an arrangement.

9.12.2.2 Inverse Definite Minimum Time (IDMT) Overcurrent Protection (51GT)

- a) The inverse definite minimum time over current protection shall provide back up protection of generating unit and for the generator transformer and various parts of the auxiliary network against faults which produce overcurrent. This protection shall also be operative on occurrence of short circuits in the generator transformer or when the generator is working in condenser mode.
- b) The measurement shall not respond to DC components and harmonics; the overcurrent protection shall practically react only to power frequency component.
- c) The function shall have an adjustable setting range of 50-200% of rated current and 0.5-5 secs. time delay. The adjustable time delay shall be achieved by different time gradings together with other overcurrent protection functions starting from generator connection point up to the unit transformer with its corresponding connection point. The setting range shall be large but small enough to detect the lowest short circuit current.

- d) Each phase current shall be individually compared with the set value of overcurrent and a phase-selective alarm shall be initiated when this set value is exceeded. A trip signal shall be initiated after a selected time T, if a over current condition persists.
- e) Similar protection covering features, as desired at (a) (relevant portion & (b) to (d) above) shall be provided for station service transformers & unit auxiliary transformers as well as excitation transformers.

9.12.2.3 Restricted Earth-Fault Protection (87N)

- a) The restricted earth-fault protection function, which can be a high impedance or low impedance type differential protection provided for protecting the generator transformer against internal faults, shall be fast, sensitive and selective, for the protected zone.
- b) The relay shall detect earth-faults where the star point of the transformers is solidly or low-impedance earthed.
- c) The function shall have high stability against maximum through fault condition & provision for preventing CT saturation, harmonics and D.C. transients.
- d) In order to limit the voltage appearing across the secondary leads under internal fault conditions to a safe level, non-linear resistors shall be provided across the relay to limit the peak voltage to 1000 volts in case of the high impedance type. Suitable arrangement shall similarly be provided for low impedance type relays.
- e) The relay shall be provided with faulty phase identification.
- f) The relay shall have an operating time less than 30 millisecs. at 2 times setting and the operating current of 0.1 to 0.4 I_n .
- g) Similar protection covering features shall be provided for UATs, Excitation Transformers and SSTs.

9.12.2.4 Over current Earth-Fault Protection / Neutral Back Up Protection (51NGT)

- a) This protection shall provide back up protection for ground faults on the star connected winding of generator transformer by monitoring the current in the generator transformer neutral and a part of the power system electrically connected to it. The relay setting shall be adequate to protect the entire star winding. The operating time is chosen to grade with the longest time set for the ground fault protection relays in the next section. The relay shall have definite time characteristics. The relay shall have the adjustable setting range of 10 to 100% of rated current and a timer setting range of 0.5 to 5 secs.
- b) Similar protection covering features shall be provided for UATs, Excitation transformers and SSTs.

9.12.2.5 Over fluxing / Over excitation Protection (24)

- a) The overexcitation protection shall be provided to safeguard the generators, generator transformers, SATs (for unit 1&6 only), UATs and Excitation Transformer against the operation at flux densities which may cause damage to the core.
- b) The protection shall be provided with a time delay to prevent false tripping during the transient events, e.g. load shedding. The tripping function shall be executed after the time delay.
- c) The relay shall be based on the principle of measurement of changes in the voltage to frequency ratio. The overfluxing capability of the generator transformer shall be checked and the characteristics matched accordingly for both alarm & trip.
- d) The relay shall be provided with the following features:
 - V/f measurement
 - Phase to phase measurement
 - Suppression of harmonics and DC components
- e) The relay shall provide an independent alarm with a definite time delay of value of V/f between 100% to 130% of rated value.

9.12.2.6 Monitoring of Insulation of H.V. Bushing for Generator Transformer (98 T)

- a) The insulation conditions at the transformer H.V terminals shall be monitored. A separate device, which may measure the zero-sequence capacitive current in the circuits of the three-phases, may be included. The device shall respond to the sum of first harmonic capacitive currents in the terminals of all the three-phases. Any partial breakdown in the terminal insulation or increase in the leakage current should cause the device to operate. The device shall have both alarm & tripping elements.
- b) If any additional VT/CT core are required for this protection, the technical particulars of the same may also be indicated in the bid to enable the purchaser for procuring the same from GIS supplier.

9.12.2.7 Monitoring of Insulation of L.V. Bushing for GT (59 T)

- a) Overvoltage protection connected to delta winding of VT shall be provided for monitoring insulation condition on the LV side of the generator transformer.
- b) The requirement of this protection will be reviewed after consultation with the prospective bidders.

9.12.2.8 Differential Protection between H.V Bushing & Bus Bar (87B)

This relay / function shall be provided for protecting generator transformer H.V bushing side to bus bar bushing. The measurement system shall have 3 phase features and it should be possible to detect faults. . The principle of operation preferably shall be based on current differential principle. Use of

either Pilot Cable or Fibre Optic media for current differential measurement techniques shall be identified by the vendor.

9.12.3 OVER ALL DIFFERENTIAL PROTECTION FOR GENERATOR & GEN. TRANSFORMER UNIT (87OA)

- a) This relay / function shall be provided for protecting generator as well as generator transformer. The measurement system shall have 3 phase features and it should be possible to detect phase faults on both sides of the generator transformer and single phase earth faults on H.V. side.
- b) Provisions of clause 9.12.2.1 (b-h) of the specification as already indicated for Transformer Differential Protection (87T), shall be applicable.
- c) As electrical braking for the generator has been provided, it will create temporary short-circuit at the generator terminals falling within the zone covered by the differential protections 87T and 87GT. Therefore, the means shall be provided to block the operation of these relays during electrical braking.

9.12.4 PROTECTIVE RELAYS FOR UNIT AUXILIARY TRANSFORMERS

- 9.12.4.1 Each generator has been provided with its own 13.8 kV /433V, 400 kVA, Delta/Star unit aux. supply transformer connected by isolated phase bus-duct to generator phase terminals.

These transformers shall be provided with the protections for the following envisaged abnormal/fault conditions:

- Multiphase and earth faults in windings and at terminals
- SC currents in the windings caused due to external faults
- Excessive currents in the windings caused due to over-loading
- Buchholz relay
- Oil winding temperature relay

The protections for Instantaneous & IDMT overcurrent (50U/51U), Restricted E/F (87RU) and Neutral Back up (51 NU) shall be provided in order to prevent above mentioned faults.

- 9.12.4.2 Instantaneous over current protection (50U) shall be a fast acting protection, 3-phase measurement type with peak value evaluation and wide frequency range.
- 9.12.4.3 The requirements regarding Restricted Earth Fault protection (87RU), Neutral Back Up Protection (51 NU) and Inverse Definite Minimum Time Overcurrent Protection (51U) are indicated at clauses 9.12.2.3, 9.12.2.4, and 9.12.2.2 respectively.

9.12.4.4 Buchholz protection:

Power transformer shall be fitted with buchholz devices of the two element type giving operation under gassing and under surge condition. All necessary indication, tripping relays associated with this protection shall be provided, mounted and connected. The Buchholz relay shall be equipped with gas sampling and testing devices to be operated from the ground level at convenient height.

9.12.4.5 Oil winding temperature:

Transformer will be provided with oil and winding temperature protection. These will be of the two stage type with adjustable settings giving alarm and trip facility. All necessary indication, tripping relay and alarm relays associated with this protection shall be supplied and connected up. All necessary means / provisions / arrangement shall be provided for other electrical trip functions of UATs.

9.12.5 PROTECTIVE RELAYS FOR THE EXCITATION TRANSFORMER

The bidder shall integrate in his protection scheme the following protections of excitation transformer as well as other protections of generator (supplied by generator supplier) and other equipments as detailed under clause 9.2.1.

- a) Instantaneous Over-current Protection for protection (50ET) against multiphase faults in the Excitation Transformers windings and the transformer terminals on the generator side.
- b) Inverse Definite Minimum Time (IDMT) Overcurrent Protection (51ET) as back up protection for multi-phase faults in the windings & the excitation transformer terminals.

In accordance with Generator scope of supply some of the rotor and excitation system relay protections will be supplied complete with excitation system. These are:

- | | |
|-------|--|
| - 49R | Rotor overload protection |
| - 40G | Loss of excitation protection |
| - 64R | Earth-fault protection for rotor Winding |
| - 81 | Frequency protection |
| - 59 | Overvoltage protection |

9.12.6 PROTECTIONS OF STATION SERVICE TRANSFORMERS

The Vishnugad Pipalkoti HEP is provided with two station service transformers rated 2500KVA each and connected by tap-off isolated bus-duct to the phase terminals of generator G1 & G4. The transformers are intended to supply power to the 11 kV station service system.

The station service transformers shall be provided with the following protections to cover multi - phase and earth faults in windings and at terminals:

- Instantaneous & IDMT Overcurrent (50 S/51S)

- Restricted E/F Protections (64RS)
- Neutral Back-up Protection (51NGS)
- Winding temp (alarm & trip), WTI & OTI

The relay schemes 64 RS & 51 NGS are not covered under the scope of this specification. However, the bidder shall integrate these relays in his protection scheme.

9.12.7 PROTECTIONS FOR 420 kV SF6 GIS EQUIPMENT

9.12.7.1 Bus Bar Protection (87A, 87B)

Bus bar shall be covered with a duplicated high speed busbar protection scheme connected to two different CT cores.

420 kV protections of the high impedance, high speed, and circulating current type shall be provided capable of detecting three phases, phase-phase and phase to earth faults, under all system generation plant conditions.

The operating time of the measuring relays shall not exceed 40 ms. at five times the relay current setting and shall be as short as possible consistent with reliable and secure operation.

The rated stability limit of each fault detecting system for phase faults shall not be less than the rated breaking capacity of the associated switch gear. The Contractor attention is also drawn to the fact that the maximum through fault current for earth faults may be in excess of the phase fault value. The minimum pick-up value shall not be less than thirty per cent of the minimum fault level for all types of faults.

The bus bar protection shall be fed from separate CT cores reserved for it.

Automatic and continuous supervision of current transformer circuits shall be provided to give an alarm when the out-of-balance current reaches an undesirable value. Operation of current transformer supervision equipment should block the protection after a time delay and shall initiate an alarm. A red lamp shall indicate the above condition.

Busbar protection shall be equipped by considering at least 1 bay as spare. It shall be equipped with all tripping relays & auxiliary relays and measuring equipments.

Bus bar Differential Relay (87 A, 87B)

Three phase bus bar differential relay including the number of systems and auxiliaries required for the complete bus bar protection system shall be provided.

The bus bar protection shall have the following features:

To enhance security, the protection scheme shall use at least two independent criteria for detecting an in-zone fault and shall initiate a trip signal only if all criteria are securely satisfied. Neither criteria shall be voltage dependent.

Two separate tripping systems shall be provided designated first and second bus bar tripping system with One Check zone covering first and second bus bar tripping system. Contacts on the appropriate high impedance relays for each tripping system shall be connected in a “two-out-of-two” basis.

Two independent bus bar protection trip relays shall be associated with each bus bar circuit- breaker. One trip relay shall be energized by the first bus bar tripping system, the other trip relay shall be energized from the second bus bar tripping system. These trip relays shall be used exclusively for the bus bar protection and for the breaker failure protection.

Each circuit-breaker trip relay shall be arranged to trip both trip coils on the circuit breaker, i.e., each bus bar circuit-breaker shall receive a total of two trip commands for a bus bar fault.

In the case of feeder circuits operation of bus bar protection trip relays shall initiate direct transfer tripping of the remote end circuit-breaker via PLCC .

The Contractor shall include for all necessary current transformers, relay panels, marshalling boxes, isolating and shorting links, etc.

Current transformer secondary bus wiring should be suitably dimensioned to reduce current transformer burdens to a minimum.

Auxiliary contacts on bus bar selector isolator used for switching current transformer secondary circuits shall consist of two switches with silver based contacts connected in parallel. Auxiliary relays will not be accepted for this purpose.

Suitable voltage limiting devices should be provided as necessary.

Conditions of Acceptance of High Impedance Bus bar Protection Systems Submitted on the Basis of Calculated Performance

During testing and take-over Calculated Performance data for instantaneous high impedance differential bus bar protection systems will be accepted in lieu of heavy current tests, subject to the following :

The rated stability limit shall not be less than the three phase symmetrical breaking capacity of the associated switch gear.

The fault setting for any type of fault shall not exceed 30% of the minimum fault current available.

Current transformer knee point voltages shall not be less than twice the relay circuit setting voltage.

The maximum peak voltage across current transformer secondary wiring shall not exceed 3kV under maximum internal fault conditions.

Associated current transformers shall be of low reactance type. Split core type current transformers will not be accepted.

The contractor shall submit for the Owner’s approval, a design report detailing the protected equipment, design parameters of associated current transformers, details of connections and burden between current transformers and relays, details of the relays circuits and performance calculations.

9.12.7.2**Local Breaker Back-up Protection (50Z)**

- a) This relay is required to be provided as a back up protection in case of failure of operating mechanism of 420 kV circuit breakers on receipt of trip command from protection relays when this back up protection shall give signal for tripping of all the adjacent breakers connected to the bus section to which the faulty circuit breaker is connected. Input shall be provided to initiate operation of the breaker failure protection from the tripping commands received from all protections including bus bar protection for the given circuit breaker due to operation of any of the protection functions.
- b) This relay may be provided either as a separate unit or may be built in the bus bar protection. The provision should be made in the latter case to use the current transformer of the given circuit breaker to operate the breaker failure scheme jointly with other protections as mentioned in para (a) above
- c) LBB protection can not operate without proper initiation. As such bidder should provide redundant trip output and breaker fail input where other forms of redundancy do not exist. Specific provision made by the bidder in his protection schemes, for proper initiation of LBB protection, shall be stated in the bid. One way of this could be by providing separate auxiliary relay in parallel with trip unit and using contacts of these for LBB initiation.
- d) One set of local breaker failure protection for each circuit breaker connected to incoming generators, bus bars & outgoing feeders shall be supplied and is to be connected in the secondary circuit of the CTs associated with that particular breaker. It would be preferable to integrate the breaker failure protections for incoming lines, bus-bars & outgoing feeders, but it should also be possible to arrange them separately.
- e) Signals initiating the breaker failure protection shall be stored for such time as is sufficient for its operation.
- f) When start signal occurs, the no. of phases for which the breaker failure protection shall trip all the circuit breakers feeding the fault current without time delay are given as under:
 - Single phase for all the circuit breakers on the 400 KV transmission lines when line circuit breakers are employed for single phase auto-reclosing.
 - Three phase for all circuit breakers on the 400 KV transmission lines when the line circuit breakers are employed for three-phase auto-reclosing.
 - Three phase for the circuit breakers of bus bars and incoming lines from generating units.
- g) Current level detectors shall be set as sensitive as the main protections. The settings employed for lines and generators shall be stated in the bid.

However for low energy faults like buchholz relay operation, special consideration may be given to ensure scheme operation by using CB contact logic in addition to current detectors.

- h) Whenever used in combination with bus bar protection scheme, tripping logic of the same shall be used for LBB protection also.
- i) Separation shall be maintained between the protective relay and CB trip coil DC circuit so that short circuit or blown fuse in the CB circuit would not prevent the protective relay from energising the LBB scheme.
- j) The breaker failure protection shall respond to all kinds of faults within the range of RMS values of periodic components of the primary current from operating current to 40 kA including possible transients & aperiodic components.
- k) The event recording facility, which records all digital inputs to the terminal, all outputs, internal fault signals shall be provided in the breaker failure protection scheme.
- l) Breaker Failure protection panel shall be equipped by considering at least 1 bay as spare. It shall be equipped with all tripping relays & auxiliary relays and measuring equipments.

9.12.8 DIFFERENTIAL PROTECTION OF 400kV XLPE CABLES (87-I, 87-II)

- a) The scope of supplies covers 2 sets of protections for XLPE cables for each of the two outgoing feeders.
- b) The current circuits of the protection scheme shall use FRLS cables with copper cores 6 mm² in section.
- c) Rated current is 1 A/5A.
- d) Cable differential protection shall be provided for protected zone of cables for fast, selective and sensitive protection.
- e) The protection function shall be of numerical biased differential type. The protection shall take care of C.T. mismatch & shall ensure sufficient compensation for errors that might be introduced as a result of asymmetric CT saturation & thereby providing high insensitivity to external faults.
- f) The protection function shall provide high insensitivity to external faults.
- g) The minimum differential current required for operation should be adjustable. The range of adjustment should be indicated in the bid.
- h) The operating time of the relay shall be of the order of 30-40 m sec. for a fault current equal to three times the rated current. Operating time of the relay offered by the bidder shall clearly be indicated in the bid.

- i) The provision shall be made for monitoring the health of the current circuits and the elements processing the differential currents of each phase.
- j) The relay shall have facility for event recording, fault recording & disturbance recording, it shall also have online measurement of the phase, differential and bias currents and comprehensive self checking feature including the analog input circuitry & the elements processing the differential currents of each phase.
- k) Thermal overload protection shall be provided.

9.12.9 400 kV FEEDER PROTECTION

- 9.12.9.1 Each line shall have two independent high speed main distance protections namely Main-I & Main-II & shall operate on different operating principles. It is proposed to use numerical relays for Main-I protections schemes and Static modular type relays for Main-II protection.
- 9.12.9.2 It shall also be possible to have single as well as three phase auto reclosing from both Main-I & Main-II protections. In addition to the above for both Main-I & Main-II protections schemes, each line shall also be protected against overvoltages.
- 9.12.9.3 The relays should not be affected by CT saturation and CVT transients. It shall be ensured that no additional delay in relay operating time is created intentionally to have stable operation.

9.12.9.4 Main-I Protection

Distance Protection (21L1)

- i) Fully numerical distance protection terminal, suitable for use with any communication scheme (permissive under-reach, over reach, blocking), shall have facility for connection to the Computerised Control System (CCS) being procured separately by the purchaser.
- ii) The distance relay shall be carrier aided non-switched type with separate measurement for phase-to- phase , phase-to-earth faults & power swing detection. It shall be multi signal processor scheme with simultaneous phase to phase & phase to earth loop impedance measurement with individual numerical measuring loops for each type of fault & each distance zone to ensure reliable and fast fault detection. The memory voltage for proper directional discrimination at close-in three phase faults shall be based on positive sequence voltage.
- iii) The relay shall have stepped time-distance characteristic with three forward zones and one reverse looking zone (meant for carrier blocking scheme). It shall have directional (mho or quadrilateral or other suitably shaped) characteristics for zone 1, zone2 & zone 3 with a facility to adjust resistance and reactance independently to cater for arc resistance and load discrimination for long lines. Details of quadrilateral / polygonal characteristics utilised for this purpose shall be indicated in the offer. It shall be possible to set the resistive reach separately for phase to phase and phase to earth faults for each zone. All adjustment and selection of configuration shall be possible through a friendly menu

structured Man Machine Interface unit on the front of the relay. The relay shall have the simultaneous communication access to the remote monitoring stations and operator control stations.

- iv) The relay shall be provided with a facility to set zero sequence compensation individually for all the zones in case of single phase to earth faults to cater for protection of multi circuit parallel lines. It shall have a facility to select main and alternate reach settings to cater for mutual coupling on account of multi circuit line conditions. If necessary, out of step tripping relays shall be provided for isolating the system during disturbances.
- v) The relay shall have built in Disturbance Recorder and shall provide the user with complete information on the last twenty disturbances locally and remotely with atleast 250 time tagged events for each disturbance. Local Man Machine Interface / communication should be based on a user friendly menu structured programmes and performed via a permanently installed man machine communication unit, type tested with the line protection. Performance certificates & type test certificates of MMI would need to be furnished alongwith the bid.
- vi) It shall have facility to store the values of prefault & post fault currents & voltages for fault analysis purposes & the same shall be displayed on the MMI. Remote communication for the purpose of parameterization & reading service values should be available. Any additional software & hardware, if required, shall be included in the bid.
- vii) The relay
 - a) Shall have excellent possibilities of ensuring extensive combination of different optional functions. The relay shall employ the technique of numerical filtering and metering in order to ensure correct performance during CT saturation and CVT transients. The relay shall have extensive self supervision and self-diagnostic features. These should be presented on a user friendly menu structured Man machine Interface (MMI).
 - b) The relay shall have sampling rate of atleast 2000 Hz (40 samples/cycle).
 - c) The relay shall operate instantaneously when circuit breaker is closed on to a fault.
 - d) It shall be suitable for single and three phase tripping.
 - e) The necessary high speed trip relays for single and three phase trip (having adequate contacts to meet the complete scheme requirements) shall be incorporated in this protection.
 - f) It shall include fuse failure protection to monitor all type of fuse failure and associated cables against open circuit. This shall inhibit tripping and initiate annunciation. However, it is necessary that the fuse failure blocking shall be disabled in the event of a single phase to ground fault.

- g) The bidder shall give his view regarding provision of Stub protection and the relay with this feature should be provided if the bidder considers the same necessary.
- h) The relay shall include weak-end-infeed logic and current reversal logic.
- i) It shall include open-conductor detection logic.
- j) The relay shall have suitable number of potential free contacts for carrier aided tripping, auto reclosing, event recorders and data acquisition system.
- k) The relay shall have a operating time less than 30 ms. and the operation of the relay should not be affected by CVT transients.

9.12.9.5 Main II Protection

Distance Protection (21L2)

The detailed description of Main-II protection shall be same as that of Main-I protection, but the relay used shall be based on separate platform.

9.12.9.6 **Overvoltage Protection (59 L1, 59L2)**

The relay shall have following features:

- Have a high drop-off to pick-up ratio greater than 95 percent.
- Have adjustable setting range for voltage and time.
- Have two stages.
- Low set stage shall monitor any one phase to phase voltage and shall have associated timer. It shall have an adjustable setting range of 0.5 to 5 seconds.
- High set stage shall monitor all three phase to phase voltage and shall have associated timer. It shall have an adjustable setting range of 2 to 20 seconds.

The protection devices responding to voltage rise above 110-130% of the nominal value as and when required, shall have the provision for controlling magnitude and direction of reactive power on transmission lines. These devices shall trip concerned line breaker(s), start LBB, block auto reclosure and send direct trip command.

9.12.9.7 **Auto reclosing relays for 400 KV lines (79L)**

Auto reclosing relays for each of 400 KV lines shall have the following features:-

- i) Micro processor based design having single phase & / three phase reclosing facilities.
- ii) High speed single shot features.
- iii) Continuous self supervision features.
- iv) Input to the auto reclosure for breaker ready signal and breaker status.
- v) Continuously variable single phase dead time.

- vi) Continuously variable three phase dead time.
- xvii) Continuously variable reclaim time.
- xviii) Facility of selecting single phase / three phase / single and three phase auto-reclose and non-auto reclosure modes.
- xix) Facilities for selecting check synchronising or dead line charging features.
- xx) Provision of suitable relays for synchronism check and dead line charging in the overall auto-reclose scheme.
- xxi) User friendly Man Machine Interface for setting different times of auto reclosures.
 - Fast simultaneous tripping of the breakers at both ends of faulty line is essential for successful auto-reclosing. As such necessary provision shall be made for communication of signals to protection signaling equipment.
 - Main-I and Main-II line protections shall start auto-reclose relay.
 - Following protections shall block auto-reclose relay
 - Breaker fail relay
 - O/V protection
 - Received direct transfer trip signals
 - Bus bar protection
 - Zone 2/3 Distance Protection
 - Carrier fail conditions
 - Circuit Breaker problems

9.13 TRIPPING LOGIC

All electrical protection shall be grouped under following groups.

1. Non-Electrical lockout faults / controlled action shutdown
2. Urgent Electrical Lockout Faults
3. Electrical Non- lockout faults.

9.13.1 Non Electrical Lockout Faults / Controlled alarm Shutdowns

The mechanical faults like turbine & generator bearing temperature “high” originating from turbine & generator side are covered under this group. The tripping of 400KV breakers of affected generator feeder is prevented till the turbine wicket gates reach the no load opening position. Normal stop operation of the unit shall also be affected through controlled action shutdown.

9.13.2 Urgent Electrical Lockout Faults

All urgent electrical faults shall initiate simultaneous tripping of 400 KV circuit breakers, Gen. Field breakers, unit auxiliary board circuit breaker alongwith shutdown of the turbine. Fault like differential protection, Stator earth fault protection, overall differential protection, restricted earth fault protections, generator transformer H.V. restricted earth fault protection, transformer buchholz protection etc are covered under this group.

The governor failure faults and machine over speed faults originating from the unit side are also covered under this group.

The manual emergency shutdown of the machine is also affected under this group.

9.13.3 Electrical Non-Lockout Failure

The faults like negative sequence, generator impedance back up etc. shall be covered under this group and shall only trip 400 KV breaker, field breaker & UAB breaker without shutdown of the turbine / Generator.

3 Nos. Master trip relays 86X (Controlled action shutdown relay), 86Y (Emergency shutdown relay) and 86 Z (Electrical shutdown relay) shall be provided. The signal contacts from those devices of Generator and Turbine will be, wherever required, multiplied in UCB and one contact of each fault signal will be given to Generator Relay Panel (GRP) to operate respective Master Trip relay. These contacts can be connected in parallel in UCB and a single group fault signal can be connected to GRP, to reduce wiring and number of input in GRP. Potential free contacts of Master Trip relays (86X, 86Y, 86Z) from GRP will be hardwired to individual device/UCB.

The following provisions shall be made:

- i) Master Trip relays (86X, 86Y & 86Z) with adequate number of potential free contacts. Typical total requirement is 12NO+6NC on each relay.
- ii) Adequate number of terminals/inputs for connecting trip signals from Unit Control Board (UCB).
- iii) One number potential free contact of each individual Trip and Non-trip alarm signals for connecting to Unit Alarm Panel (UAP) Provision of signal (potential free contact) to block dynamic braking in case of electrical faults in Generator.
- iv) Provision to block and de-block reverse power protection if synchronous condenser operation is required in future. Command signal (potential free contract) will be given from UCB for this operation.
- v) IEEE-C37-102-1995 guidelines shall be followed for the tripping logic of Unit Shutdown.

9.14 Distances to Fault Locator function

Built-in feature of numerical relay or separate fault locator function shall be provided for each of 400 kV feeders and shall be located in the respective feeder panels. This shall be capable of measuring location of fault and shall provide the following information:-

- Type of fault
- Phase of fault occurrence
- Distance to fault in terms of length

9.15 Disturbance Recorders (DR)-Detailed Requirements

Disturbance recorder shall be provided as separate unit also for Numerical type distance protection relay (Main-I). The disturbance recorder shall be microprocessor based and would be used to record the graphic form of instantaneous values of voltages & currents in all the three phases, open delta

voltage & neutral current, open or closed position of relay contacts and breakers during the system disturbances & power swing detection. Necessary auxiliary VTs, to generate open delta voltage, shall be supplied by the bidder. The bidder shall furnish a typical print out for the simulated conditions, on original paper alongwith the offer.

Each feeder shall have its own built – in disturbance recorder complete with on-line acquisition unit, restitution unit and a printer with a capacity of minimum 8 analog inputs and minimum 16 binary signals / bay or circuit. Acquisition unit shall acquire fault data and transfer them to restitution unit which shall process them on line and start the printer to give out the graphic form automatically when triggered by the fault sensors. Such disturbance recorder panels shall be placed adjacent to the protection panels of respective feeder.

DR system shall have following features:

- 1 Software Stability
The operation of the equipment shall be based on programme stored in non-volatile solid state memory. The programme shall be stable and no inadvertent change of programme shall occur.
- 2 Reliability
Large scale integrated circuits shall be used, as far as possible to reduce the number of components, inter-connections and the amount of wiring. The components used shall be subjected to strict quality control, which shall include screening of components by heat soaking and testing their functioning, prior to assembly.
3. Simplicity of Maintenance and Repair
The number and type of modules employed shall be minimum. The modules shall be of plug-in type and shall be easily accessible for maintenance and repair whenever required.
4. Immunity from the Effects of Hostile Environment
The equipment shall be designed to operate satisfactorily even when subjected to the effects of severely hostile electrical environment such as interference signals arising out of switching transients. The equipment shall be mounted in self-contained free standing cubicle and shall be of dust, vermin and rodent proof construction. Ventilation arrangements shall be provided if warranted by power dissipation level of the equipment. Tentative size and location of the cubicle in the GIS hall annexe and adjacent to protection relay panel of respective feeder shall be indicated in a sketch enclosed with the bid. Optical or special cables / converters etc, if required, shall be supplied by bidder.
5. Interface with PC
The DR should have an interface arrangement for transfer/storage of data to a PC through its serial port. Necessary PC, software, optical or special cables etc. shall be part of DR and should be included in the bid.

PC based user friendly, Disturbance Recorder Evaluation software shall be provided for the analysis and evaluation of the record data made available in the PC under DOS/ WINDOWS environment. The software features shall include, selection / amplification of time / amplitude scales of each analog and digital channel, calculations of max/min frequency, phase difference values, recording of max/min values of analog channel, group of signals to be drawn on the same axis listing / numbering of all analog / digital channels and values of current, voltage, frequency & phase difference at the time of fault / tripping.

6. Power Supply

Disturbance recorder equipment shall be suitable for operation from 220 V DC as made available by the purchaser at one point with voltage variation of +10% and -15%. Any other power supply that may be required for proper functioning of the equipment alongwith printer has to be derived by the bidder by his own equipments which shall form an integral part of the disturbance recorder system.

7. Alarms and Indications

All external and internal faults in the disturbance recorder equipment such as power supply fail, printer faulty, paper exhausted, processor / memory fail etc. are required to be indicated by means of light emitting diodes on the front of panels of the equipment. Necessary provision i.e., potential free contacts etc. as well as optical or special cables / converters, if any, shall be provided for communication of alarms & recording of events in computerised control system.

8. Technical Parameters of Recording, Scanning & Channels

- Sampling Rate : 1KHz
- Recording band width : 5-250 Hz
- Voltage Channel
 - Dynamic range 0.01 to 2 x Nominal Voltage
 - Resolution 0. 1%
- Current Channel
 - Dynamic range with full DC offset
 - 0.01 to 60 x Nominal Current

9. The equipment shall have inherent starting sensors based on over voltage, rate of change of current and rate of change of frequency. These starting sensors, when activated shall start the disturbance recorders to give out the graphic form of analog and event signals. Preserved fault data shall not get erased unless operator erases them manually. Erasing arrangement shall be provided in the restitution unit.

10. Pre-fault and Post-fault Time

Pre-fault recording time shall not be less than 100 ms and the post fault recording time adjustable at a minimum of one secs. & a maximum of not more than 5 seconds. If another system disturbance

occurs during one post fault run time the recorder shall also be able to record the same.

11. Amplitude and Event Resolution

Amplitude resolution shall not be less than 8 bit. Event resolution shall be 2 ms or better.

12. Print out

The print out shall contain the following:-

- Feeder identity
- Date and time (in hour, minutes and seconds upto 100th of a second).
- Identity of trigger source
- Graphic form of analog and event signals of all the channels.

The print out shall be clear and legible without the help of magnifying glass or any such devices. Minimum acceptable paper width shall be 8-1/2 inches (216mm approx.).

13. Type and Quantity of Paper

- Printer shall use plain paper
- The bidder shall provide 10 packets of Z-fold paper. Each packet shall have 500 sheets.
- The arrangement of feeding and removing paper rolls shall be quick and simple.

14. Time Generator

Each disturbance recorder shall have its own time generator. Time generator of any one of the disturbance recorder can be taken as master and facility shall exist to synchronise the time generators of other disturbance recorders and event loggers in that station with respect to it. The recorder shall give annunciation in case of absence of sync. pulse within a specified time. The clock of the time generator shall be such that the drift is limited to ± 0.5 seconds / day, if allowed to run without synchronisation. Facility shall exist to display the time in hour, minutes and seconds on the front of panel. Provision of potential free contacts, supply of all necessary optical or special wiring, converters etc shall be made for annunciation of alarms & recording of events in computerised control system as well as interconnections with other event recorders, event recorders as indicated above. It shall be possible to synchronise the DR with the facility of satellite time synchronization being arranged separately by prospective CCS supplier.

15. Inputs

The equipment shall be suitable for inputs from current transformers with 1A/5A rated secondary and capacitive voltage transformers with 63.5 V (phase to neutral voltage) rated secondary. Any additional device required for processing of input signals in order to make them

compatible to the equipment shall form an integral part of the equipment. However such processing of input signals shall in no way distort its waveform. The equipment shall be carefully screened, shielded, earthed and protected as may be required for its safe functioning. The input circuits shall withstand the following tests.

- 5 kV impulse test (as per IEC-255 Part-IV)
- High frequency disturbance test (as per IEC – 255 Part-IV).

9.16 TRIPPING MATRIX

9.16.1 General

The tripping matrix to be provided for each Protection group shall be programmable & in the form of logic arrays having an integral AND OR structure. Necessary coordination with the suppliers of Turbine-Generator & associated auxiliary equipments, 420 kV SF₆ GIS, Generator transformers & associated auxiliary equipments, outgoing feeders, CCS, etc. for the purpose of alarm, tripping, annunciation shall be the responsibility of the bidder. Tripping matrix logic for Unit shutdown order, bay CB tripping order etc. logic shall be as per IEEE-C37-102.

9.16.2 Matrix Inputs

Adequate number of matrix input signal channels (logic inputs) shall be supplied for mixing of the protective relay orders with other internal or external signals (such as from Buchholtz protection, pressure or temperature protection, vibration, etc). The details shall be worked out by the contractor in consultation with suppliers of other systems / purchaser at detailed design stage.

9.16.3 Matrix Outputs

- Adequate number of tripping outputs (channels) shall distribute the protection relay tripping signals to the corresponding tripping circuits. The details shall be worked out by the contractor in consultation with suppliers of other systems/purchaser at detailed design stage.
- It shall be possible to change or reprogramme the matrix at any time.
- The software tripping matrix shall be continuously supervised.

9.17 REDUNDANCY IN PROTECTIONS

- 9.17.1 All the protection functions specified and any additional included by the bidder shall be subdivided into two systems each being independent and capable of providing uninterrupted protections even in the event of one of the protection systems failing. The relays shall thus be electrically and physically segregated into two systems. Grouping shall be done to the extent possible in such a way that each systems shall independently carry out protective functions with near equal redundancy. All the duplicated protection functions shall have independent CT/PT inputs. Interconnection between these two systems shall not generally be attempted. However, if found absolutely necessary such interconnectors shall be kept to the bare minimum. D. C. supply for the two systems shall be made available from two sets of DC sources with automatic changeover between the two supplies. The protections

functions are proposed to be configured as per the following independent systems:

System I:

87 G1	Generator Differential Protections
87 T	Generator Transformer Differential Protection
64S1, 59 NS1	100 percent Stator Earth-fault Protection & 95% Stator Earth-fault Protection
64 R	Rotor Earth-fault Protection
46G1	Negative Phase Sequence Current Protection
32 G1/37G1	Generator Reverse-Forward Power & Low forward power Protection
49 S1	Stator Thermal Overload Protection
49 R	Field Winding Overload Protection
21 G1	Generator Backup Distance Protection for External Faults
24 T1	Generator Transformer Over-fluxing Protection
50/27	Dead Machine Protection
78 G1	Pole Slipping Protection
40 G1	Loss of Excitation Protection
51G1	Over currents / Earth fault Protection of Generator in Synchronous mode
51V	Inverse time O/C protection for generator
59G1	Generator Over voltage Protection
27 SC	synchronous condenser modes
27G1	Generators Under Voltage
51 NGT1	Current Protection at Single-phase Earth-fault in 400 kV Side
26X GT	Receiving/Inter tripping Circuits of Generator Transformer Temperature Detectors
87 N1	Restricted Earth fault Protection for Generator Transformer,
50 ET1	Current cut off Protection for Excitation Transformer
51 ET1	Over-current Protection for Excitation Transformer
50 IT	Current cut off Protection for independent Excitation Transformer on both LV & HV
51 IT	Over-current Protection for Independent Excitation Transformer on both LV & HV
51 N IT	Earth-fault Protection for Independent Excitation Transformer on LV.

51 NG IT	Standby Earth-fault Protection for Independent Excitation Transformer
60-1, 60-2	Voltage balance scheme or VT Circuit failure protection.
87 SST	Station Service Transformer Differential Protection
26X SST	Receiving/Inter tripping Circuits of Station Service Transformer
	Temperature Detectors Other Protections as specified/required
59 N	Monitoring of Insulation of LV Bushing for Generator Transformer
51 NGS	Earth-fault Protection for Station Service Transformer
50 U	Current cut off Protection for Unit Auxiliary Transformer on both LV & HV
51 U	Over-current Protection for Unit Auxiliary Transformer on both LV & HV
81 U/O G1	Under/Over Frequency Protection
95 G1/51G1	Split phase with O/C Protection
50 NU	Earth-fault Protection for Unit Auxiliary Transformer on HV
51 NU	Earth-fault Protection for Unit Auxiliary Transformer on LV

System II:

87 G2	Generator Differential Protections
40 G2	Loss of Excitation Protection
64S1, 59 NS1	100 percent Stator Earth-fault Protection & 95% Stator Earth-fault Protection
32 G2/37G2	Generator Reverse-Forward Power & Low forward power Protection
49 S2	Stator Thermal Overload Protection
51G2	Over currents / Earth fault Protection of Generator in Synchronous mode
46G2	Negative Phase Sequence Current Protection
21 G2	Generator Backup Distance Protection for External Faults
59G2	Generator Over voltage Protection
27G2	Generators Under Voltage
81 U/O G2	Under/Over Frequency Protection
78 G2	Pole Slipping Protection
95 G2/51G2	Split phase with O/C Protection
50 ET2	Current cut off Protection for Excitation Transformer
51 ET2	Over-current Protection for Excitation Transformer

87OA	Over-all Differential Protection
87 N2	Restricted Earth fault Protection for Generator Transformer,
24 T2	Generator Transformer Over-fluxing Protection
51 NGT2	Current Protection at Single-phase Earth-fault in 400 kV Side
81 SC	under Frequency Protection under SC Mode.
24	Generator Transformer Over-fluxing Protection
98 GT	Monitoring of HV. Bushing Insulation Device at Transformer H.V. Terminal
51 GT	Generator Transformer backup Over current Protection
63X GT	Receiving/Intertripping Circuits of Generator Transformer Gas Protection
50 S	Station Service Transformer cut off Protection on both LV & HV
51 S	Station Service Transformer Overcurrent Protection on both LV & HV
27S	Under Voltage Protection for SST
51N SST	Earth Fault Protection for SST on LV
50N SST	Earth Fault Protection for SST on HV
51 NGU	Standby Earth-fault Protection for Unit Auxiliary Transformer
63X SST	Receiving/Intertripping Circuits of Station Service_Transformer Gas Protection
64RS	Restricted Earth fault Protection for Station Service Transformer
60	Voltage Balance Scheme or VT Circuit Failure Protection
50 Z	Local Breaker Backup Protection
87B	Differential protection between HV bushing of GT & Bus Bar
87 RU	Restricted earth fault Protection for Unit Auxiliary Transformer
49 UAT	Unit Auxiliary Transformer overload Protection
27 U	Under Voltage Protection for UAT
87 N IT	Restricted Earth fault Protection Independent Excitation Transformer
50/27	A separate relay to be provided for dead machine protection.

9.17.2 Generating Unit Bay Protection at 400kV Side

System-1

Circuit breaker back up protection
GT restricted earth fault protection

System-2

Over current protection

- 9.17.3 Bus bar protection
- System-1**
- Bus bar differential protection & circuit breaker backup protection for Bus-1 and Bus-2 (87A1/87B1)
- System-2**
- Bus bar differential protection & circuit breaker backup protection for Bus-1 and Bus-2 (87A2/87B2)
- 9.17.4 Bus- Coupler protection
- System-1**
- Over voltage protection
- Earth fault protection & circuit breaker backup protection
- Over current and circuit breaker backup protection
- System-2**
- Over voltage protection
- Earth fault protection & circuit breaker backup protection
- Over current and circuit breaker backup protection
- 9.17.5 400 kV XLPE cables protection
- System-1**
- Circuit breaker back up protection (87A1/87B1)
- 400kV cable differential protection
- System-2**
- Circuit breaker back up protection (87A1/87B1)
- 400kV cable differential protection
- 9.17.5 Transmission line feeder bay protection.
- System-1**
- Distance relay protection (21) for line-1 Main-1
- Distance relay protection (21) for line-2 Main-1
- Local breaker failure protection 50Z
- Over voltage protection (59)
- Directional earth fault (64) protection
- System-2**
- Distance relay protection (21) for line-1, Main-2.
- Distance relay Protection (21) for line-2, Main-2.
- Overvoltage protection (59)
- Directional earth fault protection

- 9.17.6 In addition to above out of step blocking relays (78), separate disturbance recorder, fault locator and spares etc. shall be provided.

The distance relay shall also include built in disturbance recorder and out of step blocking (power swing blocking) facilities, auto-reclosing function, check synchronizing and dead line charging facilities.

9.18 RELAYS

Relays shall be suitable for flush or semi flush mounting on the front with connection from rear. All relays shall be designed for operating under an ambient temperature. Guaranteed & Technical Particulars of various relays may be furnished by the bidder as per Annexure-I.

9.19 SETTING CALCULATIONS

The contractor shall calculate during the detailed designs the setting values of all protection relays covered under this section and submit detailed calculations for each protection functions to purchaser for approval. During erection and commissioning, the contractor shall adjust all relays in accordance with approved drawings and system requirement.

9.20 TESTS

General

- 9.20.1 The protection systems shall include a built-in testing facility capable of testing the protection functions from the terminal inputs of primary system VT and CT circuits and the output tripping terminals. The test facility shall be manual as well as automatic. The automatic testing of the system must include such interlocks which are necessary to ensure that the machine / equipment are protected while testing is being carried out. The testing facility shall also be performed by a menu guided program within the MMC.

- 9.20.2 Means for simple functional checks of the relay circuit, tripping logic and auxiliary tripping relays shall be provided.

- 9.20.3 The analog measured values of the protection functions shall not only be internally processed, but also externally visible. The following minimum features shall be provided

- a) Display of measured values

This shall be achieved by using the serial interface and personal computer and displayed on integrated operator panel.

- b) Event recording

The measured values of protection function shall be stored as an event at the moment of its trip with relative time-tagging. Events shall also be stored in the sequence of event recorder supplied by computerised control system supplier. Necessary cables / lugs / converters etc for this purpose shall be in the scope of supply of the bidder.

c) Disturbance recording

The measured values of protection function shall be stored as either raw data or as magnitude and phase data. The raw data shall be sampled at 12 samples per electrical cycle. Disturbance recorder shall store pre-fault and post-fault data. All optical or special cables / lugs / converters etc as required, shall be supplied by the bidder.

9.20.4 Digital Self Monitoring and Testing

9.20.4.1 Each relay of the protection system shall be provided with self-supervision and diagnostics, which shall be continuously active. When a defect occurs and correct operation of the protection functions cannot be guaranteed, malfunctioning of protection function shall be immediately detected and alarm given.

9.20.4.2 The self-monitoring and testing facilities shall be divided into following routines

- a) Self-monitoring of the hardware.
- b) Cyclically executed testing routines by means of the software.
- c) Viewing of the system protection parameters and analog inputs and digital input/output signals through the PC.
- d) Injection testing with separate test equipment.

9.20.5 Manual Injection Testing

9.20.5.1 A 100% test of the protected system shall be carried out by injection test of analog voltages, currents and time, using injection testing equipment. All required injection testing equipment shall be supplied by the bidder.

9.20.5.2 The connection terminals shall enable primary system VT circuits to be interrupted and primary system CT circuits to be short circuited.

9.20.6 Automatic Testing Equipment

9.20.6.1 The automatic testing facility shall test each of the protection relays in turn and be capable of measuring all the pick-up values, phase relationships of all the analog inputs and time delays. The testing values shall be printed out by a printer. All test values shall be communicated to computerised control system for display, event recording etc. Necessary optical or special cables / connectors / converters etc. as required, shall be supplied by the bidder.

9.20.6.2 The accuracy of the measurement performed by the automatic testing must be not less than ± 0.1

9.20.6.3 The automatic testing set shall have the additional facility of comparing the measured values with a stored record of the actual settings.

It shall have high resolution in built digital clock.

A fully electronic relay test set with independently variable current and voltage amplifiers allowing differing ramps and independent setting for each phase. The amplitude, phase and frequency of each output signal should be independently controllable and adjustable from the software. The relay test set should be suitable for testing both numerical/static relays and equipped with binary inputs for tripping times. Calibrations at site by user if desired should be possible.

Detail

- 3 current ranges : continuously adjustable from 0 to 40A (without using any external amplifier) with $\geq 175\text{VA}$ AC/DC
- 6 current ranges : continuously adjustable from 0 to 25A with $\geq 90\text{VA}$ AC/DC.
- 1 current range : continuously adjustable from 0 to 75A with $\geq 400\text{VA}$ AC/DC.
- 4 voltage ranges : continuously adjustable from 0 to 300V output power $\geq 70\text{VA}$ AC/DC.
- 1 voltage range : continuously adjustable from 0 to 600V output power $\geq 150\text{VA}$ AC/DC.
- Accuracy 0.1% of each range.
- Distortion. 0.1%.
- Frequency range 0 to 2500Hz.
- Possibility to measure one phase for transducer testing.
- Current (0-20) mA
- Voltage (0-10) V
- 12 Binary inputs
- 3 Binary outputs
- 6 Analog inputs
- Units should be capable of generating low level signal outputs (voltage)
- The complete unit with laptop PC

Software

- Latest Windows
- This system shall be computer driven and shall have necessary software for advanced and fully automatic testing of IT relays, distance relays, sync. Relays, Diff. Relays and for the generation of fault conditions using COMTRADE files as well as creation of special signals.

9.20.7 Factory Tests

9.20.7.1 General

All tests shall be conducted according to the standards mentioned in these specifications and other relevant standards and as far as serial equipment is concerned, according to the established testing procedures of the manufacturer. Prior to the commencement of these tests, the contractor shall submit a detailed programme to the purchaser for approval. Detailed records, including all details of tests performed and results obtained shall be prepared by the contractor. A comprehensive list of the tests proposed to be carried out shall be submitted to the purchaser alongwith the offer. The supplier shall furnish all the type and routine test certificates to the purchaser/consultant

for approval. No equipment shall be despatched before approval of drawings / test certificates by the purchaser.

9.20.7.2 Type Tests

The complete type test certificates and data sheets for all serial equipment shall be submitted. If the same are not to the satisfaction of the purchaser, the tests which are missing shall be performed by the manufacturer at his own expense to the full satisfaction of the purchaser.

9.20.7.3 Routine Tests

- These tests must include material tests and tests during manufacture as per relevant standards and / or the manufacturer's established practice. However, for electronic modules, equipment and individual component's burn-in tests, temperature and voltage stress tests shall also be performed.
- Routine testing shall be by automatic process, wherever practical, in particular for wiring testing.
- On complete apparatus the routine tests, specified in the applicable standards, shall have to be performed.
- The manufacturer shall furnish details of an established Quality Assurance Plan, at his works, for the approval of the Purchaser.

9.20.7.4 Specific (sample) Tests

The following specific tests performed on various (sample) equipments, shall be witnessed by the purchaser:

- a) Corrosion protection test at random on all equipment
- b) Functional, damping, response and accuracy tests at random on all measuring, metering and recording instruments.
- c) Dielectric and interference tests on all equipment at random and where applicable.
- d) Functional tests of all equipment where applicable. These tests may be simulated by means of testing apparatus.

9.20.8 Site Tests

9.20.8.1 At site, the following tests shall be carried out:

- a) Checking of cabling between apparatus by the contractor, prior to acceptance tests. Written evidence shall be produced for these tests. Random checks shall be made in the presence of the purchaser.
- b) Measurement of the insulation resistance to earth of the various protection and power circuits, including cables and apparatus wherever practical & feasible.

- c) Checking of all relay settings shall be in accordance with the calculated values and afterwards primary injection tests by introducing artificially created fault wherever feasible. Carrying out testing with testing apparatus (simulated method) including primary checking of all tripping circuits. Subsequently carrying out testing of each protection relay by automatic testing equipment and taking out print out for tested values for the purpose of comparing the measured values with stored records of the actual settings.
- d) Operational checks of all control, signaling and interlocking equipment for complete conformity with designed data.

9.20.8.2 Prior to the commencement of these tests, the contractor shall submit a detailed programme to the purchaser for approval. Detailed records, including all the details of tests performed and results obtained shall be furnished by the bidder.

WARRANTY

Warranty of the complete system including hardware & software shall be minimum 2 years from the date of handing over the system to the owner. During the warranty period any spare/items/consumables required for trouble free operation and maintenance of the system shall be provided free of cost.

9.21 EQUIPMENT / SPARE PARTS

Mandatory Equipment / Spares

The scope of supply shall include all the following spare parts and equipments. These mandatory spares are considered to be sufficient for normal operation of equipment for 5 years. In case the bidder does not consider the given list of mandatory spares as adequate, he may quote additional spares in the recommended spares list.

Spares for protection system:

Protection Relay Unit of each type	One (1) set
Input/Output unit of each type	Two (2) sets
Trip matrix unit	Two (2) sets
Auxiliary relays	Four (4) of each type
Timer	Two (2) of each type
Indication lamps	20% of each type
Control switches, MCB, selector	Two (2) of each type
Switches & push buttons	
Transducers	20% of each type
Meter	One of each type
Fuse	Ten of each type
Analog input module	Two sets of each type
Power supply module	Two sets of each type
Process module	Two sets of each type
Tripping relay	Four sets of each type
Trip circuit Supervision relay	Four sets of each type
Connectors, labels, marking strip etc.	10% of each type
Ethernet switches	Two sets of each type

FOC convertor	Two sets of each type
Special tools and tackles	One set of each type required.

One set of Disturbance Recorder and one set of Secondary injection Relay Testing kit complete with timers etc. is to be supplied.

9.22 Recommended Spares

9.22.1 Apart from above mandatory spares, the spare parts list shall include other spares recommended by the bidder for each individual protection relay and hardware modules for the complete protection system. Recommended spares for all optical or special input & output cables to / from protection panels – including cable lugs / connectors / opto- converters, etc-shall also be included.

All other recommended spare parts required for maintenance during five year period and spares to meet strategic breakdown should be included by the bidder in this list.

9.22.2 The bidder is required to furnish the list of recommended spare parts in the prescribed schedule as per **Annex-II**.

9.23 GUARANTEED & TECHNICAL PARTICULARS

The bidder shall furnish the guaranteed and technical particulars as per **Annexure-I** enclosed with the tender document.

9.24 SCHEDULE OF REQUIREMENTS

9.24.1 Protection Equipment for each Unit

- Relay cubicles (glass door) for each of unit 1 & 4 complete with protections for the generators, generator transformers and transformers for excitation, unit auxiliaries & station service as per various protective devices (Cl. 9.5) and other provisions in the specifications
- 2 sets
- Same as above for each of unit 2& 3 but without the protections for station service transformers
- 2 sets

9.24.2 Protection Equipment for SF₆ GIS

Relay cubicles each for Main-I & Main-II including LBB protections for Bus-bars as per various protection devices (Cl. 9.5) and as detailed in other specification clauses
- 2 sets

9.24.3 Protection Equipment for XLPE Cable

Relay cubicles for Main-I & Main-II protections for XLPE cables as per various protection devices (Cl. 9.5, 9.12.9.4 & 5) and as detailed in other specification clauses
- 2 sets (one set for each circuit)