WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-15-02

GAS-INSULATED VACUUM CIRCUIT-BREAKER HIGH-VOLTAGE SWITCHBOARD

I N D E X

WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-15-02

GAS-INSULATED VACUUM CIRCUIT-BREAKER HIGH-VOLTAGE SWITCHBOARD

1. GENERAL

1.1 Scope

This Specification covers the design, construction, manufacture, inspection and testing of high-voltage switchboard using gas-insulated vacuum circuit-breaker.

1.2 Standards

The switchboard shall comply with the latest editions and amendments of the relevant International Electrotechnical Commission (IEC) and British Standards (BS).

In particular, the switchboard shall comply with the following standards:-

IEC 62271-1	High-voltage switchgear and controlgear - Part 1: Common specifications for alternating current switchgear and controlgear
IEC 62271-100	High-voltage switchgear and controlgear - Part 100: Alternating-current circuit-breakers
IEC 62271-102	High-voltage switchgear and controlgear - Part 102: Alternating current disconnectors and earthing switches
IEC 62271-200	High-voltage switchgear and controlgear - Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
IEC 61869-1	Instrument transformers - Part 1: General requirements
IEC 61869-2	Instrument transformers - Part 2: Additional requirements for current transformers
IEC 61869 - 3	Instrument transformers – Part 3: Additional requirements for inductive voltage transformers

IEC 61869 - 5	Instrument transformers – Part 5: Additional requirements for capacitor voltage transformers
IEC 60051	Direct acting indicating analogue electrical measuring instruments and their accessories
IEC 60073	Basic and safety principles for man-machine interface, marking and identification - Coding Principles for indicators and actuators
IEC 60099-4	Surge arresters – Part 4: Metal-oxide surge arresters without gaps for a.c. systems
IEC 60099-5	Surge arresters – Part 5: Selection and application recommendations
IEC 60137	Insulated bushings for alternating voltages above 1000V
IEC 60255-1	Measuring relays and protection equipment - Part 1: Common requirements
IEC 60269	Low-voltage fuses
IEC 60282	High-voltage fuses
IEC 60502-4	Power cables with extruded insulation and their accessories for rated voltages from 1kV up to 30kV - Part 4: Test requirements on accessories for cables with rated voltages from 6kV up to 30kV
IEC 60529	Degrees of protection provided by enclosures (IP code)
IEC 60898	Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations
IEC 60947	Low-voltage switchgear and controlgear
IEC 60947-7-1	Low-voltage switchgear and controlgear - Part 7-1: Ancillary equipment - Terminal blocks for copper conductors
IEC 61238-1-1	Compression and mechanical connectors for power cables - Part 1-1: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages up to 1 kV (Um = 1.2 kV) tested on non-insulated conductors

IEC 61238-1-2	Compression and mechanical connectors for power cables - Part 1-2: Test methods and requirements for insulation piercing connectors for power cables for rated voltages up to 1 kV (Um = 1.2 kV) tested on insulated conductors
IEC 61238-1-3	Compression and mechanical connectors for power cables - Part 1-3: Test methods and requirements for compression and mechanical connectors for power cables for rated voltages above 1 kV (Um = 1.2 kV) up to 30 kV (Um = 36 kV) tested on non-insulated conductors
IEC 62053-21	Electricity metering equipment - Particular requirements - Part 21 : Static meters for AC active energy (classes 0.5, 1 and 2)
IEC 62053-23	Electricity metering equipment - Particular requirements - Part 23 : Static meters for reactive energy (classes 2 and 3)
IEC 62056-21	Electricity metering - Data exchange for meter reading, tariff and load control - Part 21 : Direct local data exchange
BS 6121	Mechanical cable glands

1.3 Type Test Certification

The switchboard shall be of a type tested model. The Contractor shall provide the necessary certification to confirm that the relevant type tests have already been performed on essentially similar equipment. Type test certificates for the proposed switchboard shall be submitted for verification after award of the Contract.

Type test certificates of short-circuit tests shall be issued by the Association of Short Circuit Testing Authorities, (ASTA) UK or equivalent. Type tests shall be carried out in accordance with the requirements of the relevant IEC Standards or other equivalent international standards.

The following type tests shall be performed on the switchboard and associated equipment :-

(i) Type tests of circuit-breakers to IEC 62271-100

- Short-time withstand current and peak withstand current tests
- Short-circuit current making and breaking tests
- Single-phase short-circuit tests
- Capacitive current switching tests

- Magnetising and small inductive current switching tests
- Mechanical operation tests
- Dielectric tests
- Temperature-rise test
- Measurement of the resistance of the main circuit

(ii) Type tests of switch-disconnectors and earthing switches to IEC 62271-102

- Short-time withstand current and peak withstand current tests
- Short-circuit making performance of earthing switches
- Operating and mechanical endurance tests
- Dielectric tests
- Temperature-rise test of switch-disconnectors
- Test to verify the proper functioning of the position indicating device

(iii) Type tests of metal-enclosed switchgear panels to IEC 62271-200

- Dielectric tests
- Measurement of the resistance of the main circuit
- Short-time withstand current and peak withstand current tests
- Pressure withstand test for gas-filled compartments
- Internal arcing fault test for each high-voltage compartment
- Temperature-rise test
- Gas tightness tests for gas-filled compartments

(iv) Type tests of voltage transformers to IEC 61869-3

(v) Type tests of current transformers to IEC 61869-2

Type test reports with complete details including the test arrangement and test results shall be submitted to supplement the test certificates when requested by the Engineer.

The equipment supplied shall be strictly in accordance with the design of the type-tested equipment.

2. SWITCHBOARD DESIGN AND CONSTRUCTION

2.1 Standards

Switchboard and switchgear panels shall be metal-clad and comply with IEC 62271-200.

2.2 General Design Information

2.2.1 Class and Rating

Rated voltage	12 kV
Number of poles	3
Earthing of system	Solid
System frequency	50 Hz ±2%
Installation type	Indoor
Power supply for circuit-breaker operation, controls and protection	110V d.c. ±15%
Power supply for auxiliary equipment	220V ±10% 1-phase 50 Hz ±2%
Degree of protection	IP3X of IEC 60529
Insulation class	Class B

2.2.2 Site Operating Conditions

Altitude above sea level	Up to 1000 m
Maximum ambient temperature :-	
Average over 24 hours	35ºC
Peak over any 4 hours	40ºC
Minimum ambient temperature	0ºC
Average yearly temperature	30ºC
Relative humidity	Up to 98%

2.3 Panel Layout

Switchboards shall consist of free-standing panels fitted together to form a continuous board of uniform height and shape when viewed from the front. Switchboards shall be extensible at both ends.

The panel shall be metal-enclosed, and designed to IP3X of IEC 60529 or better. It shall require minimum maintenance. Each panel shall consist of a vacuum circuit-breaker, a switch-disconnector, an earthing switch, HV voltage indication device and circuit testing facilities.

Either one of the following switchboard sectioning design will be accepted:

(i) Switchboard with busbar sectioniser in single integrated switchgear panel design. Additional switchgear panel(s) dedicated for busbar earthing is acceptable on condition that the switchgear panel(s) shall be interlocked with incomer switchgear panel to prevent inadvertent earthing to live; or

(ii) Switchboard with dual switchgear panels connected by coupling cable (and/or solid insulated bar) design. Busbar earthing via the operating the coupling circuit breaker is acceptable.

The vacuum interrupter of the circuit-breaker, the switch-disconnector and the earthing switch shall all be enclosed inside a gas-insulated stainless steel enclosure. A separate enclosure shall be provided for each panel. This enclosure shall be internal arc proof to IEC 62271-200. In addition to this enclosure, all other HV compartments including the HV cable termination compartment shall also be internal arc proof to IEC 62271-200.

Forced ventilation shall not be necessary under an ambient temperature of 40^{o}C and below. Ventilating grills, where required, shall not be located on the top of a panel.

The height of panels shall be not greater than 2700 mm.

The panel shall be designed for bottom entry of 11kV power cables. Where specified in the Particular Specification, either terminating the power cables at the front or back of the panel is acceptable. Nevertheless, extensive civil modification of the cable trench to suit the switchboard installation is not allowed.

Control relays, fuses, termination blocks and other auxiliary equipment shall be mounted inside an LV compartment, which shall be provided with a lockable front door. This compartment shall be situated in the upper section of the panel with the bottom of the compartment not lower than 1000 mm above floor level. Protection relays and other equipment specified shall be flush mounted at the front door of the LV compartment. The compartment shall be designed for top entry of control cables.

Busbars shall be contained in separate chambers at the upper or bottom section of the switchboard and shall be accessible through bolted covers only.

A separate HV voltage indication device shall be provided for each phase of the HV circuit of each panel. The device shall include a socket, which shall connect to separate capacitive voltage tapping point on each phase of the switchgear in order to facilitate the use of handheld equipment for verification of circuit dead condition and secondary phasing-out.

Apparatus on different panels with similar functions shall be located at a similar physical position.

All functional equipment such as selectors, indicators and protection relays associated with a panel shall be housed within that panel. Installation of such components on a separate panel shall not be acceptable.

A front fascia having the switch positions, interlocking and padlocking facilities, indicators and label for viewing, accessing and operating shall be provided. In addition, all switch position indication shall be designed in accordance with IEC 60073.

2.4 Panel Steelwork

Panels shall be made of steel sheet suitably braced to form a rigid structure.

The panel steelwork shall be acid or phosphate treated prior to application of epoxy powder coating. The paint work shall be of high quality and the total minimum dry film thickness of the paint coating shall be 25 microns. Details of the colour of the final paint coating shall be submitted for approval.

2.5 Panel Door Fittings

The edges of hinged panel doors shall be fitted with neoprene or rubber gaskets to prevent the entry of dust or constructed with other means to prevent the entry of dust as approved by the Engineer. Hinged panel doors shall be fitted with chromium plated handles with integral locks when applicable.

2.6 Switchboard Earthing

The metal-cladding of the switchgear shall be connected to earth in a manner that any part of the switchgear can withstand a fault current of 20kA for 3 seconds.

An earthing conductor running the entire length of the metal-enclosed switchgear shall be provided. The cross-sectional area of the earthing conductor shall be not less than 30 mm x 6 mm with earth terminals of not smaller than M8. All non-current carrying metallic parts shall be effectively connected to the earthing conductor, including provision for bonding cables sheaths and armouring.

2.7 Reference Voltage

The reference voltage for under-voltage and over-voltage relays shall be taken from the load side of the voltage transformer secondary fuses installed in the incoming supply panel via bus wiring.

Where the switchboard consists of two incoming supply panels and a bus-section or dual panel bus-section panel(s), the reference voltage bus-wires shall be linked through normally open auxiliary switches on the bus-section circuit-breaker and the incoming supply circuit-breakers such that the reference voltages from each voltage transformer will not be connected in parallel.

2.8 Bus Wiring

Bus wiring shall be used for auxiliary power supply and small wiring between panels. Bus wiring leads shall be provided by the switchboard manufacturer with PVC insulated copper cables terminated on terminal blocks.

Minimum cable size shall be 4 mm^2. Cables connected to 32A fuses, 63A fuses and 80A fuses shall be of minimum 6 mm^2, 16 mm^2 and 35 mm^2 respectively.

For auxiliary power supply, each set of terminals shall be segregated by plastic barriers and provided with individual plastic covers.

Ends of bus wiring for each panel shall be disconnected for transportation. The manufacturer shall provide wiring details for reconnection on site.

3. SWITCHBOARD EQUIPMENT AND AUXILIARIES

3.1 Busbars and Busbar Connections

3.1.1 Standards

The busbar system shall comply with IEC 62271-200.

3.1.2 Class and Rating

Busbars shall be three-phase and comprise separate sections for each circuit-breaker.

The rating of busbars shall be as follows:-

System voltage and fault rating	11 kV 380 MVA
Rated voltage	12 kV
Rated current	800 A, 1250 A and 2000 A

Rated short-time withstand current	20 kA 3 second
Rated lightning withstand voltage (peak)	75 kV
Rated power frequency withstand voltage to earth (1 minute)	28 kV
Mininium rated internal arc withstand current of busbar compartment	20 kA 1 second

3.1.3 Material

Main busbars shall comprise horizontally mounted single pole solid copper bars, which shall be silicon rubber insulated with an electro-conductive layer. This layer shall be earthed and safe-to-touch. Copper-clad or aluminium busbars shall not be accepted.

The busbar support insulators shall be of cast epoxy resin or materials of approved type.

3.1.4 Busbar Jointing and Supports

Jointing of sections of busbars shall be done by mechanical means. Soldered, braced, welded or riveted joints shall not be acceptable for busbar jointing.

Jointing faces of copper conductors shall be tinned or silver-plated, or other approved treatment to maintain effective conductivity of the joint.

Busbars of each panel shall be joined together with cross pieces and end pieces silicon-insulated connection. The busbar connection method shall support swift panel replacement without movement of the adjacent panels. The busbars shall be insensitive to dirt and condensation. On extension of the switchboard or panel replacement, the gas compartment of other panels shall not be affected and no on-site gas work shall be needed.

Busbar jointing bolts, nuts, and fixing accessories shall be included in the supply. The recommended torque for tightening the bolts shall be stated in the maintenance manual.

3.2 High-voltage Circuit-breaker, Switch-disconnector and Earthing Switch

3.2.1 Class and Rating

Circuit-breakers, switch-disconnectors and earthing switches shall be of triple pole, metal-clad and indoor type.

The ratings of high-voltage circuit-breaker, switch-disconnector and earthing switch shall be as follows:-

System voltage and fault rating	11 kV 380 MVA
Rated voltage	12 kV
Rated current	400 A, 630 A, 800 A, 1250 A and 2000 A
Rated lightning withstand voltage (peak)	75 kV
Mininum rated making current (peak)	50 kA
Minimum rated breaking current of CB (r.m.s. a.c. component)	20 kA
Minimum rated short-time withstand current	20 kA 3 second
Minimum rated power frequency withstand voltage to earth (1 minute)	28 kV
Rated operating sequence of CB	O-0.3s-CO-3min-CO
Minimum rated internal arc withstand current of enclosure	20 kA 1 second
Rate of rise of transient recovery voltage of CB and time to peak	Up to 0.34 kV/μs, 60 μs
Minimum rated current of incoming supply and bus-section CB	800A

3.2.2 Circuit-breaker

The circuit-breaker shall be of vacuum type and designed in compliance with IEC 62271-100.

The circuit-breaker shall be capable of interrupting rated short-circuit fault currents at least 20 times without maintenance or interrupter replacement

Circuit-breakers for pumpsets and power transformer feeders shall be capable of breaking a minimum current of 20% of the rated operational current of the connected equipment with power factor 0.05 lagging (no-load magnetising current of the connected equipment).

The chopping current of circuit-breaker shall not exceed 5A.

Facilities shall be provided for testing the circuit-breaker operation in the fully isolated status using normal control functions.

3.2.3 Switch-disconnector and Earthing Switch

Switch-disconnectors and earthing switches shall comply with IEC 62271-102.

The insulating properties across the isolating gap created by the switch-disconnector shall comply with the requirements of IEC 62271-1.

3.2.4 Construction Features

3.2.4.1 Housing

The vacuum interrupter of the circuit-breaker, switch-disconnector and earthing switch shall be installed in a gas-insulated stainless steel enclosure. The insulation gas shall be non-toxic environmentally friendly gaseous mixture complying with IEC 62271-200. The use of sulphur hexafluoride (SF_6) for insulation shall also be acceptable.

A pressure relief device shall be installed on the enclosure. The panel shall be designed to divert the relief pressure away from the operator at the front and rear of the panel.

The enclosure shall have means for visual indication of its internal gas pressure. A pair of clean contacts shall be provided for alarm indication of low gas pressure conditions. Gas leakage rate shall be no more than 1% per year.

The gas-filled chamber shall be pre-filled to the normal pressure without any need for site topping up or replacement prior to commissioning of the switchboard.

3.2.4.2 Circuit and Busbar Earthing

Circuit earthing shall be effected by the circuit-breaker without the requirements of any loose attachments. Unless otherwise approved by the Engineer, busbar earthing shall be effected by the circuit-breaker without additional earthing cable or tools. In case use of earthing tools is accepted, complete set of earthing tools necessary for carrying out busbar earthing shall be provided together without additional changes. The earthing connection shall be completed by closing the circuit-breaker in the normal manner with the earthing switch already switched to ‘EARTHED’ position.

Selection of circuit or busbar earth position by switch-disconnector and the earthing switch shall be possible only after the circuit-breaker has been fully opened. The selection between isolation and earthing positions by the switch-disconnector and the earthing switch respectively shall be by a fully interlocked and labelled position selector, which shall be designed to permit padlocking in any position.

Facilities shall be provided on all incoming and feeder panels for earthing the circuit side. Only the bus-section panel(s) shall be provided with facilities for busbar earthing.

3.2.4.3 Circuit Testing Facilities

Unless specified in the Particular Specification, test facilities shall be provided for carrying out high-voltage tests of cables and current injection tests of current transformers of each panel individually without affecting the other panels. With the aid of interlock, test shall be effected by application of testing device at 'CIRCUIT EARTHED' position and can be de-earthed for testing.

3.2.4.4 Mechanical Interlocks in Each Panel

The following mechanical interlocks shall be provided for the circuit-breaker, switch-disconnector and earthing switch in each panel:-

(i) The switch-disconnector and the earthing switch can only be operated unless the circuit-breaker is in open position;

(ii) The circuit-breaker can only be closed unless the closing spring is fully charged;

(iii) Any test access cover can be independently locked closed and the cover can only be removed when the earthing switch is closed;

(iv) Mechanical interlock shall be provided for the switch-disconnector and the earthing switch to prevent operating handles from being moved straight from the 'CLOSED' position, via 'OPEN', to the 'EARTHED' position to avoid inadvertent earthing operation. Alternatively, separate operating shafts shall be provided for operations between 'CLOSED' and 'OPEN' of the switch-disconnector and between 'OPEN' and 'EARTHED' positions of the earthing switch;

(v) With the circuit-breaker closed to an earth position, tripping shall only be effected by the manual tripping device on the operating mechanism, which shall be lockable at the closed position;

(vi) Padlocking facilities and approved locking devices shall be supplied for manual close/open device for switch-disconnector and earthing switch; and

(vii) Interlocks shall be provided in the operating mechanism of circuit-breaker to prevent simultaneous charging of the operating springs by manual means and by the motor.

3.2.4.5 Mechanical Interlocks between Panels/Equipment

The following mechanical interlocks shall be provided between panels/equipment:-

(i) Incoming supply and bus-section panels

Mechanical interlocks shall be provided in the two incoming supply panels and the bus-section panel such that the incoming supplies shall not be permitted to operate in parallel or to earth 'live' busbars.

(ii) Station auxiliary transformer feeder panels

Mechanical interlock shall be provided in the station auxiliary transformer feeder panel to prevent opening the front and rear double-leaf doors of the enclosure of the epoxy resin encapsulated type station auxiliary transformer (provided by others) unless the transformer supply cable feeder circuit is earthed by the associated earthing switch via the circuit-breaker.

(iii) Pump starter panels

Mechanical interlock shall be provided in the pump starter panel to prevent opening the door of the corresponding pump-motor power factor correction capacitor panel (provided by others) unless the motor and capacitor supply cables are earthed by the associated earthing switch via the circuit-breaker.

The mechanical interlock specified in this Clause shall be achieved by using key interlock. If the Contractor proposes to use other type of mechanical interlocks, details of this interlock shall be submitted after award of the Contract for approval. Electro-magnetic mechanical interlocks if proposed shall be of fail-safe design.

The key interlock shall be integrated with the operation of the associated panels. The keys shall not be interchangeable for different interlock applications.

The Contractor shall submit for approval the detailed key interlock scheme together with the technical brochures for all keys, interlocks and necessary key exchange boxes within one month after award of Contract. Within one month after approval, the Contractor shall forward the keys and door interlocks specified below to the Engineer for passing to the respective equipment suppliers for installation:-

(a) For each station auxiliary transformer feeder panel, the Contractor shall supply 1 key, 1 key exchange box and 4 sets of keys and locks for the door interlocks of the transformer enclosure.

(b) For each pump starter panel, the Contractor shall supply 1 set of key and lock for the door interlock of the power factor correction capacitor panel.

The Contractor shall however make available the above interlock keys at the switchgear panels in order to verify the correct operation of the key interlock system during the witnessed inspection and tests at works.

3.2.5 Components

3.2.5.1 Operating Mechanisms of the Circuit-breaker

The circuit-breaker operating mechanism shall be of stored-energy operation by means of a motor charged spring mechanism.

The mechanism shall be of the trip-free type. Operating mechanisms for the interrupter units shall be positively coupled to ensure simultaneous operation of the three phases.

The operating mechanism shall be provided with anti-pumping protection facilities.

The motor charged spring mechanism shall be provided with means for charging the springs by hand and a lockable shrouded mechanical push button for releasing the springs. A 'spring charged' and 'spring free' indicator shall be provided.

Positively driven mechanically operated indicating devices shall be provided to indicate whether a circuit-breaker is open or closed. A 4-digit mechanical operation counter shall be provided at each circuit-breaker to register the number of mechanical operations.

A lockable shrouded push-button for direct manual tripping of the circuit-breaker shall be provided.

3.2.5.2 Operation Mechanisms of the Switch-disconnector and Earthing Switch

The operating mechanism of the switch-disconnector and the earthing switch shall be of spring-assisted or motor driven design. The switching movements of the moving contacts of the switch shall be performed independently of the operating speed of the operation handle.

Operating mechanisms shall be positively coupled to ensure simultaneous operation of the three phases and provide indication of the status of the switch.

3.2.5.3 Shutters for Operating Mechanism

Covers such as shutters etc. shall be provided to cover the aperture of the operating shafts as means of mechanical interlock to prevent insertion of operating handles or keys in order to avoid mal-operations of the circuit-breaker, switch-disconnector and the earthing switch. The covers shall be equipped with padlocks to ensure operational safety.

3.2.5.4 Auxiliary Switches

Auxiliary switches shall be of double-break type and shall be positively driven in both directions.

The necessary auxiliary switches for the control functions specified shall be incorporated with a minimum number of normally open and normally closed contacts (not changeover contacts) as follows:-

Status	No. of normally open contact	No. of normally closed contact
CB 'CLOSE'	3	3
Switch-disconnector 'CLOSE'	1	1
Earthing switch 'EARTHED'	1	1
CB 'Spring Charged'	1	1

The contacts shall be rated for 10A operational current, and shall be capable of breaking at least 2A at 110 d.c. with a L/R time constant not less than 20 ms.

Auxiliary switches shall be used for tripping and closing interlocks. The use of repeat relays for this purpose shall not be acceptable.

3.3 Surge Suppression Devices

Surge suppression devices shall be installed in each pump starter panel for suppression of steep voltage rise and spikes generated due to motor switching. The surge suppression devices shall be of metal-oxide without gaps in compliance with IEC 60099-4. The ratings of the surge suppression devices to be provided shall be in compliance with the selection and application recommendations specified in IEC 60099-5.

The breakdown voltage of the device shall not exceed the following values to cope with the motor winding insulation level:-

System Voltage	11 kV
Surge suppression switching breakdown voltage to earth (0.2kV/μs pulse)	24 kV (peak)

3.4 Voltage Transformers

3.4.1 Standards

Voltage transformers (VT) shall comply with IEC 61869-3.

3.4.2 Class and Rating

The secondary voltage shall be 110V.

The rated output per phase at a power factor 0.8 lagging shall be not less than 75VA. The minimum output shall be capable of supplying all panels in the system.

The rated voltage factors shall be 1.2 continuous and 1.9 for 30-second duration.

Ratings of the VT shall be as follows:-

System nominal voltage	11 kV
Rated highest equipment voltage	12 kV
Power frequency withstand voltage to earth (1 minute)	28 kV

VT shall have a measuring accuracy Class 1 and a protective accuracy Class 3P.

3.4.3 Construction Features

Each VT shall have a rating plate marked with all data recommended in IEC 61869-3. The VT shall be of metal-enclosed and safe-to-touch design.

VT shall have separate windings for primary and secondary sides and shall be dry-type cast resin encapsulated and natural air cooled or other approved type.

Secondary circuit fuses and/or MCBs shall be provided and shall be readily accessible for replacement.

The VTs shall be installed in a separate metal-enclosed chamber outside of the gas compartment. which shall be interlocked against the circuit earthed condition of the panel in a way that the chamber can be accessed only when the HV circuit of the panel is earthed.

For plug-in / pluggable type VTs, an isolating system shall be integrated and interlocked with the switchgear panel so that the VTs can be isolated for testing purposes if and only if the switchgear panel is in earthed condition, and without necessity to remove VTs.

For drawout type VTs, the VTs shall be designed for convenient withdrawal from and racking in with the primary circuit of the switchgear panel.

For non-drawout type VTs, the primary windings of the VTs shall be connected to the HV circuit via flexible connections for easy isolation of the VTs for circuit or VT testing.

3.5 Current Transformers

3.5.1 Standards

Current transformers (CT) shall comply with IEC 61869-2.

3.5.2 Class and Rating

CT shall be rated for 50 Hz operation and compatible with the circuit-breaker's ratings.

3.5.3 Design Features

The rated secondary current shall be 1A or 5A.

The rated primary currents in amperes shall be (10), 12.5, (15), (20), 25, (30), 40, (50), 60, (75) and their decimal multiples. The preferred values are those given in brackets.

The accuracy class of measuring CT shall be Class 1, and the class and accuracy limit factor of protective CT shall be Class 5P10. In addition, the Contractor shall provide calculations to substantiate the rated burden of CT proposed is greater than all load burdens connected to the CT.

For dual ratio CTs, all the secondary terminals shall be wired to a terminal block and clearly identified.

The secondary circuits of each CT shall be earthed at one point only. Bolted copper link at readily accessible position shall be provided for CT earthing. Each earth wire shall be terminated on separate terminals.

CT shall be of epoxy resin encapsulated type.

CT rating labels shall be fitted on the CT and on a prominent place on the exterior of the CT chamber. For dual ratio CT, the ratio in use shall be clearly indicated on a label.

3.6 Relays and Timers

3.6.1 Protection Relays

Protection relays to IEC 60255-1 shall be provided.

Protection relays and trip circuit supervision relays shall be of withdrawable type housed in cases. The relays shall be flush mounted. For current operated relay, a feature shall be incorporated to short circuit the secondary terminals of the CT when it is withdrawn from the case.

Solid-state or microprocessor based protection relays shall be provided as specified in the Particular Specification. Test terminal blocks shall be installed adjacent to the relays to facilitate testing. A complete set of portable instrument (notebook computer, software and accessories) for the configuration and testing of digital relays shall be provided if required in the Particular Specification.

Operation indication shall be provided for each protective element and within the same relay. The relay shall have a hand-reset device operable without opening the relay access cover except for undervoltage relay, which shall be equipped with self-reset contacts and a hand-reset operation indicator.

A relay test plug for each type of relay casing shall be provided.

3.6.2 Control and Timer Relays

Control and timer relays shall be of plug-in type, rack mounted, provided with cable connection terminal and anchored by quick fastening vibration-proof devices. Timers shall be of solid-state type. Contacts shall be rated as follows:-

Control relays

Rated thermal current: 16A 220V a.c.
3.5A 110V d.c.

Timer relays

Rated thermal current: 2A 220V a.c.
0.5A 110V d.c.

3.7 Low-voltage Fuses and Miniature Circuit Breakers (MCBs)

3.7.1 Standards

Fuses and fuse holders shall comply with IEC 60269-1. MCBs shall comply with IEC 60898.

3.7.2 Class and Rating

For fueses, the voltage rating shall be 415V, 50 Hz or 500V d.c. The rated breaking capacity of fuses shall be 80 kA at 415V, 50 Hz or 40 kA at 500V d.c.

For MCBs, the operating mechanism of the MCBs shall be thermal-magnetic type with inverse time-current characteristic to IEC 60898 Table 7. The MCBs shall have tripping classification of Type B and have rated short circuit breaking capacity of 6kA to IEC 60898.

3.7.3 Components

Fuse bases and carriers shall be of plastic moulded insulating material of an approved make. Fuse bases and carriers for fuses of 2-20A shall be 20A units.

Fuse bases and carriers shall be colour coded, white for isolating links, light green for tripping control and black for other fuses.

3.7.4 Mounting

Fuses and links in the same circuit shall be mounted in adjacent positions in the same row. Live terminals and contacts of fuse holders shall be effectively shrouded such that no live parts shall be exposed when the fuse is withdrawn or when the panel door is opened.

3.8 Indicating Instruments

Ammeter and voltmeter shall have bezel dimensions of 95 x 95 mm. The indicator accuracy shall be of Class 1.5 and shall have a scale length not less than 145 mm on 240^{o} angular deflection. The indicator shall be finished in phenolic black and suitable for flush panel mounting.

The ammeter for motor starter panel shall have a compressed scale above the rated circuit current to cater for motor starting current. Voltmeter shall have an elevated scale with range of around 90-120% of the nominal value. Frequency indicator shall be scaled 48-52 Hz and of accuracy Class 1.0.

Power factor indicator shall be of accuracy Class 2.5 having bezel dimensions of 95 x 95 mm.

3.9 Panel Auxiliary Equipment

3.9.1 Selector and Control Switch

The selector and control switch shall be of rotary type with minimum contact rating of 30A thermal and 16A 220V a.c. 0.4 p.f. lagging. All function selector switches shall have spade type handle and key lockable in any selected position. The locks for the same function selector switch in all switchboard in a station shall use a common key.

Handles of control switches for circuit-breakers shall turn clockwise for closing and anti-clockwise for tripping and shall be of the pistol-grip type. Control switches shall be clearly labelled as ‘TRIP-NEUTRAL-CLOSE’, with spring return to the neutral position. A mechanical interlock shall be fitted to prevent repetitive closing without moving first to the trip position, and the handle shall be capable of being locked in the neutral position.

3.9.2 Hour-run Meter

Hour-run meter shall be a synchronous clock device with a digital indicator registering 9999.9 hours and connected to either the 220V 50 Hz or the 110V d.c. control supply. The meter shall be fitted with a mechanical push-to-reset button.

3.9.3 Indicating Lamp

Indicating lamp shall be rectangular or circular shape of diameter 32 mm. 220V a.c. lamp shall be fitted with step-down transformer for 6.3V a.c. lamp bulb. Alternatively, LED type indicating lamp with equivalent brightness may also be acceptable.

'Running' or 'On' indicator shall be positioned on the right side of the 'Off' indicator when arranged in a row.

3.9.4 Push-button

Push-button shall be of matching shape with indicating lamp. It shall have not less than 2 changeover contacts with a minimum contact rating of 30A thermal and 16A 220V a.c. 0.4 p.f. lagging.

Emergency stop push-button shall have a red mushroom head of stay-put and turn-to-reset type.

3.9.5 Anti-condensation Heater

Anti-condensation heaters shall be fitted to each switchboard panel and the associated double pole isolator switch and control hygrostat shall be provided.

3.9.6 Locking Facilities

Padlocks and keys shall be supplied for the lockable devices of the switchgear panels. The key shall be unique for each padlock and fitted with an identification plate indelibly marked with the panel and function type reference. Two sets of keys shall be supplied for each lock.

A key and padlock cabinet shall be supplied for each switchboard. Hooks shall be provided for all keys and locks each identified with the key number. The key cabinet shall be fabricated from stainless steel sheets complete with lockable hinged doors.

3.9.7 Labels and Warning Notice

Each switchgear and relay panel shall be fitted with circuit labels on both the front and the rear. Labels shall be fixed by screws on the non-detachable parts of the panel at a height of 1350 mm or above. The characters on the panel labels shall be 10 mm high.

The components shall be individually labelled.

'DANGER - HV LIVE TERMINALS' warning notices shall be attached to the removable access covers of all HV compartments such as cable termination compartment, CT chambers and busbar chambers.

Warning labels with red inscription of 'DANGER - CT TERMINATION' shall be affixed to the terminals of CT circuits.

3.10 Energy Meter

The meter shall be a programmable polyphase integrated energy and maximum demand meter. The accuracy class for kWh and kVArh shall be Class 1 to IEC 62053-21 and Class 2 to IEC 62053-23 respectively. The meter shall be provided with three programmable digital/pulse outputs and three programmable 0-20mA d.c. analogue outputs for remote indications.

The meter shall be of transformer operated type. The reference voltage shall be 110V 50Hz 3-phase derived from the voltage transformers at the incoming supply panels. The rated current shall be 1A derived from the measuring current transformers at the incoming supply panels or the starter panels.

The meter shall have flexible programming capabilities for complex tariff configuration, which are based on daily and weekly schedules as well as exceptional days, and shall have facilities for load profile storage and remote meter reading. The data storage capacity shall be sufficient to store one value every 30 minutes for 90 days viz. total 4320 values. The meter shall be fitted with real time clock and calendar supported by an internal battery. The registered data shall be transferred to non-volatile memory on power failure.

Meter configuration, programming and data retrieval, which shall be multi-level password protected, shall be made via an optical communication port using IEC 62056-21 protocol with the use of a personal computer and/or via fieldbus commuication. A sealable push-button shall be provided at the front of the meter for resetting the maximum demand data.

All necessary interface probe cable, licensed softwares for meter configuration, programming, data retrieval and load profile data conversion to standard worksheet application software shall be provided.

3.11 Power Supply Terminations

3.11.1 Termination Provision

The cable termination box shall be suitable and have sufficient space for the termination of the power supply cables specified in the Particular Specification. To allow for sufficient working space, the minimum vertical distance between the HV cable bushing and the cable gland plate shall be 700 mm. Unless otherwise specified in the Particular Specification, the cable gland plate shall be installed at least 300 mm above the floor level. Alternatively, the panel shall be fixed on a mounting stand made of SS 316 stainless steel with a minimum thickness of 6 mm, which shall be at least 300 mm above the floor level.

An air-insulated cable box and gland plate capable of terminating the following XLPE insulated armoured copper conductor cables shall be supplied:-

No. of Cores	Cable Sizes (mm^2)		
	400/ 630A panel	800/1250A panel	2000A panel
1-3c	300	300	-
2-3c	300	300	-
3-1c	300	630	-
6-1c	300	630	630
12-1c	-	-	630

Cable lugs and cable glands shall be supplied to match the external cables. Insulated glands shall be provided for 1-core power supply cables. Where more than one cable enters the cable box, the clearance between adjacent glands shall be sufficient to permit satisfactory cable termination.

Screened type plug-in termination kit shall be used for XLPE cables or heat shrinkage dry-type termination kit for other types of cables. The screened type termination shall meet the testing requirement of IEC 60502-4.

The screened plug-in type termination shall facilitate cable testing, after cable termination is made, without disconnection of the termination plug from the switchgear cable terminals.

Cable glands shall be connected to the earth bar by flexible copper conductors of not less than 20 kA 1-second rating.

The cable lugs for the termination shall be designed in compliance with IEC 61238-1.

The Contractor shall provide the cable termination kits to meet the termination requirements as specified in the Particular Specification.

3.11.2 Cable Termination Compartment

The cover of the compartment shall be interlocked against the earthing switch of the panel in a way that the cover can be opened only when the HV circuit of the panel is earthed by the earthing switch via the circuit-breaker.

The cable termination compartment shall be designed for bottom entry of cables.

3.12 Cable Accessories

3.12.1 Terminal Bases and Bushings

Terminal bases and bushings shall be epoxy resin or glass-fibre polyester high-pressure mouldings. Porcelain bushings shall not be accepted.

3.12.2 Terminal Sockets for Power Cables

Cable terminal lugs shall be fabricated from hard-drawn cadmium copper with the socket portion locally annealed for crimping. The lug shall be tinned throughout.

Fixing bolts, nuts and washers for the cable sockets shall be supplied.

Stud holes in the palm of cable sockets shall have nominal diameters compatible with the bolts.

3.12.3 Mechanical Cable Glands

Cable glands for elastomeric or plastic insulated cables shall comply fully with BS 6121 type E1W. Suitable shrouds, slip-on earth tags and backnuts shall be supplied with the cable glands.

3.12.4 Small Wiring

Wires shall be black for both a.c. and d.c. connections and yellow/green for earth connections.

Each end of the wire shall be provided with a crimp lug. Wiring shall be run in a neat manner and shall enable clear visual inspection without the need for removal of cleats.

Numbered ferrules of white PVC with black characteristics shall be provided for cable core identification. Ferrules shall be capable of being fitted firmly to cable cores.

3.12.5 Terminal Blocks

Terminal blocks shall comply with IEC 60947-7-1. It shall be single-level feed-through, screw or screwless type connection, DIN rail-mounted, vibration and corrosion resistant, and modular design suitable for harsh industrial environment.

All a.c. and d.c. supply bus wiring terminals shall be fully shrouded and identified. Terminal blocks for current transformer secondary connections shall be provided with maintenance shorting links and clamps.

3.13 Spares and Tools

The following spare parts and tools shall be provided in addition to other spares and tools recommended by the Contractor:

(i) A shunt trip coil of each circuit-breaker rating.

(ii) A closing spring release coil of each circuit-breaker rating.

(iii) One set of operating and maintenance tools (including circuit-breaker, switch-disconnector and earthing switch operating handles) installed in a carrying case for each switchboard (Cl. 3.2.5).

(iv) Padlocks and keys installed in a stainless steel cabinet for each location (Cl. 3.9.6).

(v) One Portable insulation gas detector (if required).

(vi) One set of gas refilling adaptor for refilling insulation gas of gas-insulated chamber (if required).

(vii) One set of handheld HV voltage indication test unit for phase comparison and voltage detection (Cl. 2.3).

(viii) One mobile platform with steps and handrail to facilitate access to the LV compartment at the upper section of the switchboard.

4. INSPECTION AND TESTING

4.1 General

The complete switchboard supplied under the Contract including spares and tools shall be inspected by the Independent Inspection Body (IIB) at manufacturer's works prior to shipment. Tests carried out on the completely assembled switchboard shall be witnessed by the IIB. Inspection and test reports/certificates together with test arrangement drawings, circuits, calculations, and test results shall be submitted within one week after the inspection and testing.

4.1.1 Inspection

The scope of inspection shall cover the following:-

(i) General inspection checks including physical dimensions, workmanship, quality, quantity, and standards.

(ii) Verification of test reports for routine tests of switchboard carried out during manufacturing stages.

(iii) Verification of routine test reports for current transformers, voltage transformers, protection relays and instruments.

(iv) Verification of calibration reports of testing instruments for tests witnessed by IIB.

(v) Packing and protection checks.

4.1.2 Witnessing of Tests

The following tests to IEC 62271-200 carried out on the completely assembled switchboard shall be witnessed by the IIB at the manufacturer's works:-

(i) Power frequency voltage withstand tests on the main circuit.

(ii) Insulation resistance tests on the main circuit.

(iii) Measurement of the resistance of the main circuit.

(iv) Mechanical operation tests.

(v) Verification of interlocking facilities and correct operation of control circuitry.

4.2 Metal-enclosed Switchgear Panel

The following routine tests as specified in IEC 62271-200 shall be performed on the switchgear panel:

(i) Power frequency voltage withstand tests on the main circuit.

(ii) Insulation resistance tests on the main circuit and auxiliary circuits.

(iii) Measurement of the resistance of the main circuit.

(iv) Mechanical operation tests.

(v) Verification of correct wiring and performance of the CT operated protection relay circuitry by primary current injection at rated CT primary current.

(vi) Verification of interlocking facilities and correct operation of control circuitry.

(vii) Pressure tests of gas-filled enclosure.

(viii) Gas tightness tests of gas-filled enclosure.

(ix) Partial discharge test.

4.3 Circuit-breakers

The following routine tests as specified in IEC 62271-100 shall be performed on the circuit-breaker:-

(i) Power frequency voltage withstand tests on the main circuit.

(ii) Measurement of the resistance of the main circuit.

(iii) Mechanical operation tests.

(iv) Insulation resistance tests on the main circuit and auxiliary circuits.

4.4 Switch-disconnectors and Earthing Switches

Routine tests as specified in IEC 62271-102 shall be performed on the switch-disconnectors and earthing switches.

4.5 Voltage Transformers

Routine tests as specified in IEC 61869-3 shall be performed on the voltage transformers.

4.6 Current Transformers

Routine tests as specified in IEC 61869-2 shall be performed on the current transformers.

4.7 Protection Relays and Instruments

The relays and instruments shall be tested at relay and instrument manufacturer's works for verification of correct operation and calibration.

- End of this Specification -