SHUNT REACTORS

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SHUNT REACTORS

01. GENERAL

These Specifications cover the requirements for design, manufacture and factory testing of shunt reactors, their bushings and bushing current transformers.

The reactors shall be installed outdoor and shall be designed, manufactured and tested in accordance with latest edition for IEC 60076-6. All shunt reactors shall be single phase, oil immersed, self-cooled (class ONAN), self-contained complete with conservators, radiators, indoor, outdoor cubicles and all standard accessories.

The shunt reactors, their bushings and bushing current transformers unless specified hereafter shall be manufactured, tested and commissioned in accordance with the latest issue of the relevant IEC Standards.

The contractor shall also design and supply, install the Nitrogen Injection Explosion Prevention and Fire Protection system for each 500/√3 kV, 37 MVAR shunt reactor as per NTDC specification.

02 RATINGS

Following are the ratings of the shunt reactor to be supplied under this contract:

02.01 General:

(1) System, nominal voltage, line to neutral, kV, rms. 500/√3
(2) Reactor, rated voltage, phase to neutral, kV, rms. 550/√3
(2a) Continuous overvoltage rating, line to neutral, kV, rms. 575/√3
(3) Rated 2 second over voltage rating, line to neutral, % of nominal rating, not less than. 173
(4) Rated frequency, Hz. 50
(5) Neutral rated nominal voltage, kV, rms. 72.5
(6) Method of system grounding. Solid
(7) Insulation levels:

(a) Rated lightning impulse withstand voltage, kV, peak.
   
   i) Line End (Internal) of the winding. 1550
   
   ii) Neutral End (Internal) of the winding. 325

(b) Rated long-duration induced or separate source AC withstand voltage, kV, rms.
   
   i) Line End (Internal) of the winding. $U_1=598, U_2=531$
   
   ii) Neutral End (Internal) of the winding. $U_1=75.34, U_2=66.97$

(c) Separate source power frequency withstand voltage for neutral, kV, rms. 140

(8) Rated switching impulse withstand voltage phase-earth kV, peak.

(a) Line End (Internal) of winding. 1300

(b) Neutral End (Internal) of winding. 280

(9) Volt-Ampere characteristics to be linear from phase to neutral voltage, not less than, kV, rms. 361

(10) Cooling. ONAN

(11) Winding Connection Y-Neutral Solidly Grounded

02.02 MVAR and Current Rating:

(1) Nominal MVAR rating line to ground voltage, at
   
   i) 500/√3 kV 111/3
   
   ii) 550/√3 kV 134.3/3
(2) Rated continuous current A, rms. at
   i) $500/\sqrt{3}$ kV  
   ii) $550/\sqrt{3}$ kV

02.03 Saturated Reactance:

(1) 50 Hz saturated air core reactance, %  
    33.33

Tenderer to provide design parameters and applicable formula for calculation of saturated reactances.

02.04 Temperature Rise:

The maximum temperature rise of reactor windings and oil, above the maximum ambient temperature, of 50 degrees C under all conditions shall not exceed the values given below.

(1) Windings (measured by resistance) degree K.  
    55

(2) Top oil (measured by thermometer), degree K.  
    50

The temperature rise for winding, core and other parts shall be such that in no case the temperature should reach a value that will injure the winding, core and the adjacent parts or materially affect the life of the reactor.

02.05 Noise Level:

'Noise Level' at a distance of one meter from the reactor shall not exceed 81dB (NEMA Standard).

02.06 Tolerances:

(1) Tolerance on Current at Rated Voltage. The current in the three phases, when reactor is connected to a system of symmetrical voltages, shall not deviate from the average value by more than 2%.

(2) Tolerance on Losses. The total measured losses corrected according to clause 7.8.6 of IEC 60076-6 shall not exceed the total guaranteed losses by more than 10%. A penalty at the rate of twice the value of the capitalized cost of losses shall be payable by the Contractor for excess of losses over the guaranteed figure.

02.07 Harmonic Content of Reactor Current:

The maximum allowable crest value of the third harmonic component of the reactor current shall not exceed by 3% of the crest value of the fundamental when the reactor is energized at rated voltage with a sinusoidal waveform.
02.08 **Capitalization of Losses**

In the evaluation of bid, the following amounts shall be added to the CIF price of Shunt Reactor to obtain the adjudication prices:

Capital Cost of losses = US$ 5200/kw

The losses to be taken will be the guaranteed losses at rated voltage of 550/√3 kV, rated frequency and reference temperature of 75 Deg. C.

03 **GUARANTEED VALUES**

The Contractor shall supply guaranteed figures for losses and other technical particulars as listed in the Schedule of Technical Data.

The losses will be the guaranteed losses by the manufacturer at 75 Deg. C at rated frequency and at 550/√3 kV & 500/√3 kV

04 **CONSTRUCTION.**

04.01 **General Arrangement:**

The shunt reactors shall be so arranged that a line running through the high voltage bushings shall be at right angles to the incoming buswork or overhead conductors.

04.02 **Reactor Tank:**

The tank shall be of electrically welded mild steel construction suitably stiffened and braced to prevent distortion or damage under service and fault conditions or during transport by road, rail or sea or when the complete reactor filled with oil is lifted by crane or jacks.

The tank shall be oil tight and capable of withstanding, when empty, a vacuum of 720mm of mercury and a pressure of 0.4 kg/sq.cm additional to that present when completely filled with oil at a head equivalent to that imposed by the conservator in service when the oil temperature rise is 75 degree C.

After fabrication, each reactor shall be tested for oil tightness by being completely filled with oil or a liquid of equivalent viscosity at ambient temperature and subjected to a pressure equal to the normal pressure plus 0.5 kg/sq.cm. The pressure shall be maintained for a period of not less than 18 hours, during which time no leakage shall occur.

04.03 **Covers:**

Tank covers shall be of adequate strength to prevent distortion when lifted and shall be provided with all necessary inspection openings, which shall be of adequate size and pockets for thermometers and winding temperature indicators.

The connections between the cover and conservator shall be placed so as to ensure definite operation of the Buchholz relay upon the formation of gas or
sudden movement of oil. The inside of the cover shall present the minimum obstruction to the passage of gas bubbles to the Buchholz relay. Water shall not accumulate on the outside surface.

04.04 Reactor Cores:

Reactor core shall be made of high grade grain oriented, annealed, non-aging, cold rolled electrical silicon steel. Laminations shall have low losses and high permeability. The core shall be rigidly clamped with insulated clamping bolts into one piece steel structure which will retain its shape under the most severe stresses encountered during shipment and handling and under short circuit conditions. Insulated packets of the core are to be electrically interconnected so that potential difference will not exist between them. This will reduce noise level.

The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths within itself or to the grounded structure and production of flux components at right angles to the plane of the laminations which may cause local heating.

Proper care in the design shall be incorporated to avoid heating of reactor tank, core and clamping parts resulting from eddy current and hysteresis losses as a result of zero sequence flux by employing suitable measures in the design.

The core shall be grounded to the tank body only at one point through a removable link to be provided at a convenient place under the top cover of the tank so that insulation of core to earth could be measured.

Catalogues/literature of the magnetic materials to be used shall be provided. This must include, specific loss curves, BH curve and other related material to verify the losses.

04.05 Winding:

All conductors used in the coil structures shall be pure copper, free from scale, burrs and slivers. The turns and coils shall be thoroughly insulated, and all insulation shall be thoroughly treated with insulating varnish or equivalent compounds as necessary to develop the full electrical and mechanical strength of the reactor and to minimize deterioration. All permanent current carrying joints or splices shall be brazed or compressed. The coils, barriers, bracing and insulation shall be arranged to afford ample cooling oil circulation, reduce the occurrence of hot spots, and withstand deformation from short circuit forces.

04.06 Clamping Structures:

A strong rigid clamping structure shall be used to clamp the interior assembly. This structure shall also be used to fasten the core and coils securely to the reactor tank, and shall be provided with lifting lugs for untanking.

Adequate provisions shall be made to prevent movement of the reactor relative to the tank during transportation and installation or while in service.
04.07 Guides:

Suitable guides shall be provided to position various parts during assembly or dismantling operations.

04.08 Radiators:

The radiators shall be of the detachable type mounted directly on the tank. The tanks shall be fitted with suitable radiator shut-off values so that the radiators may be changed without draining the tank. It shall be possible to padlock the valves in open and close positions, the position of the valve being readily identifiable. Radiators shall be equipped with air vents, drain plugs, oil sampling valves and lifting lugs to allow complete removal or installation of a radiator unit without draining the reactor.

The radiators shall be designed to prevent accumulation of water on the outside surface and shall be accessible for cleaning and repainting.

Radiators shall withstand the pressure conditions specified for the tank. Welding should be strong and adequate so that no oil leakage takes place.

04.09 Base:

The base of the reactors shall be rigidly welded steel frame fabricated from structural shapes of adequate size to withstand moving, shipping and handling of the reactor and support the weight of the reactor on a concrete foundation in service. Jacking pads shall also be provided.

05 REACTOR OIL

A sufficient quantity of oil shall be supplied with each reactor for its filling to proper level. Insulating oil shall be pure mineral oil, refined specially for use in electrical equipment as insulating and cooling medium. It shall be free from water, sediments, foreign materials and petroleum fractions, likely to be detrimental to its insulating properties and which may be injurious to insulation, paint, varnish, metallic or other parts of the equipment. It shall not form a deposit under normal operating temperatures. It shall be free from synthetic additives of all types and shall comply with latest issue of IEC Publication 60296.

The reactors shall be suitable for use with the oil specified above and for satisfactory service shall not require oil dielectric strength above 40 kV when tested in accordance with applicable standards.
ACCESSORIES

General:

The classification of insulating materials for temperature rise must be according to the latest issue of the relevant IEC Publications.

Provisions shall be made in the design of the reactor accessories and outdoor cubicles such that proper operation is not impaired by vermin, insects, small animals and birds. The outdoor cubicles shall be designed to IEC Protection Clause of IP-55.

Conservator:

Each reactor shall be provided with a conservator complete with oil level indicators, pump valve and drain valve and having a capacity of not less than 10 percent of the total cold oil volume in the reactor and cooling equipment. The installation level of the conservator vessel(s) must not exceed 3.5 m above tank cover.

Two oil level indicators shall be fitted, one on each end of the conservator. One indicator shall be of the magnetic type and the other preferably of another type which does not discharge oil if accidentally broken. Both oil level indicators so provided shall be fitted with two stage low oil level alarm contacts. The oil level indicators shall be clearly marked with the normal level at 30°C.

The indicated range of oil levels shall correspond to average oil temperature from zero degree C to 120 degree C.

The elevation of the conservator tank shall be such that the gas detection relay elements will be below the minimum oil level in the conservator.

One end of the conservator shall be removable for cleaning purposes and the drain valve shall be so situated that the conservator can be completely emptied when mounted as in service.

The pipe from the reactor to the conservator shall be of adequate size and shall rise at an angle of three to seven degrees to the horizontal. A gate valve with handle which clearly indicates the position of the gate valve shall be provided at the conservator to cut off the oil supply to the reactor tank, when required.

Each conservator vessel shall be equipped with an oil sealed silica gel dehydrating breather of adequate size or some other suitable breathing devices which shall be located at convenient operation and maintenance level above ground, in accordance with the latest approved practices.

Lifting, Moving and Jacking Facilities:

(1) **Lifting Facilities:** Lifting eyes shall be provided for lifting the cover. Adequate facilities shall be provided for lifting the core and coil assembly from the tank.
Lugs for lifting the complete reactor shall be provided. The bearing surface of the lifting lugs shall be free from sharp edges and each lifting lug shall be provided with a hole of suitable diameter for guying purpose.

(2) **Moving Facilities:** The base of the reactor shall have members forming a rectangle which will permit rolling in the directions of the centre lines of the segments.

The points of support of these members shall be so located that the centre of gravity will not fall outside these points of support for a tilt of the base of 15 degrees or less with the horizontal, with or without oil in the reactor.

Bi-directional flanged rollers shall be provided on the reactors. Distance between roller wheels shall match with the existing shunt reactors to fit on the rail systems. Blocking devices for the roller shall be provided.

Provisions shall be made on or adjacent to the base for pulling the reactor parallel to either side.

(3) **Jacking Facilities:** Jacking facilities shall be located near the outer ends of the base. The jacking pads or lugs shall be so designed that the lifting member of jacks of suitable capacity can be inserted when the reactor is completely assembled.

06.04 **Inspection Facilities:**

Adequate facilities shall be provided for inspection, testing and minor repairs in the interior of the reactors when assembled without draining the oil. Such facilities would include at least two numbers of handholes and one number of manhole to afford easy access to lower ends of bushings, terminals, the upper portion of the coils and to permit replacement of auxiliaries without moving the tank cover.

The smallest dimension of the handholes and manhole shall not be less than 400 mm and 800 mm respectively. The cover shall have adequate handholes to facilitate lifting.

06.05 **Drain and Filter Valves and Fittings:**

Each reactor shall be fitted with the following:

(1) One drain valve of adequate size so situated that the tank can be drained of oil in reasonable time.

(2) Two filter valves of 40 mm dia, one at the top and the other at the bottom of the tank diagonally opposite to each other for connection to the oil circulating system.
(3) Devices for sampling the oil at the top and bottom of the tank but independent of the filter valves specified and situated so as to be readily accessible with the reactor in service.

All valves opening to atmosphere shall be fitted with black flanges. All valves shall be iron body with bronze or stainless steel trim and of globe type. Means shall be provided for locking the valves. Each valve shall be provided with an indicator clearly showing its positions.

06.06 Pressure Relief Device:

A pressure relief device shall be provided for rapid release of any dangerous pressure within the reactor. The device shall operate at a pressure less than the test pressure of the tank.

The discharge pipe shall preferably be located above the conservator such that on operating, oil will be discharged away from any adjacent equipment. Two electrically independent trip contacts shall be provided.

06.07 Oil Temperature Indicators:

Two oil temperature indicators one mercury type and the other of the resistance type shall be provided.

The resistance temperature indicator markings shall cover a range of 0 to 120 degree C. The words "Oil Temperature" shall be marked on the dials or on a suitable name plate.

The mercury thermometer shall be direct stem mounted in a close well.

The indicators shall have maximum temperature pointers to indicate the highest temperature reached.

The measuring element of the resistance type oil temperature indicator to be used for remote temperature indication in the control room shall be mounted inside a stainless steel tube. A duplicate indication shall also be provided on the outdoor control cabinet.

Sets of electrically independent contacts shall be provided for high temperature alarm and circuit breaker trip operation on successively higher temperatures. The contacts for alarm/trip shall be wired for use as alternate to the main scheme actuated by winding temperature sensing devices described hereinafter. Necessary wiring diagrams shall be provided showing the scheme and the changes required for the changeover.

06.08 Temperature Indicators:

Each reactor shall be provided with two resistance type devices for indicating hottest spot temperature of the windings. These indicators shall be used to furnish remote indication of the temperature in the control room, with a duplicate indication provided on the outdoor control panel.

The indicators shall be provided with a pointer to register the highest temperature reached. Corresponding CT secondary current shall be used for
heating the element to provide for the hot spot winding temperature. Two separate sets of contacts, one to operate an alarm and the other to trip the breaker on successively higher temperatures shall be provided for each device. The contacts of both the temperature indicating devices shall be connected in parallel. Each of the contacts shall be separately adjustable and provided with a setting scale.

The temperature relay and equipment shall include a heating element located in the top of oil of reactor and shall be energized from its associated current transformer which shall be installed as required. The indicator operating bulb shall be located with the heating element in a hot well and be compensated for ambient temperature. Suitable means in the design shall be provided for calibration purposes of the above winding temperature equipment.

It shall be possible to move the pointer of the temperature indicators manually in order to test the tripping, alarm and cooling apparatus circuits. The working parts of the instruments shall be visible through glass fronted covers.

Terminals, links and an ammeter shall be provided in the outdoor control cabinet for each temperature indicator for:

(1) Checking the output of the CT.

(2) Disconnecting the temperature sensing devices from the CT secondary to enable the instrument to be used as an oil temperature indicator.

Oil and winding temperature indicators shall have suitable adjustable ranges with adequate contacts for alarm and trip operations.

06.09 **Buchholz Type Gas Detector Relay:**

A buchholz type gas relay shall be installed between the reactor and oil conservator. It shall be designed to operate rapidly for internal faults in the reactor. The relay shall be equipped with two contacts, one for alarm and one for tripping the circuit breaker(s). The alarm contact shall be set to operate from a low rate of gas evolution. The shutdown contact shall be operated from high rate of gas evolution or oil movement such as experienced from internal reactor faults or flashovers. A dial shall be provided to give visual indication of accumulated gas volume up to the alarm points. Valves on each side of buchholz relay shall be provided so that the buchholz relay assembly may be removed without draining out the oil. Necessary piping with stopcock and valves shall be provided on the buchholz relay for testing the gas/air collected in the buchholz relay at suitable height from ground level. Gas analysis device and tools for determining the type of gas shall be provided.

06.10 **Grounding Terminal:**

Two tank grounding terminals located on diagonally opposite sides of the reactor and brazed to the tank shall be provided. The terminals shall be made of copper.
Connectors, as specified in the relevant section shall be provided for the grounding.

06.11 Neutral Connection:

Neutrals of shunt reactors banks shall be joined together through a neutral bus.

The neutral bus shall be made of aluminum alloy tube of 80 mm diameter with wall thickness of 10mm, supported by post insulators installed upon steel supporting structures. Neutral buses shall be extended to include the neutral connections of the spare shunt reactors also.

The neutral bus shall be connected to grounding mesh at least at two points and at appropriate locations so that the circulating currents are minimized.

07 REACTOR OUTDOOR CONTROL CUBICLES

07.01 General: An outdoor cubicle shall be provided for each single phase 500 kV shunt reactor. These cubicles shall house all the auxiliary equipment including oil temperature indicators, winding temperature indicators, protective gear, terminal boards for all alarm and trip contacts of accessories, AC/DC auxiliary supply leads etc.

The temperature indicator shall be visible from outside for direct reading of temperature.

All the control cables and auxiliary supply cables leading to the reactor or its accessories, shall be terminated at the outdoor cubicle. All the terminals shall be properly labeled.

Identification labels shall be provided on the outside of the control cabinet doors.

All wiring and cables installed in and around the sides of the reactors and connections from the accessories to the outdoor cubicle shall be enclosed in metallic rigid or flexible conduits or raceways.

A telephone jack shall be provided in each cubicle assembly. A hook for supporting head set shall be provided conveniently close to the jack. Telephone wiring upto control desks, relay room and PLC room shall be provided. Two spare headsets shall also be provided for each substation. Internal lights operating from a door switch and thermostatically controlled space heaters shall be provided in the outdoor cubicle.

The reactor outdoor control cubicle shall be provided with three phase socket of appropriate rating and wired accordingly for the operation of the oil purification plant.

A durable corrosion free resistor connection diagram and maintenance instructions plate for the temperature indicators shall be fixed in the outdoor control cabinet.
07.02 **Construction:** The outdoor cubicle shall be fabricated of sheet steel and shall be vibration free, weather proof and vermin proof. There shall be rubber gasket between the door and frame to prevent the ingress of moisture, and will comply to IP-55 protection class of IEC.

The cabinet shall be designed for accommodation of:

1. Top of oil temperature indicators and winding temperature indicators, local annunciators and associated equipment.
2. Terminal boards and gland plates for incoming and outgoing cables, circuit breakers, fuses, heaters etc.

All instruments and equipment shall be mounted on panels and back of panel shall be used for wiring. Each compartment shall have a separate access door. The door shall have lift-off hinges and be fastened by handles with provision for locking. The door of the temperature indicator compartment shall be provided with glazed window of adequate size for observing temperature indicating equipment.

07.03 **Components:** Each outdoor cubicle shall have mounted thereon, but not limited to, the following equipment:

1. Winding temperature indicators and accessories.
2. Oil temperature indicators and accessories
3. All contactors, relays, switches etc.
4. Annunciator fascia.
5. Circuit breakers with auxiliary contacts for each of AC & DC main and branch circuits.
6. One undervoltage relay to indicate AC auxiliary supply failure and one for DC supply failure.
7. Three position selector switch for CTs for thermal image. Function of this switch shall be for as follows:
   (a) Position 1: Normal operation (CT used for winding temperature indications)
   (b) Position 2: Testing of CT.
   (c) Position 3: CT used for oil temperature indication.
8. Ammeter to measure current of CT for thermal image.
9. Thermostat
(10) Humidistat
(11) Auto/Manual selector switches for heaters
(12) Humidity control heaters
(13) Lamp for interior lighting with door switch
(14) Power socket
(15) Telephone Jack.
(16) Terminal Blocks
(17) Internal wiring

08 ARRANGEMENT FOR CHANGEOVER OF ELECTRICAL CIRCUITS TO SPARE SHUNT REACTOR UNIT

08.01 General: A substation may have more than one shunt reactor bank of similar rating. Single phase reactor of each rating are kept as spare to replace any unit of any of the reactor bank in case of contingency. Arrangement for utilization of the spare reactor unit shall be such that the reactor bank, any unit of which may become defective, can be put back in operation in minimum possible time. This shall be done by avoiding physical shifting of the affected reactor unit. The changeover arrangement shall be as hereunder:

08.02 Changeover of High Voltage Connection from Defective Unit to Spare Unit: The spare unit shall be installed permanently at its foundation. A single phase overhead transfer bus shall run from the spare unit upto the relevant shunt reactor banks. Spare unit shall be permanently connected to the transfer bus. High voltage connection between the defective unit and the correspondingly circuit breaker/ disconnecting switch shall be shifted to the spare unit through the transfer bus. The arrangement is shown in specification drawing.

08.03 Changeover of Electrical Circuits from Defective Unit to Spare Unit: Arrangement for changeover of electrical connections from defective unit to spare unit shall cater to at least three banks of similar rating without requiring any modification. Two-step changeover procedure shall be adopted.

Step-1: Bank Selection
Electrical wiring from spare unit shall be routed to the reactor bank having defective unit. This shall be done from a “Bank Selector Kiosk”. Incoming wiring to this bank selector kiosk shall be from the spare unit. Outgoing
wiring shall be to each of the bank kiosk. For reactor bank of similar rating, there shall be one “Bank Selector Kiosk”.

Step-2: Units Selection
Wiring of the spare unit shall be integrated into the control, protection, metering and monitoring system of the bank having defective unit. Facility for unit selection shall be in the “Bank Kiosk”. Each shunt reactor shall have a “Bank Kiosk”. Unit selection shall be achieved through appropriate number of selector switches. Each selector switch shall have four (4) positions for function indicated in table-1 hereof.

Arrangement for switching of electrical circuits of the defective unit to the corresponding circuits of the spare unit is shown in figure-1.

Table 1
ARRANGEMENT FOR CHANGEOVER OF ELECTRICAL CIRCUITS TO SPARE REACTOR BANK KIOSK/UNIT SELECTOR: SELECTOR SWITCHES

<table>
<thead>
<tr>
<th>Position</th>
<th>Marking</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R-Y-B</td>
<td>• Normal Operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• R,Y &amp; B Units of bank are in service</td>
</tr>
<tr>
<td>2</td>
<td>Spare –Y-B</td>
<td>• R-Unit of bank is out of service.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Spare Unit wiring is switched into the control, protection and other circuits of R-phase.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• R-Unit CTs are isolated and short circuited</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• R-Unit electrical circuits other than CTs circuits are isolated</td>
</tr>
<tr>
<td>3</td>
<td>R-Spare-B</td>
<td>• Y-Unit of bank is out of service.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Spare Unit wiring is switched into the control, protection and other circuits of Y-Phase.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Y-Unit electrical circuits other than CTs circuits are isolated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Y-Unit CTs are isolated and short circuited</td>
</tr>
<tr>
<td>4</td>
<td>R-Y-Spare</td>
<td>• B-Unit of bank is out of service.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Spare Unit wiring is switched into the control, protection and other circuits of B-Phase.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• B-Unit electrical circuits other than CTs circuits are isolated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• B-Unit CTs are isolated and short circuited</td>
</tr>
</tbody>
</table>
08.04  **BANK KIOSK FOR REACTORS**

In addition to tank mounted control cabinet specified in Clause 07, another marshalling kiosk (Bank Kiosk/Unit Selector) shall be provided for the reactor bank. This kiosk shall house all the common auxiliaries required, distribution of AC & DC supplies to each single phase unit, etc.

Additionally, a ‘Bank Selector Kiosk’ shall be provided for group of shunt reactor banks having similar ratings.

The Bank-Kiosk/ Unit Selector and Bank Selector Kiosks shall be free standing fabricated from sheet steel not less than MSG 2.5mm thick seam welded at corners and ground smooth. However in case of type tested rigid frame design, the thickness of steel sheet may be reduced but not below 2 mm, according to the manufacturer’s standard design. The kiosk shall be supplied factory wired complete with all control, protection and indication systems, switches, auxiliary contactors, anti-condensation, heaters, humidistats, thermostats, interior lighting, terminal blocks, cable raceways and other necessary equipment.

09  **REACTOR INDOOR AUXILIARY CONTROL PANEL**

09.01  **General:** For the 500 kV shunt reactor bank an auxiliary panel shall be provided for installation in the control room for remote indications and annunciations.

The reactor indoor auxiliary panel shall be completely assembled, wired and tested at the factory.

The auxiliary panel shall be complete with all winding and oil temperature indicators, indication lamps, annunciators, signalling relays and contactors, etc.

The annunciation system shall provide automatic abnormal conditions in the reactors. Each annunciator equipment shall have a minimum of 24 alarm windows and shall be of the type specified in Section 14 of these Technical Provisions.

Fluorescent lamp with door operated switch shall be provided for interior lighting.

A ground bus of copper bar not less than 7 mm by 25 mm shall be provided along the back of the front and rear panel. The ground bus shall be connected to the frame of each panel.

09.02  **Construction:** The auxiliary control panels shall be of vertical type of construction and shall be fabricated from sheet steel not less than MSG 2.5 to 3 mm thick seam welded at corners and ground smooth. The control panels shall be of robust construction and manufactured and finished in accordance with NEMA-SG25.
The panels shall be suitable for bolting at the bottom to suitable steel channel sills which with necessary framing shall form a self-supporting dead front type of structure.

The panels shall have hinged doors at the rear. The hinges shall be fully concealed type and shall allow the door to swing through not less than 105 degrees from the closed position. Each door shall be provided with a three point latch with lock.

The installation of equipment shall start from the top of the panels such that any unused areas shall be at the bottom of the panels. No equipment shall be mounted less than 300 mm above the floor.

09.03 Components: The equipment to be mounted on the reactor auxiliary panel shall comprise of, but not limited to, the following:-

- Remote winding temperature indicator for each single phase unit.
- Remote oil temperature indicator for each single phase unit.
- Annunciation with at least 24 windows. The following alarm indications shall be provided for each single phase unit of the reactor bank:-
  (1) Winding temperature high-alarm.
  (2) Winding temperature high-trip.
  (3) Oil temperature high-alarm.
  (4) Oil temperature-trip.
  (5) Oil level low-alarm.
  (6) Buchholz relay operate-alarm.
  (7) Buchholz relay operate-trip.
  (8) Pressure relief device operate-alarm.
  (9) Fire fighting of the reactor fail.
  (10) Fire fighting operated.
  (11) Reactor AC auxiliary supply failure.
  (12) Reactor DC auxiliary supply failure.
  (13) AC/DC breaker tripped:
    - Test blocks
    - Terminal blocks
    - Wiring
  (14) Status indication.
(15) Water contents in oil high/CO content high/H2 content high.

(16) Ammeter.

The installation of equipment shall start from the top of the panels such that any unused areas shall be at the bottom of the panels. No equipment shall be mounted less than 300 mm above the floor.

10 SCADA AND REMOTE CONTROL FUNCTIONS

Provisions shall be made for ready connection of remote terminal units for control and indications. Potential free N/O contacts shall be made available on the terminal blocks for each fault condition. All wiring for this purpose shall be terminated in the interface panel for SCADA.

11 FACTORY TESTS ON REACTORS

The following tests shall be made on the reactors and accessories in accordance with the latest issue of IEC Publication 60076-6. However type tests shall be made only on one reactor to be selected by Engineer.

11.01 Routine Tests:

(1) Measurement of winding resistance

(2) Measurement of impedance

(3) Measurement of losses at ambient temperature

(4) Dielectric Tests:
   a) Separate Source AC withstand voltage test
   b) Long duration induced AC withstand voltage test (ALCD) according to Clause 12.4 of IEC 60076-3.
   c) Lighting Impulse(LI) voltage test (full wave).
   d) Test with lightning impulse chopped on the tail (LIC).
   e) Switching Impulse test.

(5) Measurement of insulation resistance and/or capacitance and dissipation factor (tan delta) of the winding insulation to earth.

(6) Insulation tests on auxiliary devices and wiring.

(7) Operational tests of all auxiliaries associated with the reactors.

(8) Tank pressure and vacuum tests

(9) Dissolved gases

(10) Frequency response measurement/analysis prior to transportation.
11.02 **Type Tests:**

(1) Temperature rise test

(2) Measurement of vibration for liquid immersed reactors.

(3) Measurement of acoustic sound level close to service temperature (special tests).

(4) Measurement of the harmonics of the current (special test).

(5) Measurement of loss close to reference temperature (special test).

(6) Determination of linearity of reactance (special test).

12 **BUSHINGS**

12.01 **General:** The bushings shall be manufactured and tested in accordance with latest issue of IEC 60137. These shall be oil filled or of the condenser type and shall be fitted with adjustable arcing horns.

All bushings shall be wet process porcelain, homogeneous, free from laminations, cavities or other physical flaws and shall be well vitrified, tough and impervious to moisture. Bushings shall be of glazed brown colour. Fittings made of steel shall be galvanized.

All bushings shall be hermetically sealed. The Contractor shall ensure that the bushings strike distance is not reduced by the installation of the current transformers. Each bushing shall be equipped with a voltage tap for use with a bushing potential device. Oil filled bushings shall be provided with a magnetic liquid level gauge. Bushing of the same class and current rating shall be inter-changeable. Bushings shall be supplied with lifting lugs attached to the bushing flanges.

Bushings shall be located and mounted in such a manner as to develop their rated insulation and impulse strength between their terminals and grounded metal parts.

All the bushings shall be capable of being removed from the assembled reactors without removing the reactor cover.

Bushings shall be provided with a tap for performing power factor tests.

Design of bushings shall be such that when over loaded no damage or loss of operating life in excess of that suffered by the reactor itself shall occur.
12.02 Ratings:

(1) 500 kV Bushings:

(a) Highest Voltage of Equipment (Um) Corresponding to the specified insulation level
(b) Rated phase to earth voltage
(c) Max. phase-earth voltage at which bushing shall be able to operate As per Clause 5.1 of IEC 60137 1st Edition 2003-08
(d) Rated Current, A, rms. 1600
(e) Rated short time current, (Thermal current) (corresponding to system fault level) kA, rms 40
(f) Lightning impulse withstand voltage, kV, peak 1800
(g) Switching impulse withstand voltage, dry and wet, kV peak 1300
(h) Power frequency withstand voltage, dry and wet, kV, rms. 790
(i) Creepage distance (minimum), mm 13750

(2) Neutral Bushing:

(a) Highest Voltage of Equipment, (Um) kV 72.5
(b) Rated phase to earth voltage level 72.5/3
(c) Max. phase-earth voltage at which bushing shall be able to operate As per Clause 5.1 of IEC 60137 1st Edition 2003-08
(d) Rated current, A, rms 250
(e) Rated short time current A, rms 6250
(f) Rated lightning impulse withstand voltage, kV, peak 325
(g) Power frequency withstand, voltage, dry and wet, kV, rms 140
(h) Creepage distance (minimum), mm 3000
12.03 **Factory Tests:** The bushings shall be tested in accordance with the latest issue of IEC Publication 60137.

(1) **Routine Tests:**

(a) Measurement of the dielectric dissipation factor (tan delta) and the capacitance at ambient temperature.

(b) Dry lighting impulse withstand voltage test.

(c) Dry power frequency voltage withstand test.

(d) Measurement of the partial discharge level.

(e) Test of taps insulation.

(f) Tightness test at the flange or other fixing device.

(g) Tightness test on liquid filled and liquid insulated bushings.

(h) Visual inspection and dimensional check.

(2) **Type Tests:**

The following type test shall be carried out on the bushings as applicable to HV and/or Neutral bushings according to IEC 60137. However, type test reports for the test carried out on the bushings of the design that does not differ from the offered bushings in any way that may improve the features to be checked by a type test shall be acceptable in lieu of the actual tests.

(a) The wet power frequency voltage withstand test.

(b) The dry lightning impulse voltage withstand test.

(c) Wet switching impulse withstand test.

(d) The thermal stability test.

(e) Temperature rise test

(f) Verification of thermal short-time current withstand

(g) Cantilever load withstand test.

(h) Tightness test on liquid filled, compound filled and liquid insulated bushing.

(i) Verification of dimensions.

(j) Seismic test (special test)

(k) Artificial pollution test (special test)
12.04 **Markings**
Each bushing to be supplied shall carry the markings on it in accordance with IEC 60137.

13 **BUSHING CURRENT TRANSFORMERS**

13.01 **General:** Current transformer shall be manufactured and tested in accordance with the latest IEC Publication 60044-1. All secondary leads shall be brought to an outlet box near each bushing and terminated in non-split, current shorting type, terminal block located in the weather proof case near the reactor base.

13.02 **Ratings:**

(1) **500 kV Bushing CTs:**

(a) Ratios 1000-500-250/1-1-1A

(b) No. of cores 3

(c) Standard accuracy class 5 P

(d) Accuracy limit current factor. 20

(e) Rated output of each core, at lowest tap, VA. 30

(2) **Neutral CTs:**

(a) Ratios. 1000-500/1-1 A

(b) No. of core. 2

(c) Standard accuracy class. 5 P

(d) Accuracy limit current factor. 20

(e) Rated output of each core, at lowest tap, VA. 30

13.03 **Factory Tests:** The following tests shall be made on each bushing current transformer in accordance with the latest IEC Standard Publication No. 60044-1:-

(1) **Routine Tests:**

(a) Verification of terminal markings.

(b) Partial discharge measurement.

(c) Power frequency withstand test on secondary windings.

(d) Power frequency withstand test between sections.
(e) Inter-turn over-voltage test.

(f) Determination of errors and accuracy of protective and measuring cores.

(g) Magnetization characteristics verification at each tap of each cores.

(h) Measurement of winding resistance at each tap of each core.

(i) Raito test.

(j) Polarity test.

(2) Type Tests:

The following tests, as applicable shall be made on single CT of each type in accordance with latest issue of IEC publication IEC 60044-1 and IEC 60060-1:

(a) Short time current tests.

(b) Temperature rise tests.

(c) Determination of errors and accuracy of protective and necessary cores.

(d) Radio interference voltage measurement.

However, type test reports for the test carried out on the CTs of the design that does not differ from the offered one in any way shall be acceptable in lieu of the actual tests.

14 RATING PLATES

Each reactor shall be provided with a rating plate of stainless steel fitted in a visible position. The entries on the rating plate shall be indelibly marked by engraving and shall include the data in accordance with IEC Publication 60076-6.

15 SHIPPING CONDITIONS

Reactor shall be transported from the port of landing by suitable road trailer to the site or first by railway from port of landing to nearest railway station and then by suitable road trailer to the site.

If the shipping and rail and road weight limitations permit, the reactor shall be shipped filled with oil. The Contractor shall, however have the option of shipping the reactor assembled or dis-assembled without main components such as bushings, radiators and large accessories removed.

If disassembled and without oil, due to shipping and rail and road limitations, the reactors shall be shipped in its own tank, dry air/nitrogen gas filled, under
slight positive pressure, with radiators, conservator and bushings removed. A temporary pressure gauge shall be installed to facilitate monitoring of internal gas pressure. Valves shall be sealed and effectively protected to prevent tampering or removal or loss of gas while in transit.

The method of shipment shall be such as to protect the case, radiator, core and coils, bushings, oil, parts and accessories against corrosion, dampness, breakage or vibration injury that might be encountered in transportation and handling.

16 DRAWINGS AND DESCRIPTIVE DATA

16.01 Drawings & Descriptive Data: The following drawings information and descriptive data shall be supplied with the Bid.

(1) Drawings showing details and location and type of all accessories including bushings, cabinets, etc.

(2) A set of drawings of the reactor showing outside dimensions, for both fully erected and shipping conditions, hoisting space required for untanking and location of all accessories.

(3) The technical description and data to indicate the design and constructional features of the reactor and its components in detail so as to enable the understanding of main design features of the reactor offered.

(4) A list of materials and their properties, used in the construction of the reactor. The type, the specific losses and the designed flux density for the core materials shall be indicated. Details of proposed gasket materials, method of gasket location and compression control shall be provided. Excitation curves and specific loss curves shall also be supplied.

(5) Descriptive data and literature showing characteristics, construction etc. of the following items:

(a) Oil temperature indicators

(b) Resistance type oil temperature indicators

(c) Winding hot spot temperature indicators

(d) Buchholz relay

(e) H.V. and neutral bushings

(f) Bushing CTs.

(g) Oil monitoring device.
(6) Drawings showing the major details and dimensions of the reactor outdoor control cabinets.

(7) Literature and drawings describing construction, operation and equipment offered in the Tender for firefighting system and drawings showing the arrangement of firefighting equipment.

16.02 **Approval Drawings and Descriptive Data:** The Contractor shall furnish the approval drawings and descriptive data described below:

1. Rating nameplate drawing showing details of reactor winding connections, rated MVAR and insulation values of winding and all other relevant design details.

2. Detailed schematic and wiring diagrams and control diagrams.

3. Drawings showing reactor outdoor control cabinet details, including wiring, instrumentation and controls.

4. Complete parts list and parts books.

5. Complete instructions for setting the reactors, assembling unmounted parts for putting the reactor in service and for operation and maintenance.

6. Instruction manual shall include photographs, assembly, installation and maintenance of the power reactors, including the following views of the reactors:
   - Top of assembled reactor with bushings
   - Side of assembled reactor facing HV bushings.
   - Side of core and coil assembly facing HV leads

7. Detailed physical arrangement, complete wiring diagram and technical data of the fire fighting system.

8. The available technical literature on the core material.