

VOLUME-2
PART- I
Section-9
Protection System

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9. Protection System

9.1 Intent of Specifications

The intent of these specifications is to define and cover the scope of work under this section which includes the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, storage at site, erection, acceptance testing, commissioning, performance testing, handing over to Purchaser trouble free operation of complete Protection System for Keyi Hydro Electric Project, Arunachal Pradesh as per the specifications hereunder, complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation.

It is not the intention to specify the minute details/smallest items to deliver a functional system or to define the standard manufacturing practice but to outline the performance, constructional, operational and guaranteed requirements. It is the responsibility of the contractor to ensure these requirements.

9.2 Scope of Supply

9.2.1 Generator Protection System

- Set of Multifunction, microprocessor based Numeric type protection relays, multifunction meters, lockout relays for trip functions, other devices mounted on standard rack cabinet along with necessary devices for following:-
 - Two (2) generators (main and back-up)
 - Two (2) step up generator transformers (main and back up)
 - One (1) outgoing 132kV feeders (main and back up)
 - Two (2) 11/0.433 kV step down transformer circuit
 - 11 kV Switchgear panel board protection
- Interfacing, coordination and provision of necessary contacts and/or ports for integration with plant SCADA system.
- Spare parts.
- Special Tools, if any.

9.2.2 Services

- Transportation and delivery to site including all logistics and proper site storage and preservation as per manufacturer's recommendation.
- Relay setting and testing
- Site installation and commissioning
- Consumables as required during erection
- Field / touch-up painting including all painting materials

- Performance and field acceptance testing as per the relevant clause of this section and submission of report
- Training of Purchaser's personnel including operation and maintenance staff
- All the technical documentation including preparation and submission of O & M manuals

9.3 Specific Parameters and Layout Conditions

9.3.1 Layout and General Arrangement

Protection shall be provided through relays, which shall be Numeric type protection relays.

The protection for 415 V feeders from station Auxiliary transformers has been covered in respective sections of specifications and is not covered in this section. All required protection system for 110V DC system shall be supplied along with DC system and is covered in the referred section. The Designer of protection system shall, however, co-ordinate for making all necessary provisions and operation of the protection covered in other various sections.

All required protection system for DG set shall be supplied along with DG set. The Designer of protection system shall, however, coordinate for making all necessary provisions.

The detailed scope of supply given in relevant clause is indicative only. However, all protection as per relevant IEC standards shall be provided in accordance of the capacity of this size of the machine.

The transmission line bays shall have distance protection. The distance protection relays should have built in over current and earth fault protection functions.

A single line diagram of the main electrical equipment of the power plant and its protection scheme is shown in the tender drawings. The requirement of number of current transformers may need to be examined and reviewed in view of the installation of latest state of art protection relays proposed to be installed. The relays / protection system shall be of latest art of technology on the date of supply.

All the relays shall be of reputed make with proven performance. The relay must be in operation for at least three years in three power plants in equivalent voltage level substation.

In accordance of above, the type of protection shall have to be got approved from the Purchaser before supply / despatch. The contractor shall certify for availability of spares at least for 10 years from the scheduled date of commissioning.

Tripping signal from protection relays shall be hardwired for shut down of machine and tripping of circuit breaker and shall be in the scope of the contractor.

The Contractor has to revise/upgrade the system during detailed engineering if the offered system does not meet the entire requirement. The system should be state of art/latest model available at the time of supply. If the protection system mentioned in the awarded contract becomes obsolete at the time of supply, the Contractor shall offer a latest model without any extra cost to Purchaser.

9.3.2 Time synchronisation

All relays, disturbance recorders, event recorders etc. shall be time synchronised through universal time synchronisation system as described in "Computerized control and monitoring (SCADA) System". The contractor shall co-ordinate in this regard.

9.3.3 Rating and Functional Characteristics

The system shall provide a high degree of selectivity and discrimination between faulty and healthy circuits. A microprocessor based modular system associated with a human machine communication interface shall be preferred.

All devices shall remain inoperative during internal faults and transient phenomena. They shall be insensitive to mechanical shocks, vibration and external magnetic fields.

All relays shall be suitable for local and remote reset. They shall have self-monitoring facilities and LED status indication.

The relays shall be provided with the following information, suitably located:

- Function of relay,
- Phase identification,
- Main characteristics.

The protection system shall be divided into protection groups and subgroups. Each protection group shall consist of solid state numerical protection, auxiliary relays, tripping unit and all accessories as required.

The protection groups are defined as follows:

- Mechanical protection for the generating units
- Electrical protection for the generating units
- Transformer protection for the GSU transformers
- Station Auxiliary (Step down) transformers
- 132 kV Switchgear
- 132 kV transmission line protection

Each protection group shall be divided into two subgroups. The division shall be maintained throughout to the tripping coils and shut down solenoids. Each breaker and shut down device will be equipped with one tripping coils.

Entire protective equipment along with control equipment shall be installed in the control room.

The 132 kV outgoing feeder control panels shall also be provided in powerhouse control room.

9.4 Performance Guarantee

The Protection system along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability and performance of the individual equipment as well as of the complete system.

9.5 Design and Construction

9.5.1 Standards

The system and equipment shall be designed, built, tested and installed to the latest revisions of the following applicable standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose:

Standards	Description
IEC 60255	Electrical relays
IEC 60870-5-104	Tele-control equipment and systems
IEC 60044-2	Instrument transformers - Part 2: Inductive voltage transformers
IEC 60044-1	Instrument transformers - Part 1: Current transformers
IEC 60044-5	Instrument transformers - Part 5: Capacitor voltage transformers
IEC 60044-6	Instrument transformers - Part 6: Requirements for protective current transformers for transient performance

The Contractor shall submit for the Purchaser'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 relay circuits and performance calculations.

The relays shall conform to IEC 60850.

9.5.2 Relays

9.5.2.1 Relays Functionality

The relays shall have at least following features

- The relays used in protection system of generators, generator transformers & transmission line feeders shall be of the numerical type, microprocessor based, multifunction relays and shall be complete with lock-out and auxiliary relays to perform the protective functions described herein and as shown on the contract drawings. The relays including all ancillary devices, such as interposing transformers, tripping matrix, test facilities, power supply units, etc. with all circuits shall comply with IEC 60255 recommendation,
- All communications of protection system with the control system shall be based on universally accepted Protocol namely IEC 60870-5-104,

- The protective relays shall be panel flush mounted and installed in standard cabinets with glass doors in the front of panel to be located in the Plant Control room.
- All relays shall be set and bench tested at the factory.
- There shall be suitable no. of ports at suitable location in the protection relay for any change in settings/ downloading the data and interconnect the relays,
- The relays shall have preferably front panel back lit display,
- The multifunction microprocessor relays shall, as a minimum, have the following features:
 - Fully programmable protection functions and tripping schemes
 - Independent power supplies to be fed from power supply circuits
 - Output trip contacts rated as per IEEE C37.90 for tripping duty
 - Output alarm contacts
 - A target display indicating the status of each of the relay protective functions
 - Target storage, which shall include the last 32 targets with the following information:
 - Function operated, input/output contact status, time stamp, phase, and neutral currents at the time of trip.
 - An inbuilt disturbance recorder (DR) and event recorder
- The relay package shall include extensive self-testing with an alarm indication of a self-test warning or failure.
- DR shall have at least 8 Analogue and 16 Digital channels with a scan rate of minimum 1000 Hz.
- In addition to inbuilt disturbance recorder the distance relays shall have features of fault distance locator, MW, MVAR, current and voltage display recorder.

For certain functions, where numerical relays are not available, discrete relays may be acceptable subject to approval of purchaser.

9.5.2.2 Relay Settings

The Contractor shall be responsible for the computations and settings for the relays furnished under this Contract. The relay computations and settings shall be approved by the Engineer.

The Contractor shall be responsible for the calibration and verification of the relay settings in the factory and in the field.

9.6 Protection Functions

9.6.1 Mechanical / Electrical Protection

9.6.1.1 General

The mechanical protection for the generating units shall be connected to the relevant protective devices or sensors as described in the respective sections and upon mechanical failures shall trip the turbine-generator unit and annunciate alarms.

The mechanical protection shall consist of the necessary relays, as applicable, connected to one or a group of protection devices or sensors, and a tripping unit as described in design requirements.

The protection sensors and devices are described in the relevant sections and shall be wired to terminal blocks in different wiring cubicles.

9.6.1.2 Tripping functions

At least the following protection sensors and devices shall be used to shut down the generating unit:

- Very high temperature in bearing at DE, bulb thermometers,
- Speed supervision system,
- Electrical governor fault,
- Very low governor/inlet valve oil pressure, pressure switch,
- Very low oil level in governor/inlet valve pressure tank, level switch,
- Very high temperature in bearing at NDE, bulb thermometers,
- Very high temperature in Generator winding and core, temperature supervision system,
- Excitation system failure,
- Emergency stop push buttons,
- Starting or stopping time too long,
- Total cooling water flow too low, flow indicator Tripping shall be delayed 0–10 min., adjustable,
- Generator protection trip,
- Gen. Step up transformer protection trip,

Minimum five digital inputs shall be kept as spare for later use.

9.6.1.3 Alarm functions

All tripping functions described above shall in addition to the tripping, give alarm indication to the alarm annunciation system described in Supervisory Control and Data Acquisition System (SCADA) System” including:

- High temperature in bearing at DE,

- Low governor /inlet valve oil pressure, pressure switch,
- Low oil level in governor / inlet valve pressure tank, level switch,
- High temperature in bearing at NDE,
- High temperature in Generator winding and core, temperature supervision system,
- Excitation system in trouble,
- Low oil level in governor /inlet valve sump tank, level switch,
- High oil level in governor/ inlet valve sump tank, level switch,
- Low oil level in bearing at DE,
- High oil level in bearing at DE ,
- High temperature in generator transformer winding and oil,
- GSU/ SAT transformer Buchholz relay operated,
- Oil level abnormal GSU transformer,
- Generator transformer differential pressure alarm,
- Sudden pressure release,
- High temperature in winding of SAT,
- 5 Spares for digital inputs

9.6.1.4 Over speed

To prevent over speeding of the units when tripped upon mechanical faults, tripping of excitation breaker and generator circuit breaker shall only be effected after the load-rejection and wicket gates coming to no load opening position. Adequately located position switches or other equally suitable system separately wired to the protection cubicle shall be furnished. The protection scheme shall ensure field breaker tripping after GCB is tripped.

9.6.1.5 Starting of unit

The unit shall not be ready for starting unless confirming at least the following status:

- Locking pin of main inlet valve released,
- Locking pin of Guide vane servomotor released,
- Tail race gate open,
- Mechanical brake released,
- Bearings oil level normal,
- Cooling water system healthy,
- Governor oil pressure normal,
- Governor AC/DC supply healthy,
- All control and protection supply healthy,

- No protection is operated.

9.7 Details of Protection Systems

9.7.1 Generator protection - Two (2) Sets

9.7.1.1 General

Generator protection shall be provided through numeric type relays (main and back up). The relays shall have all the inherent characteristics like- Simplicity, Flexibility, Reliability, Selectivity, Stability, Accuracy, and Sensitivity. The relay shall be microprocessor based multifunction and shall be controlled by programs. The protection device shall have provision for human machine communications interface. The programs should be externally user-friendly for operation by the operator. It should prompt the user with messages and confirmations in order to guide the user and avoid errors or incorrect situations. Provision for transfer of sets of parameter settings etc. from and to removable disk/CD shall be kept.

The device shall have provision for communication with the station control system (SCADA) via an optical fibre link.

Protection system shall be divided into various functional groups electrical emergency shutdown, mechanical emergency shutdown, controlled action shutdown, lock out trip, non-lock out trip etc. depending on the nature of fault.

9.7.1.2 Protection Functions

One (1) multifunction microprocessor relays shall be provided for protection each generator. Each multifunction relay shall include as a minimum the following programmable functions:

- Generator Differential (87G)
- Voltage controlled over current (51V).
- Negative phase sequence (46G)
- Stator ground fault 95%
- Stator ground fault 100% Overvoltage (59G)
- Rotor earth fault
- Loss of excitation (40G)
- Voltage balance (60G)
- Generator Back up impedance protection (21G).
- Reverse Power (32G)
- Under voltage (27G)
- Over voltage (59G)
- Frequency (81G)
- Breaker fail protection

- Over speed Electrical(12E)
- Under Power (37)
- PT Fuse Failure (60)

The following protection functions not covered by multifunction relays, shall be covered by other discreet devices / relays and shall be covered by contractor in the scope of protection equipment if not included in the scope of the equipment specified in other sections.

- 71 Bearing oil level - Alarm & trip
- 38 DE and NDE bearing temperature - Alarm & Trip
- 26G Generator winding temperature - Alarm and Trip
- 49S Stator thermal overload protection - Alarm and trip
- Diode Failure
- Over Voltage
- Under Voltage
- Over Excitation
- Under Excitation

9.7.1.3 Generator Metering

One (1) set of multifunction meter for UCPP in control room shall be provided for each unit. The metering shall include following functions

- Current
- Mega Watt
- Mega Var
- Mega Watt-hour
- Power factor
- Frequency

9.7.1.4 Description of Generator Protection Functions

1. Generator Differential Protection (87G)

The generator differential protection function in multifunction relay shall be based upon the high impedance stabilizing principle to provide high absolute stability for through fault. This shall be highly sensitive for internal faults and operating time shall necessarily be very short to minimize the possible damage.

- Tripping Time Maximum 50 ms
- Setting range 10 to 50 % of I_n in steps of 5% I_n
- Response ratio approx; 25%

Three-phase biased differential shall be provided with variable bias ratio. This ratio shall be such that with maximum mismatch between both end CTs. the relay shall always be securely restrained in the presence of maximum through-fault current.

The relay shall not operate in the presence of magnetizing inrush current and be capable of rapid tripping in the event of energizing onto a fault.

The relay shall detect and trip all phase and earth faults within the protection zone and shall remain stable for all faults outside the area limited by the relevant current transformers.

The pick-up ratio shall be adjustable.

Proper means shall be provided to detect internal faults which could occur during the inrush period.

The tripping time shall be less than 40 ms at a differential current equal to five times nominal setting current

The bias and basic sensitivity shall be adjustable in steps.

All necessary interposing transformers shall be provided which shall be adequately rated to ensure correct relay performance during maximum through-fault condition

2. Reverse Power Protection Function (32G)

The typical setting values would be the following:

Reverse power: 0.5 -5%

First stage time delay: 0-100 sec

Second stage time delay: 0-100 sec

3. Back up Impedance Protection Function (21G)

Back up impedance protection shall be provided with two circular zones, each with two separate independent definite programmable time delays. This shall be used as a backup protection. The operation of back up impedance protection shall necessarily be blocked in case of failure of voltage supply to the measuring unit.

4. Loss of Field and Out of Step Protection Functions (40G)

This protection function shall be provided to protect the generator from unintentional opening of field circuit breaker, opening or short-circuiting of field circuit and a fault in the automatic voltage regulator or excitation system.

The protection function shall detect the condition of loss of excitation and operate before the generator falls out of synchronism within a short time. In order to obtain a rapidly effective under excitation protection, as a second criterion the excitation voltage shall be introduced into the system. If both, the stability curve and the excitation voltage criteria are satisfied, alarm and trip shall be triggered after an adjustable time delay of 1-2 seconds. The loss of synchronism with the excitation being in normal

operation shall be detected by an integrator, which detects the periodical entering of the vector into the instability zone.

5. Negative Phase Sequence Protection Function (46G)

This protection function shall distinguish between an asymmetrical load and an asymmetrical fault. It must always trip after the fault tripping relays. It shall protect the rotor iron from excessive heating and trip the generator before the permissible I_{2t} value will have been reached. Two set levels shall be available. One fixed time for alarm and one inverse delayed for tripping.

6. Over Voltage Protection (59G)

This protection shall protect the generator against over voltages produced within the generator, for example by a failure of the voltage regulator. The relay shall operate independent of the frequency within the range of at least 0.8 - 1.2 times rated frequency. The relays shall be provided with two independent stages for delayed and instantaneous trip.

7. Under Voltage Protection Function (27G)

This protection function shall be used as a back-up protection against loss of excitation. It shall have a time-delayed stage. It shall operate independent of the frequency within the range of 0.5-1.2 times rated frequency. Typical setting and tripping ranges would be the following:

Setting range: 0.5 to 1.0 Un Tripping time: 0-100 s

8. Stator 95% and 100% Earth Fault Protection Function (64G1 & 64G2)

A complete protection function of the stator winding from short-circuits between the stator winding in the slots and the stator core shall be provided. False operation must be prevented assuring reliable discrimination between a fault in the stator circuit and other transient phenomena.

9. Under / Over Frequency Protection Function (81G)

The protection function shall have a working range of 45 - 55Hz and an adjustable time delay of 0.5 to about 5 sec.

10. Generator Voltage Transformer Fuse Failure Monitoring Protection Function (60G)

This function shall be provided for blocking of protection scheme, which may mal-operate in the event of PT fuse blowing in primary side or secondary side. It shall be of voltage balance or equivalent type. It shall have sufficient contacts to block tripping of those relays, which are voltage dependent and give alarm.

9.7.2 Generator Transformer protection -2 sets

One-(1) no. multifunction programmable numerical relays for protection of each generator step up transformer shall include following functions

- Differential Protection of transformer 87T
- Restricted earth fault protection of transformer 64TR

- Over current protection of transformer 50/51T
- Breaker fail protection
- Over-fluxing protection.

The following protection functions not covered by multifunction relays, shall be covered by other discreet devices / relays and shall be covered by contractor in the scope of protection equipment if not included in the scope of the equipment specified in other sections.

- Transformer oil level monitoring relay - Level abnormal (71T)
- Winding temperature monitoring relay - High, very High (49T)
- Pressure monitoring relay - Very High (63T)
- Oil temperature monitoring relay - High, very High (26T)
- Buchholtz relay - Stage I, Stage II
- Differential Pressure high

9.7.2.1 Description of the Generator Transformer Protection Functions

1. Transformer Differential Protection Function (87T)

The transformer differential protection function of the multifunction relay shall be of the single phase, high speed, variable bias percentage, differential type with adjustable sensitivity and harmonic restraint. The transformer differential function shall include interconnecting conductor section between powerhouse and switchyard. The relay function shall incorporate current taps or separate auxiliary current transformers to compensate for main current transformers mismatch. The relay must not operate in the presence of magnetizing inrush current, yet must be capable of rapid tripping in the event of energizing onto a fault.

2. Restricted Earth Fault Protection Function (64REF)

Transformer windings and connections shall be protected by restricted earth fault (REF) protection function of multifunction numeric type relay with measuring unit and the necessary protection against over current. The relay shall have an instantaneous trip function. The fault setting shall be between 10 per cent and 60 per cent of the rated current of the protected winding.

The rated stability limit shall not be less than the maximum current available for an external fault. This shall be taken as 16 times the rated current.

3. Over Fluxing Protection Function (24)

This protection function shall protect the generator transformer iron core from excessive heating in case of voltage rises and/or frequency dips during unit operation.

4. Breaker Fail Protection

Breaker fail protection function shall be provided for failure of any circuit breaker to open after the action of the associated protection. This protection shall trip after a time delay all other circuit breakers feeding the fault.

5. Buchholz Protection

The transformers shall be fitted with Buchholz devices of the two-element type giving operation under gassing and under surge conditions.

6. Oil and Winding Temperature

Transformers will be provided with oil and winding temperature protection. These will be of the two-stage type with adjustable settings giving alarm and trip facilities.

9.7.3 132 kV transmission Line protection - one (1) set

9.7.3.1 Distance Protection of 132 kV Line

One (1) multifunction relays for protection of 132 kV line shall be provided. Each multifunction relay as a minimum shall include following programmable functions:

- Distance protection (21P and 21G)
- Fault detector relay (64L)
- Under/Over voltage relay (27/59)
- Directional Over current and earth fault protection
- Auto reclosing

The protection system shall be used to detect phase to phase, 3 phase and all combinations of phase to ground faults. The relays shall be connected to CVT located on line side of high voltage disconnect switch.

The fault detector function (64L) shall be connected to broken delta PT to sense line to ground fault on the system.

The distance relay function (21P and 21G) shall be adjusted for a short line section to provide rapid operation in the event of system fault. The under voltage function shall be used to sense a severe system under voltage or blackout. There will three forward zone and one reverse zone of protection in distance relay.

9.7.3.2 Line Metering

One (1) multifunction line metering system shall be provided. The metering shall include following functions

- Current
- Mega Watt
- Mega Var
- Mega Watt-hour
- Power factor
- Frequency

One (1) commercial import / export metering cabinet with static meters suitable to measure active & reactive energy and having accuracy not inferior than 0.2S. The meters shall have non-volatile memory and shall store data for at least thirty five days.

A check meter shall also be provided.

The meters shall be provided with facility to download parameters through meter reading instruments as well as remote transmission of data over communication network. Necessary software for the same shall be provided.

9.7.3.3 Breaker Fail Protection

Breaker fail protection function shall be provided for failure of any circuit breaker to open after the action of the associated protection. This protection shall trip after a time delay all other circuit breakers feeding the fault.

The breaker fail protection shall be started by the trip relay of the circuit breaker and shall incorporate fast resetting type over current relay to monitor the continuous flow of current after the action of trip relay, which is the indication of failure of the circuit breaker. The protection shall act with a time delay on the output relays of the other breakers required to be tripped.

The breaker back up scheme shall cover the clearing of fault in the dead zone between the location of the CT's and the breaker for all the elements.

The breaker failure function shall be used to verify proper operation of the circuit breaker by detecting (after a preset time established to be sufficiently long for the circuit breaker to have operated) that there is no longer current flowing through breaker

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

9.7.3.4 Description of the Line protection Functions

1. Distance Relay Protection Function (21P and 21G)

Distance protection function shall be non-switched numerical type, comprised of minimum three- zone distance operation. The distance protection shall operate for all types of phase and earth faults. Separate phase and earth fault distance measuring elements shall be provided. Phase and earth fault compensation features shall be incorporated to ensure accurate distance measurement for all types of fault and to allow for variation in the path of earth faults on the system.

Zones 1 and 2 shall operate only for faults in the protected direction. Under no circumstances shall the relay operate for reverse faults even when the voltage supplied to the relay falls to zero on all three phases. Details of methods used for polarizing relays to deal with faults close to the relaying point shall be provided. The relay characteristics shall ensure adequate fault resistance cover under minimum plant and single outage conditions. Zone 3 shall be non-directional and shall be capable of being independently offset in both directions.

Starting shall be by impedance measuring relays, over current starting shall not be accepted. The relay characteristic shall cover the protected line plus the longest line emanating from the remote station

taking current in-feed into account. The starting relays shall not operate during maximum power transfer. During single phase to earth faults coinciding with maximum power transfer, only the starting relay associated with the faulted phase shall operate.

The reach of each measuring zone and starting relay shall be individually adjustable. The characteristic angle shall be adjustable between approximately 40 and 80 degrees.

Zone 2 and Zone 3 shall have a time delay setting range of minimum 0.2 to 1.0 second and 0.5 to 3.0 seconds respectively.

The sensitivity of the protection shall be adequate for definite operation under minimum plant and single outage conditions and shall not exceed thirty percent (30%) of rated current.

The operating time of each zone shall be substantially independent of fault current magnitude.

A feature shall be incorporated to ensure instantaneous tripping in the event that the circuit breaker is closed onto a fault on a previously de-energized line.

Steps shall be taken to protect the static circuitry from external impressed transient voltages, which could reach the station battery. The routing of cables should be such as to limit interference to a minimum. Any auxiliary supplies necessary to power solid-state circuits shall be derived from the main station battery and not from batteries internal to the protection.

A monitoring system shall be provided to supervise the voltage transformer supply to each distance relay. The secondary voltage of the VT shall be taken to the relay through a MCB with auxiliary contacts. In the event of a trip of the MCB, the monitoring shall inhibit relay operation and initiate an alarm.

The distance relay shall be able to operate in conjunction with the delayed auto re-closing relays.

The distance relays shall incorporate indicators to show the zone in which the relay tripped and the phase or phases, faulted. Indication must not be lost in event of a supply failure.

In addition to tripping contacts, the protection shall have, where necessary, contacts for initiating auto re-closing signalling and alarms.

Each protection shall be suitable for single pole tripping and for use in the single and three phase auto re-closing scheme.

The protection and associated auto re-closure equipment shall incorporate whatever means are necessary to ensure that all measuring and starting elements in the healthy phases of the faulted line and all measuring elements on the parallel circuit remain reset during the single phase re-closing dead time. Additionally, the inter-phase fault measuring elements on the faulted circuit shall be stable in the presence of a heavy close-up earth fault. The methods used to ensure correct stability of healthy phase elements during single-phase times and during fault conditions shall in no way prejudice the ability of the protection and auto re-closing scheme to respond to faults during the dead time.

All distance relays shall have Power swing detection with a swing time of as low as 200 ms blocking function and Internal/External faults detection function

2. Over Voltage Protection

The 33 kV transmission lines shall be protected for over voltage. The over voltage relay setting for over voltage steps from 100% to 120% in steps of 2.5% each for time delayed protection. For instantaneous over voltage protection, the setting of relay shall be 110% to 150% of rated voltage. Relay setting shall be decided after observing grid condition at time project commissioning.

3. Automatic Re-closing

Three pole and/or single shot repetitive auto re-closing equipment shall be provided for 33 kV overhead line circuit breakers, and shall include, where necessary, deadline and check synchronizing relays. Re-closing shall only take place on overhead line circuits and shall be initiated by following tripping by the distance relay Zone 1 equipment or on receipt of a permissive inter tripping signal.

The following modes of operation shall be selectable by means of a switch or switches:

- Single pole, high speed, auto re-closing only
- Auto re-closure shall only be initiated in the event of a signal phase to earth fault. All other types of faults shall result in three phase tripping without auto re-closing.
- Three pole delayed re-closing only
- Delayed re-closing shall only be initiated in the event of a single phase or two phase fault. Three phase faults shall result in tripping without auto re-closing.
- Single pole, high speed and/or three phase delayed, auto re-closing as appropriate
- No auto re-closing

Three phase tripping without auto re-closing shall take place for any type of fault.

If a second earth fault occurs during the single pole auto re-close dead time, three phase tripping with subsequent delayed three pole auto re-closing shall take place if the auto re-closure selector switch is in the single pole re-close mode, three phase tripping with lockout should follow.

The high speed and delayed re-closing dead times have to be coordinated with the equipment being provided at the remote substation by others, and will be finalized only after Contract award. Tentative ranges are, however, as follows:

High speed single pole re-closing dead time - 0.3 to 1 seconds.

Delayed three - pole re-closing dead time - 1 to 30 seconds.

The Contractor shall state available ranges.

A counting facility shall be provided to record the number of re-closures.

4. Check Synchronising Protection Function

Check synchronising protection function ensure to check that phase angle difference, voltage difference and slip frequency difference between two line sections is within permissible limits before breaker closure / auto re-closure command is initiated.

Dead line check relays function shall monitor the conditions of the line and the bus bar and permit three pole re-closing only when the line is de-energized and the bus bar is energized. The line is considered

de-energized when the voltage is less than 20 percent of nominal operating voltage, and the bus bar is considered to be energized when the voltage is at least 80 percent of nominal operating voltage.

9.7.4 SAT (Station Auxiliary Transformer) Feeder Protection - Two (2) Sets

9.7.4.1 11/0.433 kV Station Auxiliary Transformer Protection

One (1) multifunction relay for protection of each 11/0.433 kV step down transformer feeder shall be provided. Each multifunction relay as a minimum shall include following programmable functions:

- Instantaneous Over current and Earth Fault protection
- IDMT on LV and HV Side
- Standby Earth Fault on neutral side

9.7.4.2 Station Auxiliary Transformer Metering

One (1) multifunction line metering system shall be provided. The metering shall include following functions

- Current
- Mega Watt
- Mega Var
- Mega Watt-hour
- Power factor
- Frequency

9.7.5 11 kV Switchgear Protection - One (1) Set

11 kV switchgear feeder Protection is covered above as generator protection, generator transformer protection and station auxiliary transformer protection.

9.8 Protection and Tripping Relays

9.8.1 Protection Relays

Relays shall be of approved types with IEC 60255 or BRITISH Standard 142 and 5992, parts 1, 2, and 3 or IS, as appropriate, fully tropicalized and shall have approved characteristics. The protection relays shall be located in conventional panels and shall be flush mounted in dust and moisture proof cases with protection class IP54 and of the draw out type with rear connections. The protection class of the cover for all relays or protection systems, in which the modules are mounted, shall not be inferior to IP53.

All DC breakers and relays for DC main switchgear protection shall be based on AC trip and close coils and protection relays.

Any auxiliary supplies needed shall be drawn from the main station batteries and not from the separate internal batteries in the protection equipment.

Withdraw-able pattern relay shall be so designed so that when in the withdrawn position associated CTs shall be automatically short-circuited and tripping circuits disconnected.

All static relays shall be adequately protected against damages from incoming surge and shall meet relevant IEC, BS, IS and ANSI test standards.

The input circuit must be galvanically isolated from the electronic circuits. Potential free output contacts must be suitable for the direct control of breaker trip coil.

The system shall be coordinated with the protection system of the interconnected stations. All interface installations shall be included to provide fully functional systems.

The trip circuit supervision scheme shall provide continuous supervision of the trip coils and trip circuits with the circuit breaker in either the open or the closed position and scheme shall have sufficient contacts for visual/available alarm and indication.

Provision shall be made in trip circuit supervision circuits to prevent any type of mal-tripping of a circuit breaker.

Relay alarm should be equipped with well resetting indicators.

The numerical protection relays shall have an operating time of less than 20 ms and single function protection relays shall have the operating time less than 15 ms. The total time taken by the protection system including auxiliary and tripping relays to send trip command to circuit breaker from the occurrence of the fault shall not exceed 70 ms.

Each relay or relay assembly shall have a test device, which facilitates checking the correct functioning of the equipment during operation or stand still.

9.8.2 Lock-Out Relays

The lock-out relays shall be electrically tripped, manually/electrically reset, high speed multi-contact type with an operating time of approximately one cycle; the relay shall include LED indicators on the front panel for indication of relay coil health status and remote trip status. In addition to the contacts required for protective circuit operation, four normally open and four normally closed contacts shall be furnished and wired to terminal block for external use.

The following lockout relays shall be furnished for each unit:

- 86G-A Generator primary protection lock-out relay
- 86T-A GSU primary protection lock-out relay
- 86M Turbine-Generator Mechanical Fault Protection lock-out relay

The following lock-out relays shall be furnished for each line

- 86TL-A Transmission line primary protection lock out relay

The primary protection lock out relays shall be used for tripping whenever the multifunction microprocessor relay for primary protection is energized during fault. The backup protection lock out relays shall be used for tripping whenever the multifunction microprocessor relay for backup protection is energized during fault.

The mechanical lockout relay shall be activated by critical mechanical equipment faults in the turbine, generator and governor. The tripping matrix shall be provided by the contractor for approval of engineer. The mechanical trip shall include but not limited to bearing and/or winding temperature high-high, etc.

9.8.3 Auxiliary relays

Auxiliary relays for inputs from the protection sensors and devices such as thermal relays, pressure switches etc. shall be provided as specified in the following sections, and as necessary for the installation.

The relays shall be equipped with a manually reset indicator when applicable.

Each relay shall have self-resetting potential free contacts of suitable rating as needed for connection in the tripping circuits and at least two self-resetting potential free contacts for local and remote alarm and supervision, both wired to terminals.

All relays shall be clearly marked with the corresponding relay function.

Control and tripping circuitry-

The tripping circuits shall be accomplished via a tripping MATRIX.

The MATRIX shall include all electrical and mechanical signals as per alarm/tripping schedule and sequence diagram.

Trip circuit supervision systems shall be provided. They shall preferably supervise the circuits continuously irrespectively of circuit breaker position whether it is closed or open. Supervisory systems combined with automatic test facilities will also be considered.

Any fault in a tripping circuit shall be indicated individually.

The trip circuits shall not be interrupted during test procedure. Correct working shall be indicated by LED's.

For relay testing and setting by means of a portable, precision test set all required circuits shall be terminated to test plugs/switches, arranged at easily accessible locations.

An appropriate test set with all accessories shall be included.

9.8.4 Power Supply Requirements

110 V DC shall be provided for monitoring of the power supply to the control and protection of AC switchgear equipment, while AC shall be provided for monitoring of the power supply to the control and

protection of DC switchgear. Both systems shall be used to supply auxiliary voltage and tripping voltages to the protection system.

Each protection subgroup shall have feeders from circuit breakers in both DC systems with selection being made at the protection cubicle.

All components of the protection system shall function properly at DC voltages from 80%-115% of nominal voltage.

If short-circuit protection is needed inside each protection group, mini circuit breakers shall be used, having auxiliary contacts for initiating alarm for open position.

Converters and suppression filters shall be provided for each protection part.

The converters shall have high insulation level, and shall be equipped with internal fault detection, initiating alarm upon failure in the converter.

The protection systems shall be fed by the 110 V battery banks installed in the control block. Relay shall be suitable for operation on 110 V DC systems without the use of voltage dropping resistors. Each DC supply shall be designed to protect it from high voltage and surge and provide electrically isolated contacts for annunciation. Relays shall utilize a DC-DC converter type regulated power supply to provide transient surge isolation between the station battery and protection equipment. The supply units shall be equipped with input filters to protect against external voltage peaks. Protection shall be provided in the primary and secondary circuits of the DC transducers. The supply voltage and all secondary voltages produced by the DC /DC transducers shall be monitored.

9.9 Synchronizing System

The Synchronizing System common for all generating unit shall consist of the following:

- One Automatic Synchronizer (25S); with one redundant auto synchroniser
- One Synchro-check Relay (25V)
- One manual synchronizer common to all the units & lines including: one synchroscope; two white indicating lamps, for incoming and running signals; two voltmeters, for incoming and running indication; and one Automatic/Manual selector switch; Raise/Lower control switches for voltage and speed; and generator/line circuit breaker close control switch.

9.9.1 Auto Synchronizer

The Automatic Synchronizer (25S) shall be a microprocessor based device with front mounted adjustments and indicators. Once activated, the automatic synchronizer shall automatically initiate closure of the unit's generator circuit breaker when voltage magnitude, slip frequency, and phase difference are within preset limits. The device shall conform to IEEE C37.90.1 Standard Surge Withstand Capability Tests. The automatic synchronizer shall, as a minimum, have the following control and indicating features:

- Voltage acceptance feature that compares the generator/6.6 kV GT feeder voltage to the bus voltage; Breaker closure is inhibited until the value is within the front panel preset limit.

- Voltage matching feature that will automatically signal the automatic voltage regulator in the excitation system to either raise or lower the generator voltage
- Frequency matching feature that will automatically signal the governor to either raise or lower the generator speed; the speed correction pulse width shall reduce linearly with the slip frequency at low slip frequencies. Breaker closure is inhibited until the slip frequency is within the front panel preset limit.
- Adjustable breaker closing time;
- Lockout feature that will lockout the automatic synchronizer if the generator breaker trips within 15-seconds of closure by the automatic synchronizer;
- The automatic synchronizer shall allow for synchronization to a dead bus.
- LED type indicators for lockout, generator under voltage, slip frequency high and synchronizer output closed.

Syncro-check Relay (25V) shall be furnished for each generator circuit breaker to prevent closure of the breaker when voltage magnitude, slip frequency, and phase difference are not within preset limits. The sync check relay shall be functional in all modes of unit synchronization. The sync check relay shall allow for synchronization to a dead bus. The sync check relay shall be a microprocessor based device with front mounted adjustments and indicators. The device shall conform to IEEE C37.90.1 Standard Surge Withstand Capability Tests.

9.9.2 Manual Synchronizer

In "Manual" mode of synchronizing, the voltage and frequency is matched manually by use of synchroscope and Raise/Lower control switches for voltage and speed.

The synchroscope shall be of the rotating needle type. All instruments, unless otherwise specified, shall be for operation from instrument transformers having nominal 5 amperes and 110 volts secondaries.

9.9.3 Elapsed Time Meter

A panel mounted elapsed time meter shall be provided for recording the run time of the turbine generator units. The meter shall be crystal controlled and programmable for displaying run time in hours, minutes and seconds on 8-digits, 10 mm high LED display. The meter shall have an accuracy of 0.005% or better. The starting and stopping of time counter shall be from closure and opening of remote contact signal. The meter shall be suitable for operation at 110 V DC power supply and shall be equipped with a rechargeable battery for storing of time for up to 1 month continuously during power failure. The meter shall include a reset button for resetting the counter to zero.

9.10 SHOP TESTS

9.10.1 TYPE TESTS

All standard components of the protection systems shall have passed appropriate type tests in accordance with standards. The contractor is required to submit type test certificates to the purchaser.

9.10.2 ROUTINE TESTS

These tests shall include material and tests during manufacture as per the manufacturer's practice. The contractor is required to submit complete routine test reports. The following inspections and tests shall be performed on the completely assembled protection systems in the presence of Purchaser's representative:

- Visual inspection
- Wiring test
- Insulation test
- High voltage test on outgoing circuits
- Functional tests

9.11 INSTALLATION AND COMMISSIONING

All installation shall be done by skilled workers in a workmanlike manner. The contractor is required to submit detailed testing reports for the tests to be performed at site. All relay testing shall be done in association of purchaser.

9.11.1 Site Tests

The contractor shall prepare a detailed test programme based on the requirements of the applicable standards and the specifications.

All test results shall be recorded including the details of the test equipment and instruments.

- Primary Injection

Primary injection tests shall be performed to ascertain:

- ratio and polarity of CTs
- correctness of interconnections between CTs, CT groups and associated relays
- relay settings.
- Secondary Injection

Secondary injection shall be carried out on all A.C. relays using voltage and current of sine wave from and rated power frequency.

- D.C. Tests

D.C. tests shall be carried out to prove the correctness of all D.C. polarities, the operating levels of D.C. relays and the correct functioning of D.C. relay schemes, selector and control switches, indications and alarms.

- Final Check

Checks shall be made after the protection systems have been commissioned to ensure that all connections and test links have been replaced and test leads removed, as well as to confirm the

integrity of the current transformer circuits. Where necessary, voltage readings shall be taken at the terminals on each relay to ensure that loop connections between the relays are complete.

9.11.2 Performance Testing

If nothing unusual has been observed after energization, the test service period of 72 hours shall follow. During this test period, the protection system must perform correctly without any false tripping except genuine tripping due to external reasons beyond the control of the Contractor. However interrupted period due to genuine tripping shall not be counted in the test service period.

9.11.3 Field Acceptance tests

This test phase shall ensure the trouble free operation of the protection system of each generating unit, transformer and line. Finalizing of the setting and co-ordination of various protections including co-ordination of protection between the units with network, line, 6.6 kV switchgear protection shall also be ensured.

9.12 Drawings, Documents and Design Calculations

9.12.1 Design memorandum

The Contractor shall submit to Purchaser a design memorandum prepared in accordance with clause 1.2" of "Section 1-General Technical Specifications of the proposed equipment /system fulfilling the contract specification/requirement for approval prior to submission of drawings and documents. The design memorandum shall include the design philosophy, methodology, system description, input parameters for design, standards and codes, design & selection criteria, equipment data, material specification, major technical features, basic arrangement / layout etc.

9.12.2 Drawings and documents

The Contractor shall submit all the drawings and documents in accordance with requirements stipulated in clause 1.2.2 - Technical Documents" of "General Technical Specification (GTS)".

9.12.3 Design and Setting calculation

The Contractor shall submit the design and setting calculation in accordance with Clause 1.2.6 of "General Technical Specification (GTS)" covering at least the following, for review / acceptance.

- Complete protection scheme
- CT & PT application check
- Setting for different relays
- DC power requirements

9.13 Delivery, Installation and Commissioning

The Contractor shall follow the requirements of Delivery, Installation and commissioning elaborated in “General Technical Specifications.”

9.14 Spare Parts

The spare parts shall be as per following list for supply.

Sl. No.	Description	Quantities
1	Self reset Trip relays of type used	2 (two) sets of each type used
2	Trip circuit supervision of type used	2 (two) sets of each type used
3	Auxiliary relays of type used	2 (two) sets of each type used
4	Auxiliary relay socket of type used	2 (two) of each type used
5	Test block	2 (two) nos.
6	Numerical relays	1 (one) set each type used
7	DC/ DC converters, power supply filters and other power supply units	2 (two) sets of each type used

9.15 Special Testing instruments

The Contractor shall propose the list of testing instruments including their make and detailed specification to be accepted by the Purchaser.

Proposed list shall include following mandatory items:

- Relays / card / module extraction tools.

9.16 Special Tools

The Contractor shall propose the list of recommended special tools (other than those included under “Tools and Appliances” above) including their make and detailed specification as recommended by manufacturer(s) and to be accepted by the Purchaser.

9.17 Quality Assurance and Testing

The bidder shall submit the quality assurance plan along with bid for approval of the purchaser. The Contractor shall follow the quality assurance and testing requirements as per quality assurance plan approved by the purchaser.

9.18 Guaranteed and Technical Particulars

Guaranteed and Technical Particulars as called for in Vol. VI shall be furnished along with the bid. Bids lacking in this may be considered unresponsive. Particulars subject to guarantees shall be clearly marked

9.19 Completeness of Equipment

All fittings and accessories of the protection equipment and associated auxiliary & ancillary equipment which may not have been specifically mentioned in these specifications, but are usually necessary for completion of the above equipment, shall be deemed to be covered by the specification; and shall be indicated and furnished by the supplier without any charges to the purchaser.

9.20 Deviation from Specifications

While the purchaser does not bind himself to accept any deviation, due consideration will be given to any special devices or equipment put forward by the supplier with a view to increase the efficiency of the equipment and minimize the maintenance cost of the equipment as a whole.

Should the supplier wish to depart from these specifications, he shall submit a complete and itemized list of such deviations, together with full particulars of the reasons for the deviations in a separate schedule with special reference to clause and paragraph nos. of this specification. Unless this is done and also the purchaser's concurrence in respect of such deviations is obtained in writing, the equipment offered shall be deemed to comply in every respect with these specifications.