

#### **14.5.4 Outdoor Cubicles**

##### **a. Circuit and Equipment**

The following 20 kV and 6.6kV switchgear equipment shall be supplied and installed in the substation.

- (i) 20 kV transmission line circuit, comprising,**
  - Three phase bus
  - Disconnecting switch for line
  - Disconnecting switch for lightning arresters
  - Lightning arresters
  - Cable heads
  - Space for MOF(Metering Out Fit)will be supplied from PLN
- (ii) 20 kV switchgear and the secondary circuit of the main transformer, comprising,**
  - Three phase bus
  - Circuit breaker with draw out type
  - Current transformers and Relays
  - Ground voltage transformers and Relays
  - Cable heads
- (iii) 6.6 kV transformer primary circuit, comprising,**
  - Three phase bus
  - Disconnecting switch for transformer
  - Current transformers and Relays
  - Ground voltage transformers and Relays
  - Cable heads

##### **b. Enclosure**

- (i) Type**

The outdoor cubicles shall be of self supporting, outdoor installation, metal enclosed cubicle of robust construction.
- (ii) Construction Requirement**

The enclosure shall be provided with access doors to facilitate inspections of the equipment. The position indicating lamps and inspection windows for the circuit breaker shall be provided on the front doors. The door shall be provided with suitable handles with locks.

The enclosure shall be provided with suitable cable terminal compartments for the cross-linked polyethylene (XLPE) insulated power cables.

The secondary circuits of instrument transformers shall be brought out to the terminal blocks for the connection of control cables to the measuring instruments and relays on the control board.

A copper ground busbar shall be provided in the cubicle. Clamp type grounding terminals shall be provided for connecting the ground busbar to the lead wire from the station grounding system.

Space heaters for 220 volt AC shall be provided inside the cubicles to prevent moisture condensation. A manual switch to control the heaters shall be provided in the cubicle.

**(iii) Accessories**

The following items shall be provided for the enclosures:

- Name plates for the Plant to be housed
- Channel bases
- Foundation bolts and nuts
- Grounding pads
- Lighting fittings
- Other necessary accessories

**(iv) Test**

The following tests shall be carried out at the manufacturer's workshop before shipment.

- Appearance check
- Power frequency voltage test
- Impulse voltage test
- Temperature rise test

**c. Busbars and Connection**

**(i) Type**

The busbars and electrical connections shall be of copper or aluminium alloy and shall be sufficiently insulated from ground and from each other.

**(ii) Ratings**

The busbars will be rated adequately in accordance with the requirements of the system.

**d. Circuit Breaker**

**(i) Type**

The circuit breaker shall be vacuum circuit breaker of three pole, single throw type, complete with necessary controls and wiring and any other accessories needed for operation.

**(ii) Ratings**

The circuit breaker will be rated adequately in accordance with the requirements of the system.

**(iii) Operation Mechanism**

The circuit breakers shall be provided with operating mechanism capable of remote and local electrical control and also local manual operation.

**(iv) Accessories**

The following items shall be provided for the circuit breaker:

- Rating plate
- Position indicating lamps red and green
- Necessary terminal connections
- Local control box with pushbuttons of "ON" and "OFF"
- Manual charging handle
- Maintenance tools

**(v) Testing**

The following test parts shall be furnished and quoted:

- Appearance check
- Power frequency voltage test on the main circuit
- Voltage withstand tests on control and auxiliary circuits
- Measurement of the resistance of the main circuit
- Mechanical operating test
- Measurement of making and breaking time

**e. Current Transformer**

**(i) Type**

The current transformer shall be of single phase, epoxy mould type.

**(ii) Ratings**

The current transformer will be rated adequately in accordance with the requirements of the system.

**(iii) The following items shall be provided for the current transformers**

- Rating plates
- Necessary terminal connection
- Other necessary accessories

(iv) Spare Parts

The following spare parts shall be furnished and quoted

- one (1) current transformer of each rating

(v) Tests

The following tests shall be carried out at the manufacturer's workshop before shipment:

- Appearance check
- Measurement of current ratio
- Check of relative polarities
- Power-frequency voltage test on primary winding

f. Grounding Voltage Transformer

(i) Type

The grounding voltage transformer shall be voltage transformer of three- phase, epoxy mould type with one residual voltage winding and shall be draw-out type.

(ii) Ratings

The grounding voltage transformer will be rated adequately in accordance with the requirements of the system.

(iii) Accessories

The following items shall be provided with necessary accessories

(iv) Spare Parts

The following spare parts shall be furnished and quoted

- 500% of actual use of fuses

(v) Tests

The following tests shall be carried out at the manufacturer's workshop before shipment:

- Appearance check
- Measurement of current ratio
- Check of relative polarities

g. Three Pole Disconnecting Switch

(i) Type

The disconnecting switch shall be of outdoor use, pole mounted, three pole, single throw, manual gang operated type which can be operated at the front of cubicles.

(ii) Ratings

The grounding voltage transformer will be rated adequately in accordance with the requirements of the system.

**(iii) Accessories**

The following items shall be provided for the outdoor disconnecting switch:

- Rating plate
- Manual operating mechanism with operating handle assembly with padlock and keys
- Required materials for installing the disconnecting switch
- Necessary terminal connection
- Grounding terminals
- Other necessary accessories

**(iv) Tests**

The following tests shall be carried out at the manufacturer's workshop before shipment:

- Appearance check
- Power frequency voltage dry test
- Mechanical operating tests

**h. Lightning Arresters**

**(i) Type**

The lightning arresters shall be of outdoor use, pole mounted, explosion proof, gapless type.

**(ii) Ratings**

The lightning arresters will be rated adequately in accordance with the requirements of the system.

**(iii) Accessories**

The following items shall be provided for the lightning arresters

- Rating plates
- Required materials for installing the lightning arresters
- Necessary terminal connection
- Grounding terminals
- Other necessary accessories

**(iv) Tests**

The following tests shall be carried out at the manufacturer's workshop before shipment:

- Appearance check
- Power frequency starting voltage test
- Measurement of leakage current

- Power frequency voltage dry test
- Pressure relief device test

#### 14.5.5 Indoor Cubicles

##### a. Circuit and Equipment

Indoor metal enclosed cubicles for the Jatibarang power station shall be supplied and installed for the generator circuit, 150 kVA station service transformer, the DC supply equipment and the excitation system, comprising:

- (i) For generator circuit
  - Three phase bus
  - Circuit breakers with draw-out type
  - Disconnecting switch
  - Current transformers for protective relaying and measuring
  - Voltage transformer for protective relaying and measuring
  - Surge absorbers
  - Cable heads
- (ii) For the station service transformer
  - Three phase four wire bus
  - Disconnecting switch with power fuses
  - Current transformers for measuring
  - Voltage transformer for measuring
  - Moulded case circuit breakers for AC circuit
  - Required sets of motor starter units of the control of all motors associated with the turbine/generator unit.
- (iii) For the DC supply equipment
  - One-set of 110V DC bus
  - Space for the battery charger (see 14.5.6)
  - Eight (8)-set of moulded case circuit breakers for DC circuit
- (iv) For the Excitation system
  - Space for excitation transformer
  - Voltage transformer for AVR (Automatic Voltage Regulator)

Indoor metal enclosed cubicles for the Krapyak substation shall be supplied and installed for the 20 kV transmission line equipment, comprising:

(v) 20 kV transmission line circuit, comprising ,

- Three phase bus
- Disconnecting switch for line
- Disconnecting switch for lightning arresters
- Lightning arresters
- Cable heads
- Circuit breaker with draw out type
- Current transformers and Relays
- Ground voltage transformers and Relays

b. Enclosure

(i) Type

The cubicles shall be of self supporting, indoor installation, metal enclosed cubicle type of robust construction.

(ii) Construction Requirement

The enclosure shall be provided with access doors to facilitate inspections of the equipment. The operation position of the breakers shall be indicated on the front doors. The door shall be provided with suitable handles with locks.

The enclosure shall be provided with suitable cable terminal compartments for the cross-linked polyethylene (XLPE) insulated power cables.

A copper ground busbar shall be provided in the enclosure. Clamp type grounding terminals shall be provided for connecting the ground busbar to the lead wire from the station grounding system.

Space heaters for 220 volt or 380 volt AC shall be provided inside the enclosure to prevent moisture condensation. A manual switch to control the heaters shall be provided in the enclosure.

(iii) Accessories

Accessories for the enclosures shall be as specified.

c. Busbars and Connection

(i) Type

The busbars and electrical connections shall be of copper or aluminium alloy and shall be sufficiently insulated from ground and from each other.

(ii) Ratings

The busbars will be rated adequately in accordance with the requirements of the system.

**d. Circuit Breaker**

**(i) Type**

The circuit breaker shall be vacuum circuit breaker of three poles, single throw type, complete with necessary controls and wiring and any other accessories needed for operation.

**(ii) Ratings**

The circuit breaker will be rated adequately in accordance with the requirements of the system.

**(iii) Operating Mechanism**

The circuit breakers shall be provided with operating mechanism capable of remote control and also manual operation.

**(iv) Accessories**

The following items shall be provided for the circuit breaker:

- Rating plate
- Position indicating lamps red and green
- Auxiliary switches
- Trip indicator

**(v) Testing**

The following test parts shall be furnished and quoted:

- Appearance check
- Power frequency voltage test on the main circuit
- Voltage withstand tests on control and auxiliary circuits
- Measurement of the resistance of the main circuit
- Mechanical operating test
- Measurement of making and breaking time

**e. Current Transformer**

**(i) Type**

The current transformers shall be of single phase, epoxy mould.

**(ii) Ratings**

The current transformer shall be of the approximate rating for the circuit.

**(iii) Accessories**

Accessories for the current transformer shall be as follows:

- Rating plates
- Necessary terminal connections



(iv) Spare Parts

The current transformers spare parts shall be as follows:

- 500% of actual use of fuses.

(v) Tests

The current transformer shall be subjected to the test as follows:

- Appearance check
- Measurement of voltage ratio
- Check of relative polarities

f. Voltage Transformer

(i) Type

The voltage transformer shall be of single phase, epoxy mould type.

(ii) Rating

The voltage transformers shall be of the appropriate rating for the circuit.

(iii) Accessories

The following items shall be provided for the voltage transformer

- Rating plates
- Necessary terminal connections

g. Grounding Voltage Transformer

(i) Type

The grounding voltage transformer shall be of three- phase, epoxy mould type with one residual voltage winding and shall be draw-out type.

(ii) Ratings

The grounding voltage transformer shall have the appropriate rating for the circuit.

(iii) Accessories

Accessories for the grounding voltage transformer shall include the following items:

- Name Plates
- Channel Base
- Foundation bolts and nuts
- Grounding pads
- Other Necessary accessories.

(iv) Spare Parts

Spare parts for the grounding voltage transformer shall be follows:

- 500% of actual use of fuses.

(v) Tests

The grounding voltage transformer shall be subjected to the following tests:

- Appearance check
- Measurement of voltage ratio
- Check of relative polarities

**h. Moulded Case Circuit Breakers**

(i) Type

The moulded case circuit breakers shall be manual operated, fixed type or suitable type for combination with the motor starter where required. Each moulded case circuit breaker shall be provided with thermal time delay overcurrent tripping mechanism.

The rated frame currents and rated trip currents shall be determined by the Contractor to suit the circuit load and overcurrent protection and shall be subjected to the Engineer's approval.

(ii) Accessories

The following items shall be provided for the moulded case circuit breakers:

- Rating plates
- Manual trip button

(iii) Spare Parts

The following spare parts shall be furnished and quoted

- One (1) moulded case circuit breaker of each rating

**14.5.6 150 kVA Station Service Transformer**

**a. Type and Ratio**

The transformer shall be of three-phase, dry-type, self cooled, built-in cubicle type.

**b. Rated Output and Voltage**

The continuous rated output of the transformer shall be 150 kVA on any of the taps. Rated voltage shall be 6.6 kV to 380 – 220 V of three-phase four wire system,

**c. Impedance Voltage**

Impedance voltage at the rated output shall be about 3.5 percent on all tapping.

d. Bushings

The bushings for 6.6 V side and 380 -- 220 V side shall be of single piece porcelain type. All bushing shall be brown or white glazed.

e. Tap Changer

The off circuit tap changer shall be provided on 6.6 kV side (generator bus side) with taps at 6.9 -- 6.6 -- and 6.3 kV. The tap changer shall be capable of operating under off circuit condition from the outside of transformer. Tap position must be clearly indicated and means of locking shall be provided. All taps shall be rated for full output.

f. Battery Charger

(i) Type and Requirement

The battery charger shall be of the type design for continuous use. The battery charger shall be housed in the metal enclosure cubicle described in Sub-Clause 14.5.5.a.(iii).

The battery charger shall be provided with a load voltage compensating device to limit the maximum DC output voltage as required.

#### 14.5.7 Moulded Case Circuit Breakers for DC

a. Type and Requirement

The moulded case circuit breakers (MCCB) shall be two pole for DC circuit, manual operated, fixed type with time delay overcurrent tripping and magnetic instantaneous short circuit current tripping mechanism. The MCCB shall be mounted in the metal enclosure cubicle described in Sub-Clause 14.5.5.a.(iii)

b. Ratings

The circuit breakers shall be adequately rated. The rated trip current be determined by the Contractor to suite the over current protection and shall be subject of the Engineer's approval. The rated short circuit breaking for DC circuits shall also be determined by the Contractor on the basis of short circuit fault current on the DC circuits.

c. Accessories

Accessories for each moulded case circuit breaker shall be as specified.

#### 14.5.8 Storage Batteries

a. Type and Rating

The storage batteries, shall be provided to supply 110 volt DC power, co-ordinating with the battery charger as specified in Clause 14.5.6. The battery shall be Nickel Cadmium, enclosed type, 150 ampere hour at 5 hours discharge rate suitable for the generating Plant control and for the emergency lightning of the powerhouse.

The storage batteries shall be housed in a self supporting, metal enclosure having front doors with handles and locks and shall be installed in the power station adjacent to the battery charger.

**b. Construction**

The batteries shall be of heavy-duty, long life construction.

**c. Accessories**

The following items shall be supplied as accessories:

- (i) Sufficient quantity materials for the first filling up and operation of the batteries.
- (ii) One set of instruments, including voltmeter, hydrometers and thermometer.
- (iii) Rating plate
- (iv) Grounding pad
- (v) Other necessary accessories

## **14.6 CONTROL AND PROTECTION EQUIPMENT**

### **14.6.1 General**

The control, measuring, protective relaying, recording and data logging equipment to be supplied and installed in the control room of power station are as follows:

**a. Control and relay board consisting of:**

- (i) Main control panel for all power station Plant
- (ii) Relay for all power station Plant
- (iii) Unit automatic control Plant
- (iv) Automatic synchronising equipment and panel
- (v) Recording for temperature of bearings and power output
- (vi) Data logging for power output, water level and discharge

The control and relay board shall be furnished with instrument, indicating meters, control switched, annunciators, test blocks, wiring and other miscellaneous devices as required in the Specification. The control and relay board shall include all required auxiliary and accessory devices, such as auxiliary current and voltage transformers, protective devices, fuses, and resistors, whether or not expressly specified.

### **14.6.2 Requirement for Design**

The main control panel, relay panel, unit automatic control panel shall be so arranged as to form a line and to provide the best convenience for operation and control in a limited control room space. The Contractor shall prepare arrangement and detailed drawings, equipment lists wiring diagrams based on the requirements of meters, relays, control switched, indicating lamps and other devices including those to be supplied under other paragraphs.

It shall be the Contractor's responsibility to properly design the electrical control, protective relaying, alarm and indication schemes related to all Plant in the power station including the turbine generator, transformers, switchgear and other electrical and mechanical equipment.

### 14.6.3 Control System

The control system will make provision for headwater level monitoring with automatic adjustment of flow by wicket gate position in order to optimise available stream flow at all times.

#### a. Start/stop Control

The ordinary start/stop operation of the generating unit, turbine, generator and synchronising circuit breaker shall be performed on the main control panel under automatic sequence control which shall be initiated by a master switch (No.1) two positions of "START" and "STOP".

The auxiliary Plant related to the generating unit shall be automatically operated in the automatic control sequence.

The start/stop operation shall be performed by the following sequence

##### (i) Starting sequence

- Establishing of starting condition
- Opening of inlet valve
- Starting of turbine
- Bring the unit to synchronous speed
- Application of generator field excitation
- Synchronising of generator to the power system
- Taking on load

##### (ii) Normal Stopping Sequence

- Decreasing of the load intermittently to nearly zero
- Open the synchronous circuit breaker
- Open the field circuit breaker
- Closing of inlet valve
- Stopping of the unit to standstill

The control system of the generating Plant shall also be designed to permit manual starting and stopping of step-by-step operation.

Selection of "Automatic" or "Manual" control mode shall be made on the governor panel by a selector switch (No.43A) two positions of "AUTO" and "MANUAL".

The control system shall be such that it is possible to change over from "Automatic" control to "Manual" control or vice versa while the unit is

running, standing, in process of starting or in process of stopping without the operating status.

b. Voltage Control

The voltage control shall be performed on the main control panel by a control switch (No.7-90) with the two positions or "RAISE" and "LOWER" for common use to the automatic voltage regulator (AVR) and manual voltage regulator.

Selection of control mode for the voltage control shall be made on the excitation control panel by a selector switch with two positions of "AVR" and "MANUAL".

c. Speed and Load Control

The speed and load control shall be performed on the main control panel by a control switch (No.7-65) with two positions of the "RAISE" and "LOWER" for common use to the speed setter and load setter. The load limited control shall also be performed on the main control panel by a control switch with two positions of "RAISE" and "LOWER".

d. Synchronising Control

The circuit breaker for the generation circuit shall be used as synchronising breaker. The synchronising control shall be available on the main control panel by a selector switch with three positions of "AUTO", "OFF" and "MANUAL". The synchronising system shall be such that the automatic synchronising can be applicable whether the generating unit is operated under "Automatic" or "Manual" control mode.

e. Switchgear Control

ON/OFF switching operation for the 20 kV and low voltage circuit breakers shall be performed remotely from the main control panel. Interlocks as required shall be provided on the control system to prevent maloperation of switchgear.

#### 14.6.4 Protection and Alarm

Protective relays shall be used for protection and alarm of the generating Plant, 20 kV switchgear, and station-service supply system. The Contractor shall ensure that the protection and alarm schemes are in every respect suitable for the Plant. The protective relays shall be mounted on the panel.

The protection and alarm scheme shall be classified into two groups as follows:

a. Emergency Stop Protection

When serious electrical and mechanical faults take place in the running unit or in the power system, the unit shall be brought to emergency stop. Resetting of the lock-out condition of the unit shall be made manually by push-button switch to be mounted on the main control panel.

(i) Emergency Stopping Sequence

The emergency stop protection may be performed by the following sequence:

- Tripping of synchronising circuit breaker

- Operation of governor shutdown device
- Decreasing of load forcedly
- Tripping of field circuit breaker
- Closing of guide vanes
- Closing of inlet valve
- Stopping of unit to standstill

The emergency stop sequence and lockout relaying (No.86-1, 86-2, 86-5) shall be provided on the relay panel or on the unit automatic control

**(ii) Protection**

The emergency stop protection shall be conducted by the following relays and abnormal conditions:

- Overvoltage relay on the generator circuit
- Overcurrent relay on the generator circuit
- Ground overvoltage relay on the main transformer circuit (20 kV circuit)
- Overcurrent relay on the main transformer circuit (20 kV circuit)
- Excitation system heavy fault
- Emergency manual shutdown switch
- Turbine bearing temperature, high (2<sup>nd</sup> stage)
- Generator bearing temperature, high (2<sup>nd</sup> stage)
- Guide vane servomotor trouble
- Inlet valve servomotor trouble
- Overspeed relay
- Governor fault

**(iii) Alarm**

The following light troubles and abnormal conditions shall provide the buzzer alarm and indication on the fault annunciator:

- Turbine bearing temperature, high
- Generator bearing temperature, high
- Turbine starting trouble
- Shaft sealing water, no flow
- Water supply system trouble
- Main transformer oil temperature, high
- Main transformer oil level, low

- Station service transformer winding temperature, high
- Excitation system light trouble
- Station service supply circuit undervoltage
- Moulded case circuit breaker, tripped
- D.C. undervoltage relay for D.C. 110 V circuit
- D.C. ground detecting relay for D.C. 110V circuit
- Battery charger, trouble
- Reservoir water level, high and low
- Generated power, low

#### 14.6.5 Measuring

Measuring instruments shall be provided on the main control panel and synchronising panel to indicate following items.

##### a. On Main Control Panel

- (i) Generator terminal voltage
- (ii) Generator kW output
- (iii) Generator kWh value
- (iv) Speed indicator
- (v) Guide vane opening and load limited position
- (vi) 20 kV line voltage
- (vii) 20 kV line kW power
- (viii) 20 kV line kWh value
- (ix) Station service transformer secondary voltage
- (x) Station service transformer secondary kWh value
- (xi) Reservoir water level

##### b. On Synchronising Panel

- (i) Generator terminal voltage
- (ii) Main transformer primary voltage
- (iii) Generator circuit frequency
- (iv) Main transformer primary circuit frequency
- (v) Synchroscope

##### c. On Recording panel

- (i) Hydraulic turbine bearing temperature



- (ii) Generator bearing temperature
- (iii) Generator kWh value
- (iv) Speed indicator

#### 14.6.6 Indication and Annunciation Items

Group status indicators and group fault annunciators shall be provided on the main control panel. Wording on each indicator may be abbreviated as the case may require and notation on each fault annunciators shall be in device number or abbreviated wording in character.

Indicating lamp assemblies shall properly be provided on the control panel for position indicator of circuit breakers and disconnecting switch.

##### a. Group Status Indicator

Group Status indicator shall be provided for the following items:

- (i) The generating unit is operated under manual control
- (ii) The generating unit is at stand still "STOP"
- (iii) All generator starting conditions are established
- (iv) The inlet valve is fully opened "INLET VALVE"
- (v) The generating unit is running "RUNNING"
- (vi) The generator field excitation is applied "EXCITATION"
- (vii) The generator is operated in parallel with the power system "PARALLEL"

#### 14.6.7 Board Construction

The main control panel, relay panel and unit automatic control panel shall be arranged to form self supporting, dead front, vertical simplex type board construction. The board shall be totally enclosed, by sheet steel panels not less than 2.3 mm thick, with angle or channel edge bent to 7 mm radius, seam-welded at corners, and ground smooth. Panels shall be bolted at the bottom to suitable steel channel sills with necessary framing which will hold the structure rigidly together to form a self-supporting dead front type of structure. Outside panels shall not be drilled or welded for attaching wires, resistors, or control board devices.

Vertical edges of panels shall be so formed and bolted together that no gaps exposed to view will pass a 0.8 mm feeler gauge. The simplex type board shall be provided with access doors at rear side for ready access to the equipment inside each panel.

The synchronising panel to facilitate manual synchronising shall be provided on one side of the board at convenient location.

#### 14.6.8 Arrangement

The main control panel shall be so arranged by the Contractor and shall be subject to the Engineer's approval.

The mimic diagram of generator, transformers, circuit breakers with illuminated pushbutton switches and disconnecting switch with position indicating lamps shall be provided on the main control panel to form single line diagram for main circuit, which will simulate actual electrical connections.

The mimic buses and symbols shall be made of plastic strips secured to the panel surface by concealed screws or other approved means. The mimic diagram showing buses which shall be at least 10 mm wide and 2 mm thick, and symbols shall be colour coded for respective voltage.

#### **14.6.9 Meters and Instrument**

All indicating instruments shall be of flush mounted back connected, dust-proof and heavy duty switchboard type. Each indicating metre and instrument shall have a removable cover, either transparent or with a transparent window. Each metre and instrument shall be suitable for operation with the instrument transformers under both normal and short circuit conditions.

Scale plates will have a permanent white circular or rectangular finish with black pointer or markings. The scale ranges shall be determined from current transformers and voltage transformer ratio.

Each wattmeter and watt-hour metre shall be fitted a reverse running stop. All indicating instruments shall be approximately 110 mm square enclosures and shall be provided with clearly readable long scale, approximately 240 degrees. The maximum error shall be not more than one and a half (1.5) percent of full scale range.

The water level indicators shall be of digital type of four figures suitable for the water level gauging equipment provided.

#### **14.6.10 Synchroscope**

The synchroscope shall be furnished complete with accessories and shall be designed so that the indication pointer shall rotate by the relative phase of the generator terminal and main transformer primary voltage circuits. The pointer shall not rotate if the voltage from either circuit is lost. The synchroscope shall have full 360 degree scale and shall be marked to show the synchronism point.

#### **14.6.11 Group Status Indicator**

The groups status shall be provided with visual indicating of operating status and conditions. Pushbutton for lamp test shall be provided on the main control panel.

#### **14.6.12 Control and Instrument Switches**

All control switches shall be of flush mounted, back connected, dust proof and heavy duty switchboard type. Each illuminated pushbutton switch shall be integrated with light emitting diode (LED)

Selector switches and synchronising switch shall be of maintained contact type with the required number of positions and shall have round notched

handle. Each selector switch and synchronising switch shall be provided with an escutcheon plate to show each operating position. The switch identifications shall be engraved on the escutcheon plates or on separate nameplates.

#### **14.6.13 Indicating Lamp Assemblies**

Indicating lamps assemblies for the main control panel shall be of the switchboard type, with appropriate coloured lamp covers integrally mounted. The lamps covers shall be made of a material which not be softened by the heat from the lamps.

#### **14.6.14 Automatic Synchronising Equipment**

One set of automatic synchronising equipment shall be provided on the main control panel. The automatic synchronising equipment shall be designed to permit either manual or automatic control turbine speed, generator voltage and circuit breaker closing, for the purpose of connecting the generator with the existing power system with a minimum disturbance to the generator or the system.

The automatic synchronising equipment shall include an automatic synchroniser, a voltage relay and speed matcher.

The voltage shall be feed from the voltage transformers connected to low voltage bus and generator circuits as shown on the single connection diagram.

#### **14.6.15 Protective Relays**

Each protective relay shall be of the flush mounted, back connected, dust proof, switchboard type, with rectangular case.

Auxiliary relays which may be continuously energised shall operate successfully over a range of 75 percent of the rated voltage without exceeding the temperature rise limits for the operating coils.

The detailed requirements for protective relaying are as follows:

a. **Generator AC Overvoltage Relay**

Protection for overvoltage in the generator circuit shall be provided by overvoltage relay with high speed times characteristics.

b. **Overcurrent Relay**

Protection for short circuit fault and overload shall be provided by overcurrent relays with the suitable time characteristic.

c. **Ground Overvoltage**

Ground overvoltage relays for protection of ground fault in the generator circuit and 20 kV circuit.

d. **AC Undervoltage Relay**

AC undervoltage relay for the secondary circuit of the station service transformer

e. **Power Relay**

Alarm for low power generation shall be provided by the power relay on the generator circuit. The relay shall be suitable detection of generating output of under 40% rated.

f. **Lockout Relay**

Lockout relay for the Emergency stop protection shall be provide with manual reset features for the operating contacts.

#### **14.6.16 Test Blocks**

Test blocks shall be provided in the main control panel and relay panel as required. The test block shall be of the back connected semi flush mounted, switchboard type with removable covers. All test block shall be provided with the suitable circuit identification and shall be arranged to isolate completely the instrument from the instrument transformer and other external circuits so that no other device will be affected, and means shall be provided for testing either from an external source of energy or from the instrument transformer by means of multiple test pugs. The test blocks and plugs shall be arranged so that the current transformer secondary circuits can not be open circuited in any position while the test plugs are in place, being inserted, or being removed.

#### **14.6.17 Unit Automatic Control Panel**

The unit automatic control panel shall be equipped with all necessary relays and instruments for automatic control of the turbine generator unit. If a program controller is applied to the automatic sequence control function, the emergency stopping sequence, circuit breaker tripping sequence, lockout relaying and required interlocks shall be provided on the unit automatic control panel or on the relay panel separately from the programmable controller function.

The programmable controller shall be provided with a power supply unit for auxiliary power supply.

#### **14.6.18 Equipment Details**

The panel mounted equipment and devices shall include but not be limited to the following :

a. **Main Control Panel**

- (i) AC voltmeter rated for generator circuit
- (ii) Wattmeter rated for generator circuit
- (iii) Speed indicator 0 - 1500 rpm
- (iv) Guide vane opening and load limited position indicator
- (v) AC voltmeter 0 - 30 kV for 20 kV distribution line
- (vi) Wattmeter rated for 20 kV for 20 kV distribution line
- (vii) AC voltmeter 0 – 500 V for station service transformer secondary

- (viii) Wattmeter 0 – 400 kW for station service transformer secondary circuit
- (ix) Set of group fault annunciator
- (x) Set of group status indicator
- (xi) Set of mimic bus
- (xii) Mater control switch – positions of "START" and "STOP"
- (xiii) Control switch with two position of "RISE" and "LOWER" for speed and load setter
- (xiv) Control switch with two positions of "RAISE" and "LOWER" for load limited.
- (xv) Control switch with two positions of "RAISE" and "LOWER" for voltage regulator.
- (xvi) Control switch with the three position of "AUTO", "OFF" and "MANUAL" for synchronising control
- (xvii) Control switch for manual emergency shutdown
- (xviii) Control switch with two positions of "ON" and "OFF" for low circuit breaker
- (xix) Control switch with two positions of "ON" and "OFF" for 20 kV circuit breaker
- (xx) Lockout relay reset switch
- (xxi) Audible alarm reset switch
- (xxii) AC voltmeter selector switches
- (xxiii) DC control source supply switch
- (xxiv) Watt-hour meters
- (xxv) Set test blocks

**b. Relay Panel**

- (i) Overcurrent relays for generator circuit
- (ii) Overvoltage relay for generator circuit
- (iii) Ground overvoltage relay for generator circuit
- (iv) Power relay for generator circuit
- (v) Direct current overvoltage relay for excitation system
- (vi) Lockout relay
- (vii) Overcurrent relays for 20 kV distribution line
- (viii) Ground overvoltage relay 20 kV distribution line

- (ix) Under voltage relay for station service transformer secondary circuit
- (x) Overspeed relay
- (xi) Synchronous speed relay
- (xii) Under speed relay
- (xiii) Set of auxiliary relays

c. Synchronising panel

- (i) Synchroscope
- (ii) AC voltmeters 0 – 500 V
- (iii) Frequency meters 45 – 50 – 55 Hz

d. Recording panel

- (i) Forebay water level
- (ii) Recording watt-hour
- (iii) AC voltmeters 0 – 500 V
- (iv) Data Logger
- (v) Generator kWh value
- (vi) Discharge by hydraulic turbine
- (vii) Discharge by valve

#### 14.6.19 Accessories for Control and Relay Board

The Contractor shall include in the supply the following accessories for the correct installation, operation and maintenance of the equipment:

- a. Channel bases
- b. Side (or end) panels
- c. Ground bolts and nuts
- d. Grounding pads
- e. Test plugs for test terminals
- f. Relay testing plugs
- g. Maintenance tools
- h. Other accessories recommended by the manufacturer

#### 14.6.20 Spare Parts for Control and Relay Board

The following items shall be supplied and quoted spare parts:

- a. 500% of actual use of indicating lamps of each type

- b. 50% of lamps covers of each colour for indicating lamps
- c. 500% fuses of each type and rating used
- d. 100% of resistors for indicating lamps
- e. One (1) complete assembly of each type of protective relay, auxiliary relay, timing relay, print circuited board, rectifier and other special device.
- f. 5% or at least one (1) piece of each type of small component like resistor, inductors, capacitors, transformers, transducers etc.
- g. One (1) set of spares recommended by the manufacturer for other devices, which are not covered above.

#### **14.6.21 Test for Control and Relay Board**

The following tests shall be carried out at the manufacturer's workshop in the presence of the Engineer before shipment.

- a. Construction inspection
- b. Sequential operation tests
- c. Meter and relay tests
- d. Battery charger characteristics tests

The tests as specified shall be carried out by the Contractor at the Site.

### **14.7 CABLES AND FITTINGS**

#### **14.7.1 Scope**

The following materials shall be supplied and installed in the Jatibarang power station and the Krapyak substation under this paragraph:

- a. 20 kV Power cables and fittings
- b. 6.6 kV Power cables and fittings
- c. Control Cables
- d. Other materials

#### **14.7.2 20 kV Power Cables and Fittings**

- a. General

This section covers the manufacture, testing before shipment transport to the site, erection and tests at the site of 20 kV power cables.

The contractor shall choose the type of cable from mentioned below, and comply with Cable schedules and Drawings.

All power cables will be adequately sized according to the electrical requirements of the system.

- (i) Aluminium conductor, triplex cross-linked polyethylene insulated and PVC sheathed copper tape shield (AI-CVT) power cable.
- (ii) Aluminium single conductor, cross-linked polyethylene insulated and PVC sheathed copper type shield (AI-CV) power cable.

**b. Requirements**

The following high voltage cables to be incorporated in the 20 kV power supply system shall be furnish by the Contractor.

- (i) Interconnection between the end of over head transmission line at top of No.1 Steel tower and the terminals in the 20 kV metal cubicle of the Jatibarang power station.
- (ii) Interconnection between the terminals in the 20 kV metal cubicle and the 20 kV terminals of the Main transformer.
- (iii) Interconnection between the end of over head transmission line and the terminals in the 20 kV metal cubicle of the Krapyak substation.

**c. Construction**

The cable construction shall be as follows :

- (i) Rated voltage 20 kV  
Single-core, and/or triplex three (3)-core insulated conductors each containing :

- Conductor made of stranded aluminium conductors.
- Conductor insulated with cross-linked polyethylene or ethylene-propylene rated for 90 conductor temperature.
- Copper tape shield.

Each of the three-phase conductors shall be permanently identified by means of colours applied longitudinally in the insulation or by an alternate means approved by the Engineer.

- (ii) Fittings for 20 kV AI-CV cable and/or 20 kV AI-CVT cable shall be as follows :

Fittings for 20 kV AI-CV cable and/or 20 kV AI-CVT cable shall consist of outdoor and indoor terminating sets, junction boxes and cable brackets. The indoor terminating sets shall be used for the terminals in the cubicles.

**d. Tests**

The following tests shall be carried out at manufacturer's workshop :-

- (i) Tensile tests
- (ii) Elongation tests
- (iii) Resistance tests
- (iv) Withstand voltage test for power cable
- (v) Characteristics



(vi) Construction

### 14.7.3 6.6 kV Power Cables and Fittings

a. General

This section covers the manufacture, testing before shipment transport to the site, erection and tests at the site of 6.6 kV power cables.

The Contractor shall choose the type of cable from the below mentioned, and comply with Cable schedules and Drawings.

All power cables will be adequately sized according to the electrical requirements of the system.

- (i) Copper conductor, triplex cross-linked polyethylene insulated and PVC sheathed copper tape shield (Cu-CVT) power cable.
- (ii) Copper single conductor, cross-linked polyethylene insulated and PVC sheathed copper type shield (Cu-CV) power cable.

b. Requirements

The following high voltage cables to be incorporated in the 6.6 kV power supply system shall be furnish by the Contractor.

- (i) Interconnection between the 6.6 kV terminals of the main transformer and the terminals in the 6.6 kV outdoor metal cubicle of the substation.
- (ii) Interconnection between the terminals in the 6.6 kV outdoor metal cubicle of the substation and the terminals in the 6.6 kV indoor metal cubicle of the cubicle room in the power station.
- (iii) Interconnection between the 6.6 kV indoor metal cubicle of the cubicle room and the line terminals of the generator.
- (iv) Interconnection between the neutral terminals of the generator and the terminals of the neutral grounding resistor cubicle.

c. Construction

The cable construction shall be as follows :

- (i) Rated voltage 6.6 kV
- (ii) Single-core, and triplex three (3)-core insulated conductors each containing :
  - Conductor made of stranded copper conductors.
  - Conductor insulated with cross-linked polyethylene or ethylene-propylene rated for 90 conductor temperature.
  - Copper tape shield.

Each of the three-phase conductors shall be permanently identified by means of colours applied longitudinally in the insulation or by an alternate means approved by the Engineer.

Fittings for 6.6 kV Cu-CV cable and/or 6.6 kV CV-CVT cable shall be as follows :

Fittings for 6.6 kV Cu-CV cable and/or 6.6 kV Cu-CVT cable shall consist of indoor terminating sets, junction boxes and cable brackets. The indoor terminating sets shall be used for the terminals in the cubicles.

**d. Tests**

The following tests shall be carried out at manufacturer's workshop :-

- (i) Tensile tests
- (ii) Elongation tests
- (iii) Resistance tests
- (iv) Withstand voltage test for power cable
- (v) Characteristics
- (vi) Construction

**14.7.4 Low Voltage Cables and Fittings**

**a. General**

The term "Low voltage" is applied to cable rated 600 V and under.

The type of low voltage cables shall be as follows :

- (i) Polyvinyl chloride (PVC) insulated and termite-proof PVC sheathed control cable (CVV)
- (ii) PVC insulated and termite-proof PVC sheathed control cable with copper tape electrostatic shielding (CVV-S).
- (iii) Single or multi copper cores cable with copper shielding tape or mesh. The sectional area of core shall not be less than 2.5 square mm.
- (iv) Colours of core insulation shall be as follows:

One core .....	Black
Two cores.....	Black and white
Three cores .....	Black, white and red
Four cores .....	Black, white, red, and green
Five cores.....	Black, white, red, green, and yellow
Six cores .....	Black, white, red, green, yellow, and brown

**b. Insulated Wires**

600 V, PVC insulated wires shall be used for power heater circuits inside equipment. The minimum size shall be 2.5 square mm. Soft annealed copper stranded wire appropriately sized based on the likely fault current and protection in the circuit shall be supplied to connect the ancillary Plant, metal enclosures, motors, switchgear etc. to the station grounding system.

**c. Construction and Requirement**

**(i) Requirement**

The following low voltage power and control cables are required to be furnished by the Contractor.

- Cable required for connections of all Plant furnished under this specification.
- Cables between AC cubicle and 380 V and 220 V AC distribution panels.
- Cables between DC cubicle and 110 V DC distribution panels.
- Construction
- Control cables shall be constructed as follows.
- Multi-conductor cables rated for 600 volts.
- Conductor made of a minimum cross-sectional area of  $3.5 \text{ mm}^2$  made up of stranded copper conductors.
- Insulated conductors bonded together by a non-fibrous non-hygroscopic filler.
- Polyester packing tape over the filter.

For the following circuits, shielded cable shall be provided on the conductors.

- Overall copper shield on cables for outdoor use in the substations.

**d. Tests**

The following tests of power cables shall be carried out at manufacturer's workshop before shipment:

- (i) Measurement of resistance
- (ii) Insulation test for power cables and insulated wire
- (iii) Characteristic test
- (iv) Construction check

**14.7.5 Other Materials**

All construction materials such as steel conduit pipes, PVC pipe, angle steel, channel steel, steel plates, cable supporting brackets and racks, cable rack cover, cable shaft cover, cleat, bolts, nuts and other items required for putting the generating plant into operation shall be provided without extra charge and shall comply with the highest grade specified in the relevant standard.

Conduit pipe or PVC pipe shall be provided in locations where control cables or insulated wires will be exposed in the power station and the outdoor switchyard.

Cable supporting brackets and racks with suitable cleats shall be provided for installation of all power and control cables in the cable duct in the powerhouse and outdoor switchyard.

Steel plates shall also be supplied to cover the block out or extra space where conduit pipes or cable running through.

## **14.8 ANCILLARY EQUIPMENT**

### **14.8.1 Scope**

The following equipment shall be supplied and installed in the power station under this paragraph:

- a. Telephone Systems
- b. Lightning and Auxiliary Service System

### **14.8.2 Telephone Systems**

#### **a. General**

The telephone equipment to be supplied and installed for the power plant is as follows :-

- (i) Private automatic branch exchanger (PABX)
- (ii) Telephone sets (Indoor and outdoor types)
- (iii) Communication cables and conduit
- (iv) Accessories

#### **b. Design and Construction Characteristics**

The telephone system shall be of an automatic telephone system with twenty (20) internal connection lines.

Telephone sets (or stands) shall be incorporated in the out-standing locations at the power house, substation and control room.

#### **c. Type and Apparatus to be Provided**

The following outlines of the equipment shall be incorporated in the Jatibarang power station telephone system.

- (i) Private Automatic Branch Exchanger (PABX)  
PABX shall provide automatic exchanging of the telephone circuits incorporated in the Jatibarang power station, namely the private telephone lines and public telephone lines.
- (ii) Telephone console  
One set of telephone console shall be incorporated into the control desk in the control room. A package console available as a standard item is to be used for private telephone circuits.
- (iii) Telephone set  
Following three kind of telephone sets shall be incorporated in the system.

Type A : Table set type

Type B : Wall attachment type

Type C : Outdoor water proof type (encased in metallic cabinet)

Classification of usage and location of installation of the telephone sets are given in the Table below.

Location	Telephone Set Type		
	A	B	C
i) Power house			
Second floor			
Office room	3		
First floor			
Control room	2		
Machine shop		1	
Entrance hall		1	
Basement-1F			
Cubicle room		1	
Basement-2F			
Machine hall		1	
Valve room		1	1
ii) Outdoor			
Substation			1
iii) Others			
Garage		1	
Dam control center	1		
Spare	3	2	1
Total	9	8	3

d. Cable Installation

The telephone network configuration is a radial network. Each apparatus is connected via individual pilot cable pairs with the central unit.

Cable installation shall comprise the complete outdoor installation and indoor installation including supply and laying of cables, conduit cables, conduit and supply of all ancillary devices necessary for the proper functioning of the telephone system.

The conduit system shall be of galvanised rigid steel with all the necessary, boxes, fittings, fastening brackets, etc. required for a complete installation.

e. Test

The following tests shall be carried out at the manufacturers' workshop :

- (i) Appearance inspection
- (ii) Construction inspection
- (iii) Operation set
- (iv) Insulation resistance measurement

- (v) Other necessary test

### 14.8.3 Lighting and Auxillary Service System

a. General

The lightning and auxiliary service system shall be supplied and installed in the following:

- (i) Outdoor area lighting around powerhouse.
- (ii) Indoor lighting and auxiliary service for the powerhouse.

The following apparatuses and materials shall be furnished and installed to complete the lighting and auxiliary service system:

- (i) Distribution panels
- (ii) Concrete pole(s) for outdoor lamps

All conduits and electrical wires for lighting fixtures and auxiliary service such as convenience outlets etc.

- (i) Lighting fixtures including bulbs and supports
- (ii) Miscellaneous materials to complete the system

b. Electrical Apparatus and Materials

- (i) Distribution panels

Electric circuits, classification, rating and numbers of circuit breaker shall be included in Contractor's drawings and submitted in advance for approval of the Engineer.

- (ii) Lighting fixture

- Fluorescent lighting fixtures shall be industrial type high power factor and rapid start.
- Incandescent lighting fixtures shall have high quality lamp holders in accordance with the local standard.
- Mercury lighting fixtures shall be equipped with a screwed base lamp holder suitable for high pressure mercury lamp, and appropriate stabiliser of high power factor for stable operation
- The lighting fixtures for outdoors use shall be of a weather proof type. Special care shall be exercised on selection of fixtures so that illumination of the lamps is not obstructed by accumulation of insects and dust.

- (iii) Outdoor lighting supports

Supports of the outdoor lighting fixtures around the powerhouse shall be concrete poles, with height not less than 7.00 mm from the ground. Wiring for outdoor lamps shall be placed underground.

- (iv) Joint boxes

The boxes for wire joints to be concealed in concrete shall be of galvanised sheet steel type and shall be fitted with appropriate

covers, where necessary, to set the boxes in flush with the finished surface of the structure. The boxes to be used for the exposed installation shall be of galvanised cast steel or alloy to be fitted with appropriate fitting and covers.

(v) Tumbler switches

Wall switches shall be of the enclosed flush or surface mounting tumbler type, single pole, 240 volt, 15 amperes and shall be fully recessed within the boxed with suitable plate for covering.

(vi) Convenience outlets

Convenience outlets shall be of 2 pin type, 240 volt, 15 amperes, three wire grounded type, and provided with suitable outlet box and cover plates. Waterproof convenience outlet shall be provided with a thread cap and thread socket.

(vii) Conduits

The rigid steel conduits shall be of thick wall galvanised type the conduits shall have a minimum thickness of 2.3 mm and have a minimum inside diameter of 16 mm. Where the conduit installed is exposed, it shall be coated with epoxy enamel.

(viii) Miscellaneous materials

All apparatus, accessories and materials which have not been specifically mentioned but which are necessary for the performance of the works shall be provided by the Contractor.

c. Installation Work

(i) General

All installation works shall be carried out by the Contractor in accordance with regulations of this section and the instruction of the Engineer. The arrangement of fixtures and apparatus shall conform to the Contractor's drawings.

(ii) Lightning fixtures

The exact location and height of fixtures shall be determined by the structural and mechanical limitations of building, and fixtures shall be installed in such a manner as to avoid obstructions and to give proper illumination. Fixtures shall be installed in such a manner as not to damage outlet boxes, conduit tubes, wall, ceiling, etc, by their weight.

(iii) Conduit work

Conduit shall be concealed within or pierced through the structure without effect on their construction and strength. The cut ends of conduit shall be smoothed. Pull boxes shall be provided for the conduit system to give easy leading in or replacement of the wires. The bending radius of the conduit tube shall be not less than 6 times its inside diameter without normal bend. Exposed runs of conduit shall have steel supports spaced not more than 1.5 metres. They shall be installed with runs parallel or perpendicular to adjacent walls, structural members, or intersections of vertical planes and ceilings, with right-angle turns, so as to create a neat appearance.

Switch boxes or outlet boxes with appropriate covers shall be installed at the appropriate locations. When necessary, the Contractor shall relocate outlets so that, when fixtures or other fittings are installed, they will be symmetrically located according to room layout and will not interfere with other work or equipment.

Conduit shall be installed in such a manner as to insure against trouble from the collection of trapped condensation. U-shaped runs shall be avoided as far as possible. Conduit shall be connected mutually by means of junction and pull boxes with galvanised locknuts and bushings. Connected portions of conduit system shall be coated with anti corrosive paint. Exposed runs of conduit including boxes, support and all other fittings shall be complete with finished paint, of which colour will be indicated by the Employer.

The contractor shall exercise the necessary precautions to prevent dirt, plaster, trash or moisture in conduit pipe, fittings, and boxes during the course of installation.

(iv) Cabling and Wiring

The conductor shall be continuous between outlets, and no junction shall be made except within outlet or junction boxes. The conductor shall be drawn through ducts of conduits after they have been cleaned. Oil or grease shall not be used as a lubricant for the drawing operation, but an approved compound may be used for this purpose.

(v) Indoor Cable Laying

Cables shall be securely fastened along the structure with saddles or other suitable supports spaced not more than 1.5 metres apart. Metallic racks and the like shall be installed in cable ducts and shaft for laying, where necessary. Conduits shall be utilised where the cables may be damaged. Cables shall be laid in conduit where they are concealed in the concrete structure to protect the cables and to provide easy replacement.

(vi) Cable laying in trench

The cables to be installed in the floor trenches shall be laid on the floor of the trench or fastened on the wall of the trench or fastened on the wall of the trench in neat workmanship. Each cable shall be provided with tag which indicate circuit number or circuit destination. The cables to be fastened installed on the trench wall shall be supported with factory made devices at 1.5 m intervals.

(vii) Grounding

Unless otherwise directed by the Engineer, all non current carrying metal parts of electrical Plant and fixtures shall be grounded through the rigid steel conduit system. All joints of conduits shall be tight. The conduits shall be connected with the grounding mesh as far as applicable. Grounding rods shall be installed where required or as indicated by the Engineer.

(viii) Pull boxes

Pull boxes shall be installed at locations determined by the Contractor after consultation with the Engineer. The pull boxes



shall be of sheet metal galvanised type, the size of which shall be 150 mm x 150 mm x 100 mm.

**d. Spare parts**

The following spare parts shall be supplied:

- (i) 10% of actual use of lighting fixture of each type
- (ii) 200% of actual use of bulbs and tubes of each type used for indoor lighting
- (iii) 20% of actual use of mercury lamps used for outdoor lighting
- (iv) 200% of actual use of fuse or breaker of each type
- (v) 5% of other apparatus

**e. Tests**

At the Site

The following tests shall be carried out by the Contractor at the Site after the completion of Installation :

- (i) Operation test
- (ii) Measurement of insulation resistance
- (iii) Circuit continuity test

## **14.9 GROUNDING SYSTEM**

### **14.9.1 Grounding System and Connections**

The power station grounding system shall be provided by the Contractor.

The Contractor shall establish by measurement at the site the most suitable location for the earth electrodes. Electrical measurements of the subsoil shall be made at various depths from which the ground resistivity and hence the expected resistance of the proposed grounding system may be predicted.

Earth connections will be provided for each item of Plant with a suitable terminal point for connection to the station main grounding system. This system will comprise a continuous main copper earth bar installed around the station with subsidiary and branch copper connections to the various items of Plant.

The steelwork of generators, switchgear, transformers, resistors, and other electrical apparatus and building steelwork shall each be connected to the main earth by means of a separate subsidiary connection.

Cable sheaths may be earthed in groups by a separate branch connection to each item of Plant in the group, the branch connections being connected by a single subsidiary connection to the main earth bar.

All connections to earth bars shall be made with a single branch and there shall be no sub-branches.

All copper bars and joints buried in open ground, or in concrete floors, or laid in sand filled chases, or drawn in ducts shall be protected. In all other locations the copper bars shall be protected where necessary against corrosion.

#### **14.9.2 Grounding Bars and Cables**

The quality of copper bar shall be medium drawn strip of not less than 100 percent International Standard. Earth cables shall have a PVC sheath.

Where copper bars and joints are buried in open ground or in concrete floors, or laid in sand filled chases, or drawing in ducts, they shall be protected.

Where joints are to be buried, the backfilling or trenches and sand filling of chases shall not be carried out until the Engineer has inspected and approved the joint.

Precautions shall be taken to avoid corrosion of earth electrodes, bars and cleats in contact with dissimilar metals or with concrete or masonry.

The grounding system shall be designed and installed by the Contractor in a manner approved by the Engineer. No grounding conductor shall be smaller section than 25 mm x 3 mm. Where the earth bar is 150 mm<sup>2</sup> or larger it shall be secured by stand off bolted saddles at intervals of not more than 1.2 m. Installation of grounding cables shall conform to the requirements of the installation of power cables.

Joints on earth bars shall be made by low temperature brazing or thermit welding process.

All joints shall have a resistance not exceeding that of an equivalent length of conductor, and the Engineer may require any joint to be tested to prove compliance with this requirement.

No grounding conductor shall be drilled with a hole larger than 12 mm diameter clear for attachment to the apparatus to be earthed, where holes larger than this are required a suitable tab shall be fitted to the end of the conductor.

#### **14.9.3 Earth Electrodes**

Where required, earth electrodes to be supplied and installed under this Contract shall consist of either.

- a. Cast iron plates, 1.2 m<sup>2</sup>, which shall be placed vertically in holes or
- b. Cast iron pipes or
- c. Copper rods or
- d. Copper mats

Bolted removable links and a copper terminal strap shall be provided in the connections between the electrodes and the main earth conductor and shall be housed and mounted in an accessible position. Those in the ground shall be in a shallow manhole local to the system earth point.

Dissimilar metals liable to electrolytic action must be avoided in the connections between the main earth bar, links and electrodes.

#### **14.9.4 Cleats for Earth Bar**

Cleats shall be of the heavy brass stand off type shaped to suit the size of the bar. Cleats shall be of the two holes fixing and shall secure the conductor against movement when finally tightened up.

All cleats shall be fixed to brickwork or concrete by ragbolts or other approved means and to steelwork by self tapping screws.

No drilling of the earth conductor shall be allowed except in the jointing or terminating unless approved by the Engineer.

#### **14.9.5 Terminations**

Earth terminal studs, washers and locknuts shall be provided on all apparatus and machines. The building steelwork shall be also be bonded to the grounding system.

Where earth terminal studs are specified they shall consist of 12 mm diameter brass studs drilled and tapped into the machine frame or stanchion.

#### **14.9.6 Bonding and Grounding of Cable Sheaths and Terminations**

At point near each termination of all power cables not laid in trefoil, and fused at 63 amps and above, the bonding and grounding of multi-core power cables shall be means of a branch earth tape connection from each cable gland armour clamp, to the earth bar. Cables protected by fuses below 63 amps shall be earthed in similar manner at the supply end only. The surfaces of the armour clamp, armour wire and gland are to be thoroughly clean to ensure a first class connection.

Except where otherwise approved, single core cables carrying alternating currents shall be run in close trefoil formation so as to keep to a minimum losses and voltage rise. With this arrangement, the cable armour shall be insulated from the switchgear or other apparatus at bolt ends and bonded and earthed via a link at the supply end of the cable. The clamps must be carefully insulated from the Plant.

#### **14.9.7 Lighting Protection**

The power station shall be adequately protected against lightning strikes to protect fully all Plant installed within the power station area to a failure rate of shielding from direct lightning strikes or not greater than 0.1 per cent per annum.