

KARNATAKA POWER TRANSMISSION CORPORATION LIMITED

**SECTION - SHUNT REACTOR &
NEUTRAL GROUNDING
REACTOR**

CONTENTS

| | | |
|-----|--|----|
| 1. | GENERAL..... | 3 |
| 2. | TYPE OF REACTOR..... | 3 |
| 3. | TRANSPORTATION | 3 |
| 4. | PERFORMANCE | 4 |
| 5. | DESIGN REVIEW | 6 |
| 6. | CONSTRUCTION DETAILS..... | 7 |
| 7. | PAINTING SYSTEM AND PROCEDURES..... | 28 |
| 8. | INSULATING OIL..... | 28 |
| 9. | PREPARATION FOR STORAGE OF SPARE UNITS..... | 30 |
| 10. | BUSHINGS | 30 |
| 11. | NEUTRAL FORMATION AND EARTHING ARRANGEMENT..... | 33 |
| 12. | SPARE UNIT CONNECTION ARRANGEMENT..... | 34 |
| 13. | COOLING EQUIPMENT | 35 |
| 14. | WIRING & CABLING | 35 |
| 15. | VALVES..... | 36 |
| 16. | INDIVIDUAL MARSHALLING BOX AND COMMON MARSHALLING BOX..... | 37 |
| 17. | CURRENT REACTOR (BUSHING & OUTDOOR NEUTRAL CURRENT REACTOR..... | 39 |
| 18. | SURGE ARRESTER | 40 |
| 19. | FITTINGS & ACCESSORIES | 43 |
| 20. | ONLINE DISSOLVED GAS (MULTI-GAS) AND MOISTURE ANALYSER..... | 46 |
| 21. | ON-LINE INSULATING OIL DRYING SYSTEM (CARTRIDGE TYPE) | 48 |
| 22. | OIL SAMPLING BOTTLE..... | 50 |
| 23. | OIL SYRINGE | 50 |
| 24. | VOID | 51 |
| 25. | HAND TOOLS..... | 51 |
| 26. | TEST KIT..... | 51 |
| 27. | INSPECTION AND TESTING..... | 52 |

1. GENERAL

This specification covers design, engineering, manufacture, testing at manufacturer's works, delivery at site including all materials, accessories, spares, unloading, handling, proper storage at site, erection, testing and commissioning of the equipment specified.

2. TYPE OF REACTOR

2.1 The shunt reactor shall be of either gapped core type or magnetically shielded air core type (shell type) construction. The impedance ratio (X_0/X_1) specified shall be achieved by any one of the following methods:

- a) Adopting single phase construction in separate tanks.
- b) Adopting 5 limb core construction. For 3-Phase

In case of coreless construction following requirements are stipulated.

- a) A magnetic shield shall be provided around the coreless coils.
- b) Non-magnetic material sheet shall form the central core to minimize the Vibrations.

3. TRANSPORTATION

3.1 The Contractor shall be responsible to select and verify the route, mode of transportation and make all necessary arrangement with the appropriate authorities for the transportation of the equipment. The dimension of the equipment shall be such that when packed for transportation, it will comply with the requirements of loading and clearance restrictions for the selected route. It shall be the responsibility of the contractor to coordinate the arrangement for transportation of the Reactor for all the stages from the manufacturer's work to site.

3.2 The contractor shall carry out the route survey along with the transporter and finalise the detail methodology for transportation of reactor and based on route survey, any modification/ extension/ improvement to existing road, bridges, culverts etc. if required, shall be in the scope of the bidder.

3.3 The main tank of the reactor shall be inland transported on Hydraulic trailers equipped with GPS system for tracking the location of Reactor at all times during transportation from manufacturer works to designated site. The contractor shall intimate to Employer about the details of transporter engaged for transportation of the Reactor. The requisite details for tracking the Reactor during transit shall be provided to Employer. Requirement of Hydraulic trailer is envisaged for 400kV Shunt

Reactor.

- 3.4 All metal blanking plates and covers which are specifically required to transport the reactor shall be considered part of the reactor and handed over to the Purchaser after completion of the erection. Bill of quantity of these items shall be included in the relevant drawing/document.
- 3.5 The Contractor shall despatch the reactor filled with dry air at positive pressure. The necessary arrangement shall be ensured by the contractor to take care of pressure drop of dry air during transit and storage till completion of oil filling during erection. The total duration of storage at site with dry air shall preferably be limited to three months after which the Reactor shall be processed and filled with oil. The dry air cylinder(s) provided to maintain positive pressure can be taken back by the contractor after oil filling. A dry air pressure testing valve with necessary pressure gauge and adaptor valve shall be provided.

In case, turret having insulation assembly, is transported separately, then the above dry air arrangement shall be provided for turret also.

- 3.6 Reactor shall also be fitted with sufficient number of Electronic impact recorders (on returnable basis) during transportation to measure the magnitude and duration of the impact in all three directions. The acceptance criteria and limits of impact, which can be withstood by the equipment during transportation and handling in all three directions, shall not exceed “3g” for 50mSec (20Hz) as per KPTCL pre- commissioning document or as per contractor standard whichever is lower.

4. PERFORMANCE

- 4.1 Shunt Reactors will be connected to the transmission system for reactive compensation and shall be capable of controlling the dynamic over voltage occurring in the system due to load rejection. Typical line parameters of Transmission Lines are given below:

| Line | Positive Sequence impedance Ohm/kM | Zero Sequence impedance Ohm/kM | Susceptance mhos/km | |
|-----------|---------------------------------------|-----------------------------------|---------------------|-----------|
| | | | Positive | Zero |
| 400kV D/C | 9.177E-6+j1.582E-4 | 1.557E-4+j6.246E-4 | 7.33E-3 | 4.0237E-3 |
| 400kV S/C | 9.167E-6+j1.50E-4 | 1.550E-4+j6,250E0-4 | 7.32E-3 | 4.22E-3 |

- 4.2 Shunt Reactors of 420kV Class shall be capable of operating continuously at a voltage 5% higher than their rated voltage

without exceeding winding hot spot temperature of 140 deg C. Maximum ambient temperature shall be considered as 50°C.

- 4.3 Shunt Reactors of 245kV Class and below shall be capable of operating continuously at a voltage 10% higher than their rated voltage without exceeding winding hot spot temperature of 140 deg C. Maximum ambient temperature shall be considered as 50°C.
- 4.4 The neutral grounding reactors are required for grounding of the neutral point of shunt reactors (for line reactor only) to limit the secondary arc current and the recovery voltage to a minimum value.
- 4.5 The shunt reactors shall be designed for switching surge overvoltage of 2.5 p.u. and temporary overvoltage of the order 2.3 p.u. for few cycles followed by power frequency overvoltage upto 1.5 p.u. The reactor must withstand the stress due to above transient conditions which may cause additional current flow as a result of changed saturation characteristics/ slope beyond 1.5 p.u. voltage.
- 4.6 The winding hot spots shall be calculated using the maximum localized losses, insulation thickness at the maximum loss positions and the oil flow patterns in the winding. The oil temperature rise in the winding shall be used to determine hot spots rather than the bulk top oil temperature. The hot spot for all leads shall be calculated and it shall not exceed the calculated hot spot of the windings.
- 4.7 The hot spot temperatures and surface temperatures in the magnetic circuit (Core) shall be calculated with maximum allowed 125 deg C and 120 deg C respectively under over voltage conditions specified above.
- 4.8 Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or non-metal material shall not exceed the safe operating temperature of that material. Adequate temperature margins shall be provided to maintain long life expectancy of these materials.
- 4.9 Tank hotspot temperature under over voltage condition specified above shall not exceed 130 deg C considering maximum ambient temperature as 50 deg C.
- 4.10 The thermal and cooling system shall be designed for maximum continuous operating voltage U_m (where $U_m = 420$ kV).
- 4.11 In addition, the Reactor shall be designed to withstand the following over-voltages repeatedly without risk of failure (w.r.t.

Hotspot temperature of 140°C & core saturation):

- 1.05 U_m Continuous
- 1.50 U_m for 5 seconds
- 1.25 U_m for 1 minute

4.12 The magnetic circuit will be designed such that the reactor is linear upto 140% of rated voltage.

4.13 Radio Interference and Noise Level.

4.7.1 The reactor shall be designed with particular attention to the suppression of harmonic voltage, especially the third and fifth so as to minimise interference with communication circuit.

4.7.2 The noise level of reactor, when energised at maximum continuous operating voltage and frequency shall not exceed the values specified at Annexure-A measured under standard conditions as defined in IEC.

4.7.3 Additional Warrantee

Manufacturer shall provide additional warrantee of five years (in addition to the warrantee specified in the bidding documents) for the Reactor in case any of the followings is observed within specified warrantee period:

- a) Repair inside the Reactor either at site or at factory is carried out after commissioning.
- b) The concentration of any fault gas is more than values of condition-1 indicated in clause no 6.5 of IEEE-C57.104-2008, which are given below:

| H2 | CH4 | C2H2 | C2H4 | C2H6 | CO | CO2 | TDCG |
|-----|-----|------|------|------|-----|------|------|
| 100 | 120 | 1 | 50 | 65 | 350 | 2500 | 720 |

- c) The winding Tan delta goes beyond 0.005 or increase more than 0.001 within a year w.r.t. pre-commissioning values. No temperature correction factor shall be applicable.
- d) The moisture content goes above 12 ppm at any temperature during operation.

5. DESIGN REVIEW

5.1 The reactor shall be designed, manufactured and tested in accordance with the best international engineering practices

under strict quality control to meet the requirement stipulated in the technical specification. Adequate safety margin w.r.to thermal, mechanical, dielectric and electrical stress etc. shall be maintained during design, selection of raw material, manufacturing process etc. in order to achieve long life of reactor with least maintenance.

- 5.2 Raw material and sub-vendors used by reactor manufacturer shall be declared before commencement of manufacturing. The validity of Type tests of Reactor shall be 10 years as on the last date of submission of bid, provided that offered reactor design is identical to the type tested Reactor and same active materials (CRGO, Conductor and Insulation) of same grade & from the same sub-vendors are used. In case of any change of either active materials or sub-vendors, the type tests shall be carried out by the contractor at no extra cost to KPTCL.
- 5.3 Design reviews shall be conducted by Purchaser or an appointed consultant during the procurement process for Reactors; however the entire responsibility of design shall be with the manufacturer.
NOTE: If design review is conducted by appointing an external Consultant by KPTCL, the cost of consultancy charges shall be borne by the bidder.
Purchaser may also visit the manufacturers works to inspect design, manufacturing and test facilities.
- 5.4 The design review will commence after placement of award with the successful bidder and shall be finalised before commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the reactor under the scope of this specification. It shall be conducted generally following the “CIGRE TB 529 : Guidelines for conducting Design review for Reactors”.
- 5.5 The manufacturer shall provide all necessary information and calculations to demonstrate that the reactor meets the requirements for mechanical strength and durability due to inrush current. The latest recommendations of IEC and CIGRE shall be applied for short circuit withstand evaluation.
- 5.6 The manufacturer will be required to demonstrate the use of adequate safety margins for thermal, mechanical, dielectric and vibration etc. in design to take into account the uncertainties of his design and manufacturing processes. The scope of such design review shall include but not limited to the requirement as mentioned in **Annexure – E**.

6. CONSTRUCTION DETAILS

The construction details and features of each Shunt Reactor

shall be in accordance with the requirement stated hereunder. The components and fitting associated with Reactors are subject to Purchaser's approval and design review.

6.1 Tank

- 6.1.1 Tank shall be of welded/ bolted construction and fabricated from tested quality low carbon steel of adequate thickness. Unless otherwise approved, metal plate, bar and sections for fabrication shall comply with BS-4360/ IS 2062. Material Samples, technical literature, drawings, test reports and list of the names of the principal users with experience gained shall be supplied on request.
- 6.1.2 Tank shall be capable of withstanding, without damage, severe strains that may be induced under normal operating conditions or forces encountered during lifting, jacking and pulling during shipping and handling at site or factory. Tank, tank cover and associated structure should be adequately designed to withstand, without damage or permanent deflection / deformation, the forces arising out of normal oil pressure, test pressures, vacuum, seismic conditions and short circuit forces specified
- 6.1.3 All seams and those joints not required to be opened at site, shall be factory welded, and wherever possible they shall be double welded. Welding shall conform to BS-5135/ IS 9595. After fabrication of tank and before painting, dye penetration test shall be carried out on welded parts of jacking bosses, lifting lugs and all load bearing members. The requirement of post weld heat treatment of tank/stress relieving shall be based on recommendation of BS-5500 table 4.4.3.1/ IS 10801.
- 6.1.4 Tank stiffeners shall be provided for general rigidity and welded to the tank continuously along its end and sides (Intermittent welds will not be accepted). These shall be designed to prevent retention of water. Short edges on stiffeners should be avoided for better paint adhesion.
- 6.1.5 The tank shall be of proven design either bell type with bolted/ welded joint or conventional type with welded/ bolted top cover. Bell type tank shall be provided with joint at about 500 mm above the bottom of the tank. The welded joint shall be provided with flanges suitable for repeated welding. The joint shall be provided with a suitable gasket to prevent weld splatter inside the tank. Proper tank shielding shall be done to prevent excessive temperature rise at the joint.
- 6.1.6 Tank shall be provided with:
 - a) Lifting lugs: Four symmetrically placed lifting lugs shall be

provided so that it will be possible to lift the complete Reactor when filled with oil without structural damage to any part of the Reactor. The factor of safety at any one point shall not be less than 2.

- b) A minimum of four jacking pads in accessible position to enable the Reactor complete with oil to be raised or lowered using hydraulic jacks. Each jacking pad shall be designed to support with an adequate factor of safety at least half of the total mass of the Reactor filled with oil allowing in addition for maximum possible misalignment of the jacking force to the centre of the working surface.
 - c) Suitable haulage holes shall be provided.
 - d) Provision of 04 no. of Gate valves for UHF sensors for PD Measurements at various locations. Location of valves shall be finalized during design review.
 - e) Suitable provisions of pockets for OTI, WTI & RTDs including two spare pockets.
- 6.1.7 The tank shall be designed in such a way that it can be mounted on the plinth directly.
- 6.1.8 The base of each tank shall be so designed that it shall be possible to move the complete Reactor unit by skidding in any direction without damage when using plates or rails.
- 6.1.9 Tank MS plates of thickness >12 mm should undergo Ultrasonic Test (UT) to check lamination defect, internal impurities in line with ASTM 435 & ASTM 577.
- 6.1.10 After fabrication of tank and before painting, Non-destructive test (dye penetration test) is mandatory on the load bearing members such as base plate joints, jacking pads and lifting devices etc.
- 6.1.11 Suitable guides shall be provided for positioning the various parts during assembly or dismantling. Adequate space shall be provided between the covers & windings and the bottom of the tank for collection of any sediment.
- 6.1.12 Tank should be provided with adequately sized inspection covers, either in circular shape or in rectangular shape, preferably at diagonally opposite sides of the tank to access the active part and one at each end of the tank cover for easy access of the lower end of the bushings, earthing connections and tap changers etc. for inspection. Inspection covers shall be bolted type and shall not weigh more than 25 kgs. Handles shall be provided on the inspection cover to facilitate its lifting.

6.2 Tank Cover

- 6.2.1 The tank cover shall be designed to prevent retention of water and shall not distort when lifted. The internal surface of the top cover shall be shaped to ensure efficient collection and direction of free gas to the buchholz relay.
- 6.2.2 At least two adequately sized inspection openings one at each end of the tank, shall be provided for easy access to bushings and earth connections. The inspection covers shall not weigh more than 25 kg. Handles shall be provided on the inspection cover to facilitate lifting.
- 6.2.3 The tank cover shall be provided with pockets for oil and winding temperature indicators. The location of pockets shall be in the position where oil reaches maximum temperature. Further, it shall be possible to remove bulbs of OTI/WTI/RTD without lowering the oil in the tank. The thermometer shall be fitted with a captive screw to prevent the ingress of water.
- 6.2.4 Bushing turrets, covers of inspection openings, thermometer pockets etc. shall be designed to prevent ingress of water into or leakage of oil from the tank. Currents flowing in tank cover and bushing turrets - To allow for the effect of possible induced and capacitive surge current, the tank cover and bushing turret shall be fixed to the Reactor in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.
- 6.2.5 All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. If gasket is compressible, metallic stops/other suitable means shall be provided to prevent over-compression.
- 6.2.6 The Reactor shall be provided with a 100 mm nominal diameter butterfly valve and bolted blanking plate, gasket and shall be fitted at the highest point of the Reactor for maintaining vacuum in the tank.
- 6.2.7 It should be possible to inspect Buchholz relay or Oil surge relay, standing on tank cover or suitable arrangement shall be made to access Buchholz relay safely
- 6.2.8 **Gas venting** - The reactor cover, and generally the internal spaces of the reactor and all pipe connections shall be designed so as to provide efficient venting of any gas in any part of the reactor to the Buchholz relay. The space created under inspection/manhole covers shall be filled with suitable material to avoid inadvertent gas pockets. The Covers shall be vented at least at both longitudinal ends. The design for gas venting shall take into accounts the slopes of the plinth (if any) on which the Reactor is being mounted.

6.3 **Gasket for tank & cover**

All gasketed joints shall be designed, manufactured and assembled to ensure long-term leak proof and maintenance free operation. All gasketed joints shall preferably be O-ring and designed with gasket-in-groove arrangement. If gasket/O-rings is compressible, metallic stops/other suitable means shall be provided to prevent over-compression. All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. All matching flanges of gasket sealing joints should be machined (except curb joints). Gasket with intermediate stops are not acceptable. To the extent possible, the seamless gasket should be used for openings on tank/cover such as turrets, bushing, inspection covers, etc. All tank gaskets/O-rings used shall be of NBR (Acrylonitrile Butadiene Rubber) suitable for temperature conditions expected to be encountered during operation. The gasket material and additives should be fully compatible with Reactor insulating fluid/oil. The gasket should not contain oil soluble sulphur compounds. The properties of all the above gaskets/O-Rings shall comply with the requirements of type-IV rubber of IS-11149. Gaskets and O-rings shall be replaced every time whenever the joints are opened.

6.4 **Roller Assembly**

The Reactor shall be placed directly on concrete plinth foundation. To facilitate the movement of reactor to its foundation over rail track, bi-directional flanged wheels and axles shall be provided. It shall be suitable for fixing to the under carriage of Reactor. The rail track gauge shall be 1676 mm. Two rails shall be provided.

Flanged bi-directional wheels and axels shall be so designed that under both the directions of movement they shall not deflect sufficiently to interfere with the movement of the Reactor. Wheels shall be provided with suitable bearings, which shall be rust and corrosion resistant. Fillings for lubrication shall also be provided.

Scope shall include supply of complete two sets of rollers assembly for movement of reactors over rail track for each substation in case scope covers more than one reactor per sub-station under the package Otherwise, atleast one set shall be supplied.

6.5 **Foundation and Anti Earthquake Clamping Device**

- 6.5.1 To prevent Reactor movement during earthquake, suitable clamping devices shall be provided for fixing the Reactor to the foundation.

The contractor shall supply necessary bolts for embedding in the concrete foundation. The arrangement shall be such that the Reactor can be fixed to or unfastened from these bolts as desired. The fixing of the Reactors to the foundation shall be designed to withstand seismic events to the extent that a static coefficient of 0.3g applied in the direction of least resistance to that loading will not cause the Reactor or clamping devices as well as bolts to be over stressed. Details of device used and its adequacy shall be brought out in additional information schedule.

- 6.5.2 For foundation of separately mounted cooler bank of Reactor, fixing of cooler support shall be through Anchor Fastener with chemical grouting and no pockets for bolting shall be provided.
- 6.5.3 For support of cooler pipes, Buchholz pipe (if required) and fire-fighting pipe pylon supports, pre-fabricated metallic support from pit shall be provided which shall be further encased with concrete to prevent rusting.
- 6.5.4 All control cubicles shall be mounted at least one meter above Finished Ground Level (FGL) to take care of water logging during flooding. Suitable arrangement (ladder and platform) shall be provided for safe access to control cubicles.

6.6 Conservator & Oil Preservation System:

- 6.6.1 Conservator shall have air cell type constant oil pressure system to prevent oxidation and contamination of oil due to contact with moisture. Conservator shall be fitted with magnetic oil level gauge with potential free high and low oil level alarm contacts and prismatic oil level gauge.
- 6.6.2 Conservator Protection Relay (CPR)/Air cell puncture detection relay shall be externally installed on the top of conservator to give alarm in the event of lowering of oil in the conservator due to puncture of air cell in service
- 6.6.3 Conservator tank shall have adequate capacity with highest and lowest visible-levels to meet the requirements of expansion of total cold oil volume in the reactor and cooling equipment from minimum ambient temperature to top oil temperature of 110 deg C. The capacity of the conservator tank shall be such that the reactor shall be able to carry the specified overload without overflowing of oil.

- 6.6.4 The conservator shall be fitted with lifting lugs in such a position so that it can be removed for cleaning purposes. Suitable provision shall be kept to replace air cell and cleaning of the conservator as applicable.
- 6.6.5 Conservator shall be positioned so as not to obstruct any electrical connection to reactor.
- 6.6.6 Pipe work connections shall be of adequate size for their duty and as short and direct as possible. Only radiused elbows shall be used.
- 6.6.7 **Oil Preservation Equipment**
The requirements of air cell type oil sealing system are given below.
- 6.6.7.1 Contact of the oil with atmosphere is prohibited by using a flexible air cell of nitrile rubber reinforced with nylon cloth.
- 6.6.7.2 The temperature of oil is likely to rise upto 110deg C during operation. As such air cell used shall be suitable for operating continuously at this temperature.
- 6.6.7.3 Air cell of conservator shall be able to withstand the vacuum during installation/maintenance periods. Otherwise provision shall be kept to isolate the conservator from the main tank when the latter is under vacuum by providing a vacuum sealing valve or other suitable means in the pipe connecting main tank with the conservator. The Reactor manual shall give full and clear instructions on the operation, maintenance, testing and replacement of the air cell. It shall also indicate shelf life, life expectancy in operation, the recommended replacement intervals and the supplier.
- 6.6.7.4 To prevent oil filling into the air cell, the oil filling aperture shall be clearly marked.
- 6.6.7.5 The connection of air cell to the top of the conservator is by air proof seal preventing entrance of air into the conservator. The main conservator tank shall be stencilled on its underside with the words "Caution: Air cell fitted". Lettering of at least 150mm size shall be used in such a way to ensure clear legibility from ground level when the Reactor is fully installed. To prevent oil filling into the air cell the oil filling aperture shall be clearly marked. The Reactor rating and diagram plate shall bear a warning statement that the "Main conservator is fitted with an air cell".
- 6.6.7.6 The contractor shall furnish the leakage rates of the rubber bag/air cell for oxygen and moisture. It is preferred that the leakage rate for oxygen from the air cell into the oil will be low

enough that the oil will not generally become saturated with oxygen before 10 years. Air cells with well proven long life characteristics shall be preferred.

6.7 Piping works for conservator

- 6.7.1 Pipe work connections shall be of adequate size for their duty and possibly short and direct. Only radiused elbows shall be used.
- 6.7.2 The feed pipe to the Reactor tank shall enter the reactor cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the reactor side of the Buchholz relay, and straight for not less than three times that diameter on the conservator side of the relay. This pipe shall rise towards the oil conservator, through the Buchholz relay, at an angle of not less than 5 degrees. The feed pipe diameter for the main conservator shall be not less than 80 mm. Gas-venting pipes shall be connected to the final rising pipe between the reactor and Buchholz relay as near as possible in axial direction and preferably not less than five times pipe diameters from the Buchholz relay.
- 6.7.3 A double flange valve of preferably 50 mm and 25 mm size shall be provided to fully drain the oil from the main tank conservator.
- 6.7.4 Pipe work shall neither obstruct the removal of the opening of inspection or manhole covers.
- 6.7.5 No metal corrugated bellow (Flexible metal system) should be used in the feed pipe connecting main tank to conservator.

6.8 Dehydrating Filter Breather (Condition Controlled Maintenance Free type Breather)

Conservator shall be provided with maintenance free type breather.

- 6.8.1 The main Reactor tank conservator shall be fitted with a Maintenance-Free type silica gel Breather which shall be equipped with a microprocessor control unit and LED status indication.

6.8.2 Dehydrating breather's operating principle:

When the oil conservator breaths-in (e.g. at reduced load), the air flows through a filter made of high-grade steel wire mesh. The equipment fitted with filter & the dust cap, filters the dust, sand and other dirt particles from the air. The filtered air flows through the desiccant chamber filled with colourless, moisture adsorbing pellets and are dehydrated. The dehydrated air rises further via the

pipe in the oil conservator. The desiccant is dehydrated by the built-in heating unit which is controlled by sensors, thus obviating the need for periodic desiccant replacement. The dehydrating breather is mounted on the pipe to the oil conservator at a height of 1200mm approximately from Reactor rail top level.

6.8.3 **Technical Features:**

- 6.8.3.1 Material & External Construction of the Breather shall be such that all external parts are suitable for outdoor use & resistive to Reactor oil, ultraviolet rays, pollution & salt water and shall work without any trouble for ambient temperature between 0°C to +80°C.
- 6.8.3.2 Following LEDs for local display on control unit, and suitable contacts & analog signal shall be provided for wiring to remote location:
- a) Led for Power of control unit – ON
 - b) LED for Filter heater – ON
 - c) LED for Anti-condensation heater (of control unit) – ON
 - d) LED & relay contact for “Device Error”
 - e) LED & relay contact for Regeneration active (De-humidification in process)
 - f) Analogue output signal (4-20mA) for the Temperature of air (in filter unit/pipe).
- 6.8.3.3 The Breather shall be equipped with test button which should allow to carry out a self-test and to check the functions like relay circuits, heating or the signal transmission in the control room, etc. at any time.
- 6.8.3.4 Control unit shall be equipped with communication port for downloading the operational data logged by the unit. All necessary software required for downloading and analyzing the logger data shall also be provided by the supplier. Supply of Laptop/PC for above software is not envisaged.
- 6.8.3.5 The moisture and temperature measurement system (Sensor) installed should be modular making it easy to replace the same if at all the same is necessary during the service of breather.
- 6.8.3.6 The equipment shall operate at input supply of 230V AC, 50Hz. Any converter if required shall be supplied with the equipment.
- 6.8.3.7 Degree of Protection shall be at least IP55 for which type Test report shall be submitted. Necessary protective devices shall be

provided in order to protect the equipment against over voltages & high-frequency interference.

- 6.8.3.8 The control unit shall be equipped with suitable heater to prevent moisture condensation.
- 6.8.3.9 The size of condition controlled maintenance free dehydrating breather shall be decided based on the volume of Reactor oil during detailed engineering.
- 6.8.4 The equipment shall be covered on warranty for a period of 5 years from the last date of complete commissioning and taking over. During this period, if the equipment needs to be shifted to suppliers works for repairs, supplier will have to bear the cost of spares, software, transportation etc. of this equipment for repair at test lab/works. Further supplier shall make alternate arrangement for smooth operation of the Reactor.
- 6.8.5 Condition Controlled Maintenance Free Type Breather of alternate proven technology shall also be acceptable.
- 6.8.6 Further, provision shall also be made to fix conventional dehydrating breather. The piping and flange arrangement shall be made such that it is possible to fix both the maintenance free type breather and conventional dehydrating filter breather. Such an arrangement is envisaged for smooth operation of the Reactor incase of exigencies i.e., withdrawal /removable of maintenance free type breather for repair/service.

Also, the required capacity and number of conventional dehydrating filter breather shall be supplied as spare for the main tank conservator.

6.9 **Pressure Relief Device**

One PRD of 150mm Diameter is required for every 30000 Litres of oil. However, at least two numbers PRDs shall be provided. Its mounting should be either in vertical or horizontal orientation, preferably close to bushing turret or cover. PRD operating pressure selected shall be verified during design review.

PRD shall be provided with special shroud to direct the hot oil in case of fault condition. It shall be provided with an outlet pipe which shall be taken right up to the soak pit of the Reactor. The size (Diameter) of shroud shall be such that it should not restrict rapid release of any pressure that may be generated in the tank, which may result in damage to equipment. Oil shroud should be kept away from control cubicle and clear of any operating position to avoid injury to personnel in the event of PRD operation.

The device shall maintain its oil tightness under static oil pressure equal to the static operating head of oil plus 20 kPa.

It shall be capable of withstanding full internal vacuum at mean sea level. It shall be mounted directly on the tank. Suitable canopy shall be provided to prevent ingress of rain water. One set of potential free contacts (with plug & socket type arrangement) per device shall be provided for tripping. Following routine tests shall be conducted on PRD:

- a. Air pressure test
- b. Liquid pressure test
- c. Leakage test
- d. Contact operation test
- e. Dielectric test on contact terminals.

6.10 **Sudden Pressure Relay**

One number of Sudden Pressure relay with alarm/trip contacts **(Terminal connector Plug & socket type arrangement suitable for 2.5sq.mm control cable)** shall be provided on tank of Reactor. Operating features, size and quantity shall be reviewed during design review. Pressurized water ingress test for Terminal Box (routine tests) shall be conducted on Sudden Pressure Relay/Rapid pressure rise relay. Suitable canopy shall be provided to avoid ingress of rain water.

6.11 **Buchholz Relay**

A double float, reed type Buchholz relay shall be provided in series of the connecting pipe between the oil conservator & the Reactor tank with minimum distance of 5 times pipe diameter between them. Any gas evolved in the Reactor shall collect in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation and taking gas sample. A copper tube shall be connected from the gas collector to a valve located about 1200 mm above ground level to facilitate sampling with the Reactor in service. Suitable canopy shall be provided to prevent ingress of rain water. The device shall be provided with two potential free contacts (plug & socket type arrangement suitable for 2.5 Sq.mm control cable), one for alarm/trip on gas accumulation and the other for tripping on sudden rise of pressure.

The Buchholz relay shall not operate during starting/ stopping of the Reactor oil circulation under any oil temperature conditions. The use of pipe or relay aperture baffles shall not be used to decrease the sensitivity of the relay. The relay shall not mal-operate for through fault conditions or be influenced by the magnetic fields around the Reactor during the external fault

conditions. Pressurized water ingress test for terminal box (Routine test) shall be conducted on Buchholz relay.

6.12 **Oil Temperature Indicator (OTI)**

All Reactors shall be provided with a 150 mm dial type thermometer for top oil temperature indication with angular sweep of 270°. It shall have adjustable, potential free alarm and trip contacts, (plug & socket type arrangement suitable for 2.5 Sq.mm control cable) besides that required for control of cooling equipment if any. Maximum reading pointer and resetting device shall be provided in the OTI. A temperature sensing element suitably located in a pocket on top oil shall be provided. This shall be connected to the OTI by means of capillary tubing. Temperature indicator dials shall have linear gradations to clearly read at least every 2°C. The range of temperature should be 0-150°C with accuracy of ± 1.5 degree C or better of full scale deflection.

The setting of alarm and tripping contacts shall be adjustable at site & setting values will be reviewed during detailed engineering based on manufacturer's recommendation.

OTI shall be so mounted that the dials are about 1200mm from ground level. Glazed door of suitable size shall be provided for convenience of reading.

In addition to the above, the following accessories shall be provided for remote indication of oil temperature:

a) Temperature transducer with Pt100 sensor

RTD shall be provided with Pt100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The Pt100 temperature sensor shall have three wire un grounded system. The calibration shall be as per IS: 2848 or equivalent. The Pt100 sensor may be placed in the pocket containing temperature sensing element. RTD shall include image coil, for OTI system and shall provide dual output 4-20mA for remote OTI and SCADA system individually. The transducer shall be installed in the Individual Marshalling Box. Any special cable required for shielding purpose, for connection between Pt100 temperature sensor and transducer, shall be in the scope of manufacturer. 4-20mA signal shall be wired to Numerical RTCC panel/BCU (SAS) for further data transfer to SCADA through IEC 61850 compliant communication.

b) Remote oil temperature indicator

It shall be suitable for flush mounting on Employer's control panel/ Numerical RTCC panel and shall operate on 4-20mA input available from the above transducer. Any special cable

required for shielding purpose, for connection among Individual Marshalling Box, Common Marshalling Box/Cooler control cabinet and remote OTI control circuit, shall be in the scope of Contractor/Manufacturer.

6.13 Winding Temperature Indicator (WTI)

The Reactor shall be provided with a dial type hot spot indicator of about 150mm diameter for measuring the hot spot temperature of each winding [HV, IV & Tertiary (if applicable)]. It shall have angular sweep of 270°. Range of temperature should be 0-1500°C with accuracy of $\pm 1.5\%$ (or better) of full scale deflection. The instruments should be capable of withstanding high voltage of 2.5kV AC rms, 50Hz for 1 minute. The terminal provided for auxiliary wiring should be Press-fit type.

The Thermometer shall have adjustable, potential free alarm, trip contacts besides that required for control of cooling equipment, if any. Instrument should be provided with maximum reading pointer and resetting device, switch testing knob & anti-vibration mounting grommets (for projection mounting). Type of switch (NO/NC) shall be heavy duty micro switch of 5A at 240V AC/DC. Adjustable range shall be 20-90% of full scale range. The instruments case should be weather proof and epoxy coating at all sides. Instruments should meet degree of protection of IP55 as per IEC 60529. A temperature sensing bulb located in a thermometer pocket on tank cover should be provided to sense top oil. This shall be connected to the WTI instrument by means of flexible stainless steel armour to protect capillary tubing. WTI shall have image coil and auxiliary CTs, if required to match the image coil mounted in local control box. The setting of alarm and tripping contacts shall be adjustable at site.

The WTI shall be so mounted that the dials are about 1200mm from ground level. Glazed door of suitable size shall be provided for convenience of reading.

The setting of alarm and tripping contacts shall be adjustable at site and setting values will be reviewed during detailed engineering based on manufacturer's recommendation.

In addition to the above, the following equipment shall be provided for remote indication of winding temperature for each of the winding:

- a) Temperature transducer with Pt100 sensor for each winding**
RTD shall be provided with Pt100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The Pt100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per IS 2848 or

equivalent. The Pt100 sensor may be placed in the pocket containing temperature sensing element. RTD shall include image coil, Auxiliary CTs, if required to match the image coil, for WTI system and shall provide dual output 4-20mA for remote WTI and SCADA system individually. The transducer, Auxiliary CT shall be installed in the Individual Marshalling Box. Any special cable required for shielding purpose, for connection between Pt100 temperature sensor and transducer, shall be in the scope of Contractor. 4-20mA signal shall be wired to Numerical RTCC/BCU (SAS) for further transfer of data to SCADA through IEC 61850 compliant communications.

b) Remote winding temperature indicator (RWTI)

It shall be suitable for flush mounting on Employer's control panel/ digital RTCC panel and shall operate on 4-20mA input available from the above transducer. Any special cable required for shielding purpose, for connection among Individual Marshalling Box / Cooler control cabinet, Common Marshalling Box and remote WTI control circuit, shall be in the scope of contractor.

Separate individual RWTI shall be provided for display of temperature for each of the three windings (HV, IV and LV).

The auxiliary supply for ROT1 & RWT1 if required will be 220V DC only.

6.14 Fibre Optic Temperature Monitoring System:

Temperature measurement of Oil and windings shall be done using Fiber optic sensors, meeting following criteria:

1. System shall be of proven and rugged technology. The temperature sensing tip along with the fibre optic cable shall be of an already type tested design. Details of the relevant tests conducted shall be submitted along with the offer. The probes shall be directly installed in each phase/winding of Reactor to measure the winding hot spot and at the top (inside) of the Reactor to measure top oil temperature. There shall be minimum sixteen probes inside the reactor. Twelve (12) probes shall be installed at the hottest spots of each of the phase winding. Of the remaining probes, two (2) probes shall be at the top (inside) of the Reactor for measuring top oil temperature and two (2) probes at the hottest spot of the core.
2. The locations of the probes shall be proposed by the Manufacturer by identifying the hot spots with necessary supporting calculations/documents and shall be finalized by agreement with the Purchaser.

3. Probes shall be able to be completely immersed in hot reactor oil; they shall withstand exposure to hot Kerosene vapor during the reactor insulation drying process (VPD). The probes shall meet the requirement to eliminate the possibility of partial discharge in high electrical stress areas in the Reactor.
4. Temperature range of the system should be -30°C to 200°C & accuracy of $\pm 2^{\circ}\text{C}$ with no recalibration required. The probes shall not get damaged/affected during filtration of the Reactor.
5. Probes shall be all Silica, Double Teflon jacketed fibre with perforations/slits in the outer jacket to allow complete oil filling. The fibre with Teflon jacket shall be strong enough to withstand the severe conditions prevailing inside an EHV Reactor.
6. A Microprocessor based monitoring & recording unit shall be a part of the system. In order to facilitate measurement of temperature from the optical sensors, microprocessor based monitoring unit having at least 16 channels shall be provided. System should include analog outputs for each measurement channel. Temperature resolution of the analog outputs shall be $\pm 0.1^{\circ}\text{C}$ and the systems shall offer a user programmable temperature alarm outputs with 16 relays, alarm lamps (LED) and controller system status indicators. All inputs and outputs of the system shall meet the requirements of surge test of IEEE C37.90.1-2002 in which a 4000 V surge is applied to all the inputs and outputs without permanent damage to the instrument. The microprocessor based unit shall be of an already type tested design & details of type tests conducted shall be submitted with the offer. The device shall be communicable type & the protocol shall be IEC 61850 compliant. Provision for Time Synchronization with GPS shall be made.

The temperature monitoring system shall be direct measurement non-calibrating type. It shall read & display temperature of each Fibre Optic sensor measurement channel. The system shall work in independent mode and failure of one channel should not affect the performance of the other healthy channels. The logic for each relay should not consider the temperature channels for which probe error is detected and the out-put should return to normal state immediately after the probe error is detected.

7. The system shall be capable of retaining temperature data of 90 days at one (1) reading/ minute and should retain maximum temperature of each channel until reset.
8. The manufacturer should submit data showing that the probes are located in the hottest point of the winding, while submitting drawings for approval.

9. a. The fiber optic cable within the tank shall be rigidly supported to prevent injury from vibration and clamped securely so that they will not be displaced or deformed during short circuit.
- b. The fiber optic cables are to be brought out of the main tank through the tank wall penetrator feed through plate. The Feed through plate shall be welded on the Tank such that no oil leakage/moisture ingress will occur. The external fiber optic extension cable shall then be run to main control cabinet, routed inside the conduits with large bend radiuses.
10. The controller shall be housed in the cooler control cubicle or in a separate box of IP56 class mounted on the reactor tank. The position shall be clearly indicated in the GA drawings.
11. Temperature rise test measurements shall be made with the FO Thermometers. The equipment shall be operational during temperature rise tests and demonstrated during these tests. During probe verification, the hottest spot for each phase shall be identified, and temperature data for all probes recorded and reported in the test report.

6.15 Earthing Terminals

- 6.15.1 Two (2) earthing pads (each complete with two (2) nos. holes, M16 bolts, plain and spring washers) suitable for connection to 75 x 12 mm galvanised steel grounding flat shall be provided each at position close to earth of the two (2) diagonally opposite bottom corners of the tank.
- 6.15.2 Two earthing terminals suitable for connection to 75 x 12 mm galvanised steel flat shall also be provided on each individual/common marshalling box and any other equipment mounted separately. For the tank-mounted equipment like online drying/ Online DGA/etc double earthing shall be provided through the tank for which provision shall be made on the tank and connected through two flexible insulated copper link.
- 6.15.3 Equi-potential flexible copper link of suitable size at least 4 Nos. for Tank mounted turret with tank and tank with cover and or Bell shall be provided. For other components like - pipes, conservator support etc connected to tank shall also be provided with equipotential flexible copper link.
- 6.15.4 Each Reactor Unit should have provision for earthing and connection to grounding mat when not in service.

6.16 Core

- 6.16.1 The core shall be constructed from high grade non-ageing, Cold Rolled Grain Oriented (CRGO) silicon steel laminations. Indian Reactor manufacturers shall use core material as per above specification with BIS certification.
- 6.16.2 The leg magnetic packets (cheeses) shall be made from state of the art low loss electrical steel. The “Cheeses” shall be designed to minimize losses and equalize the distribution of flux in the legs.
- 6.16.3 The “cheeses” shall be bonded using high temperature epoxy resins to assure that they will remain bonded in service at the maximum temperatures that will occur in the magnetic circuit and for the full expected life. Vacuum impregnation is preferred. The contractor shall present data on the characteristics of the packets at the time of design review.
- 6.16.4 Material with high temperature withstand capability such as ceramic/ slate spacers shall be used to separate the packets. High temperature, mechanically stable material shall be used between the end packets and the top and bottom yokes. Special care shall be taken not to impede the cooling in these areas.
- 6.16.5 Means shall be provided to distribute the flux from the “cheeses” and the windings to the top and bottom yokes to prevent concentrations of flux with resulting high temperatures in the yokes.
- 6.16.6 The yokes shall be designed such that high temperatures resulting from unequal distribution of the flux in the yokes will not occur.
- 6.16.7 The spaces between “cheeses” will be designed so that high temperatures will not result due to fringing of flux at the oil gaps between them. The designer shall calculate the temperatures resulting from fringing.
- 6.16.8 The structural design shall be made so that pressure will be maintained to prevent loosening resulting from thermal expansion and contraction during all loading cycles.
- 6.16.9 The design shall be made in such a way that excessive vibration does not occur in the windings, structural supports of the windings and magnetic circuit and this will be subjected to design review.
- 6.16.10 The structure shall be designed to withstand the clamping and magnetic forces. The calculated magnetic forces will be furnished at the time of design review.

- 6.16.11 The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths within itself or to the earthed clamping structure and production of flux component at right angles to the plane of laminations which may cause local heating. The step-lap construction arrangement is preferred for better performance in respect of noise, No-load current and No-load loss.
- 6.16.12 The hot spot temperature and surface temperature in the core shall be calculated for over voltage conditions specified in the document and it shall not exceed 125 deg C and 120 deg C respectively.
- 6.16.13 Insulation of core to clamp/frame shall be tested at 2.5kV DC for 1 minute without breakdown after the Reactor is filled with liquid and insulation resistance should be at least 500 Mega ohm for new Reactor.
- 6.16.14 Core and winding shall be capable of withstanding the shock during transport, installation and service. Adequate provision shall be made to prevent movement of core and winding relative to tank during these conditions.
- 6.16.15 All steel sections used for supporting the core shall be thoroughly sand/shot blasted after cutting, drilling and welding.
- 6.16.16 Each core lamination shall be insulated with a material that will not deteriorate due to pressure and hot oil.
- 6.16.17 The supporting frame work of the core shall be so designed as to avoid presence of pockets which would prevent complete emptying of tank through drain valve or cause trapping of air during oil filling.
- 6.16.18 Adequate lifting lugs will be provided to enable lifting of active part (core & winding).
- 6.16.19 Core assembly shall be manufactured in such a way that lamination shall remain flat and finally assembled core shall be free from distortion.
- 6.16.20 Single point core earthing should be ensured to avoid circulating current. Core earth should be brought separately on the top of the tank to facilitate testing after installation on all Reactors. The removable links shall have adequate section to carry ground fault current. Separate identification name plate/labels shall be provided for the 'Core' and 'Core clamp'. Cross section of Core earthing connection shall be of minimum size 80 Sq.mm copper with exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 Sq.mm tinned copper where they are clamped between the laminations.

In case core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the lamination, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.

- 6.16.21 If grounding of the core cheeses are required a separate strap shall be brought to a terminal located in a waterproof enclosure on the tank. Separate ground leads will be routed from the top and bottom yokes to separate terminals in the enclosure.
- 6.16.22 A drawing showing the details of the earthing design and connection shall be furnished during detailed engineering.

6.17 Internal Structure Design

- 6.17.1 The structural design shall be made so that pressure will be maintained to prevent loosening resulting from thermal expansion and contraction during all loading cycles.
- 6.17.2 The design shall be made in such a way that excessive vibration does not occur in the windings, structural supports of the windings and magnetic circuit and this will be subjected to design review.
- 6.17.3 The structure shall be designed to withstand the clamping and magnetic forces. The calculated magnetic forces will be furnished at the time of design review.
- 6.17.4 Core and winding shall be capable of withstanding the shock during transport, installation and service. Adequate provision shall be made to prevent movement of core and winding relative to tank during these conditions.

6.18 Calculation of hot spots

- 6.18.1 The winding hot spots shall be calculated using the maximum localized losses, insulation thickness at the maximum loss positions, and the oil flow patterns in the winding. The oil temperature rise in the windings shall be used to determine hot spots rather than the bulk top oil temperature.
- 6.18.2 The hot spot temperatures and surface temperatures in the magnetic circuit shall be calculated. The maximum allowed hot spot temperature will be 125 deg C. The maximum allowed tank surface temperature will be 120 deg C.
- 6.18.3 The hot spot for all leads shall be calculated and it shall not exceed the calculated hot spot of the windings.

- 6.18.4 The hot spot in the windings and magnetic circuit shall be calculated for the over voltage conditions specified.

6.19 Core and supporting structure temperatures

- 6.19.1 Under normal operation, the temperature of any part of the core or its support structure in contact with oil shall not exceed 120 deg C. The temperature of these parts shall not exceed 130 deg C under the most extreme operating circumstances.
- 6.19.2 Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or non-metal material shall not exceed the safe operating temperature of that material. Adequate temperature margins shall be provided to maintain long life expectancy of these materials.

6.20 Windings

- 6.20.1 The manufacturer shall ensure that windings of all Reactors are made in clean, dust proof (Cleanroom class ISO 9 or better as per ISO 14644-1), humidity controlled environment with positive atmospheric pressure.
- 6.20.2 The conductors shall be of electrolytic grade copper free from scales and burrs. Oxygen content shall be as per IS 12444. Epoxy bonded continuously Transposed conductor (CTC) shall be used in main winding for rated current of 400A or more.
- 6.20.3 The conductor insulation shall be made from high-density (at least 0.75 gm/cc) paper having high mechanical strength. The characteristics for the paper will be reviewed at the time of design review.
- 6.20.4 The insulation of Reactor windings and connections shall be free from insulating compounds which are liable to soften, ooze out, shrink or collapse and be non-catalytic and chemically inactive in Reactor oil during service.
- 6.20.5 Coil assembly and insulating spacers shall be so arranged as to ensure free circulation of oil and to reduce the hot spot of the winding.
- 6.20.6 The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes.
- 6.20.7 The conductor shall be transposed at sufficient intervals in order to minimize eddy currents and to equalise the distribution of currents and temperature along the winding.

- 6.20.8 The winding shall be designed to withstand the dielectric tests specified. The type of winding used shall be of time tested. An analysis shall be made of the transient voltage distribution in the windings, and the clearances used to withstand the various voltages. Margins shall be used in recognition of manufacturing tolerances and considering the fact that the system will not always be in the new factory condition.
- 6.20.9 The barrier insulation including spacers shall be made from high-density pre-compressed press board (1.15 gm/cc minimum for load bearing and 0.95 gm/cc minimum for non-load bearing) to minimize dimensional changes. Kraft insulating paper used on conductor should have density of >0.75g/cc. The characteristics of the insulation paper will be reviewed at the time of design review.
- 6.20.10 All spacers shall have rounded edges. Radially stepped spacers between winding disks will not be accepted.
- 6.20.11 Wherever required, electrostatic shield, made from material that will withstand the mechanical forces will be used to shield the high voltage windings from the magnetic circuit.
- 6.20.12 All insulating materials and structures shall be protected from contamination and the effects of humidity during and after fabrication and after receipt, by storing them in a separate, climate-controlled area. All blocks shall be installed such that the grain is oriented in the horizontal direction, perpendicular to the winding compressive forces. Aspect ratio of selected conductor shall be chosen suitably based on manufacturer's experience to result in stable winding under normal and abnormal service condition after assembly.
- 6.20.13 All winding insulation shall be processed to ensure that there will be no detrimental shrinkage after assembly. All windings shall be pre-sized before being clamped.
- 6.20.14 Winding paper moisture shall be less than 0.5%.
- 6.20.15 Windings shall be provided with clamping arrangements which will distribute the clamping forces evenly over the ends of the winding.
- 6.20.16 **Either brazing/crimping type of connections are permitted for joints.** It shall be time proven and safely withstand the cumulative effect of stress which may occur during handling, transportation, installation and service including line to line and line to ground faults/short circuits. Manufacturer shall have system which allows only qualified personnel to make brazing or

crimping joints.

7.0 PAINTING SYSTEM AND PROCEDURES

The typical painting details for reactor main tank, pipes, conservator tank, radiator, control cabinet/ marshalling box / oil storage tank etc. shall be as given in **Annexure – F**. The proposed paint system shall generally be similar or better than this. The quality of paint should be such that its colour does not fade during drying process and shall be able to withstand temperature up to 120 deg C. The detailed painting procedure shall be finalized during award of the contract.

8.0 INSULATING OIL

- a) Uninhibited Mineral insulating oil shall be used & shall comply with IEC-60296- 2012 (Latest version).

Supplier shall furnish type test certificate complying to IEC-60296-2012 (latest version) from any NABL accredited oil testing laboratory.

The oil shall be got tested by R&D section, KPTCL before filling and after filling into the Reactor (before energizing) as per relevant standards.

- b) Sufficient quantity of oil necessary for first filling of all tanks, coolers and radiator at the proper level along with 10% extra oil for topping up shall be supplied in non-returnable containers suitable for outdoor storage.
- c) At manufacturer's works the quality of oil used for first filling, testing and impregnation of active parts shall meet at least parameters as mentioned below. The oil test results shall form part of equipment test report.
- BDV (kV rms) 70 kV (min.)
 - Moisture content 10 ppm (max.)
 - Tan-delta at 90degC 0.01 (max.)
 - Resistivity at 90degC 6×10^{12} ohm-cm (min.)
 - Interfacial Tension 35 mN/m (min.)

Oil sample shall be drawn before and after heat run test and shall be tested for dissolved gas analysis and furnish the value as base value for future test. Samples for DGA shall be taken from sampling device within 24 hours prior to commencement of temperature rise test and immediately after this test as per approved test plan. The acceptance norms with reference to various gas generation rates during the temperature rise test shall be as per IEEE C57-130/IEC 61181/ CIGRE Guidelines.

Value of DGA tests conducted before and after heat run test shall be furnished as base value for future test.

8.1 Particles in the oil

The particle analysis shall be carried out in an oil sample taken before carrying out FAT at manufacturers work and after completion of the oil filtration at site. The procedure and interpretation shall be in accordance with the recommendation of CIGRE report WG-12.17 - "Effect of particles on Reactor dielectric strength".

8.2 Moisture content in the solid insulation

Dummy insulation test block shall be inserted in the active part of Reactor at factory and same shall be used to detect the volume moisture content. Before application of vacuum and oil filling in the Reactor, it will be ensured that moisture content in the dummy insulation test block is less than 0.5%. Measurement shall be carried out as per IEC.

8.3 Oil filling

8.3.1 Procedures for site drying, oil purification, oil filling etc shall be done as per Field Quality Plan (FQP).

8.3.2 The duration of the vacuum treatment shall be demonstrated as adequate by means of water measurement with a cold trap or other suitable method but shall generally not be less than 72 hours. The vacuum shall be measured on the top of the Reactor tank and should be less than 1mbar.

8.3.3 Oil filling under vacuum at site shall be done with reactor oil at a temperature not exceeding 65°C. Vacuum shall not be broken until the Reactor is oil filled up to the Buchholz relay.

8.3.4 The minimum safe level of oil filling (if different from the Buchholz level) to which the Reactor shall be oil filled under vacuum, shall be indicated in the manual.

The Ultra High Vacuum type oil treatment plant of suitable capacity (**minimum 6000** litres per hour) suitable for treatment of oil in EHV class Reactor shall be used in order to achieve properties of treated oil. The plant shall be capable of treatment of new oil (as per IEC 60296 and reconditioning of used oil (as per IS: 1866/IEC: 60422 for oil in service) at rated capacity on single pass basis as follow:

- a) Removal of moisture from 100 ppm to 3 ppm (max.)
- b) Removal of dissolved gas content from 10% by Vol. to 0.1% by vol.
- c) iii) Improvement of dielectric strength break down voltage from 20 to 70 KV
- d) Vacuum level of degassing chamber not more than 0.15

torr/0.2 mbar at rated flow and at final stage. Machine shall have minimum of two degassing chambers and these should have sufficient surface areas to achieve the final parameters.

- e) Filter shall be capable of removing particle size more than 0.5 micron in the filtered oil.
- f) Processing temperature shall be automatically controlled and have an adjustable range from 40° C to 80° C.

8.3.5 Transportation of Oil

The insulating oil for the Reactor shall be delivered at site generally not before 90 days from the date of commissioning, with prior information to the Employer.

Insulating oil shall be delivered to the site in returnable oil drums / flexi bag / tanker. The oil drums / flexi bag / tanker shall be taken back without any extra cost to Employer within generally 45 days after utilisation of oil but in any case before contract closing. However, the spare oil shall be delivered in non-returnable drums.

9.0 Preparation for storage of spare units (if applicable)

The spare reactor shall be completely erected, oil filled and commissioned similar to the other reactors and kept on the foundation after completing all necessary activities for long term storage. Any special maintenance procedure required during long term storage shall be clearly brought out in the instruction manual. All pre commissioning tests on the spare Reactor similar to the unit kept in service shall be carried out by the contractor.

Purchaser intends to replace any of the reactor unit by the completely assembled oil filled spare reactor fitted with bushings, cooler etc by isolator switching arrangement and without physically shifting the reactor.

In case, due to space limitation, Isolator based switching arrangement is not possible, the completely assembled oil filled Reactor is to be shifted by manual pulling through rail track/road from its foundation to the other location within the substation. As any unit may be designated as the spare, all units must be prepared accordingly.

10.0 BUSHINGS

- 10.1 Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition, substation layout and movement along with the spare Reactor with bushing erected and provided with proper support from

one foundation to another foundation within the substation area. The electrical and mechanical characteristics of bushings shall be in accordance with IS/IEC 60137. All details of the bushing shall be submitted for approval & design review.

10.2 Bushing for various voltage rating shall be as follows

52 kV and above voltage class Bushing shall be RIP (Resin Impregnated paper)/RIS (Resin Impregnated Synthetic) condenser type with composite polymer insulator (housing). However, for 52kV Bushing, OIP (Oil Impregnated Paper) with porcelain insulator is also acceptable

36 kV and below voltage class bushing shall be solid porcelain or oil communicating type.

10.3 Oil filled condenser type bushing shall be provided with at least following fittings:

- (a) Oil level gauge.
- (b) Tap for capacitance and tan delta test. Test taps relying on pressure contacts against the outer earth layer of the bushing is not acceptable.
- (c) Oil filling plug & drain valve (if not hermetically sealed)

10.4 Bushings shall be provided with tap for capacitance and tan delta test. Test taps relying on pressure contacts against the outer earth layer of the bushing is not acceptable.

10.5 Where current Reactors are specified, the bushings shall be removable without disturbing the current Reactors.

10.6 Bushings of identical rating shall be interchangeable to optimize the requirement of spares. Mounting dimensions of bushing shall be as per drawing mentioned at Annexure.

10.7 Porcelain used in bushing manufacture shall be homogenous, free from lamination, cavities and other flaws or imperfections that might affect the mechanical or dielectric quality and shall be thoroughly vitrified, tough and impervious to moisture.

10.8 Polymer/composite insulator shall be seamless sheath of a silicon rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environment influences, external pollution and humidity. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer.

10.9 The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core. The technique being followed with detailed procedure and sampling shall be finalized during finalization of

MQP.

The weather sheds of the insulators shall be of alternate shed profile as per IS/IEC 60815-3. The weather shed shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections. The vulcanization for extrusion process shall be at high temperature and for injection moulding shall be at high temperature & high pressure. Any seams/burrs protruding axially along the insulator, resulting from the injection moulding process shall be removed completely without causing any damage to the housing. The track resistance of housing and shed material shall be class 1A4.5 according to IEC60587. The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. The composite insulator shall be capable of high pressure washing.

End fittings shall be free from cracks, seams, shrinks, air holes and rough edges. End fittings should be effectively, sealed to prevent moisture ingress, effectiveness of sealing system must be supported by test documents. All surfaces of the metal parts shall be perfectly smooth with the projecting points or irregularities which may cause corona. All load bearing surfaces shall be smooth and uniform so as to distribute the loading stresses uniformly.

The hollow silicon composite insulators shall comply with the requirements of the IEC publications IEC 61462 and the relevant parts of IEC 62217. The design of the composite insulators shall be tested and verified according to IEC 61462 (Type & Routine test).

- 10.10 Clamps and fittings shall be of hot dip galvanized/stainless steel.
- 10.11 Bushings turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay.
- 10.12 No arcing horns shall be provided on the bushings.
- 10.13 Corona shield, wherever required, shall be provided at bushing terminal (air end) to minimize corona.
- 10.14 Bushing shall be specially packed to avoid any damage during transit and suitable for long storage, with non-returnable packing wooden boxes with hinged type cover. Without any gap between wooden planks. Packing Box opening cover with nails/screws type packing arrangement shall not be acceptable.
- 10.15 Oil end portion of RIP/RIS Bushings shall be fitted with metal housing with positive dry air pressure and a suitable pressure monitoring device shall be fitted on the metal housing during

storage to avoid direct contact with moisture with epoxy. The pressure of dry air needs to be maintained in case of leakage. Alternatively, oil filled metal housing with suitable arrangement for taking care oil expansion due to temperature variations shall also be acceptable. Manufacturer shall submit drawing/documents of packing for approval during detail engineering. Detail method for storage of bushing including accessories shall be brought out in the instruction manual.

- 10.16 The terminal marking and their physical position shall be as per IS 2026/IEC: 60076.
- 10.17 Tan delta measurement at variable frequency (in the range of 20Hz to 350Hz) shall be carried out on each condenser type bushing (OIP & RIP/RIS) at Reactor manufacturing works as routine test before despatch and the result shall be compared at site during commissioning to verify the healthiness of the bushing.
- 10.18 Tan delta value of OIP/RIP/RIS condenser bushing shall be 0.005 (Max) in the temperature range of 100C to 400C. If Tan δ is measured at a temperature beyond above mentioned limit, necessary correction factor as per IEEE shall be applicable.
- 10.19 Spare Bushing shall be specially packed suitable for long storage with non-returnable packing, the details of which shall be provided to the purchaser
- 10.20 The terminal marking and their physical position shall be as per IEC: 60076.
- 10.21 Terminal connectors:
- a) Bushing terminals shall be provided with terminal connectors of approved type and size for connection of external parts. Terminal connectors must have been successfully designed and type tested strictly as per Section – General Technical Requirement.
 - b) Contractor shall submit the drawings of Bushing terminal connectors which he intends to supply and obtain owners approval before arranging procurement/manufacturing.

11.0 NEUTRAL FORMATION AND EARTHING ARRANGEMENT

11.1 For 1-Phase Unit:

If specified in BPS, the contractor shall connect the neutrals of single phase Shunt Reactor by overhead connection to operate in three phase banks. All material like conductor, clamp connectors, earthing materials, Bus post insulator, support structure etc required for neutral formation and connection

with neutral CT and earthing of neutral shall be provided by contractor. The neutral terminals of winding of the three (3) single phase Reactors shall be connected to an overhead common 3" IPS Al tube. The neutral formation shall be such that neutral winding of single phase spare Reactor can be disconnected or connected to either of the three phase banks unless approved otherwise.

11.2 For 3-Phase Unit:

The neutral of the shunt reactor shall be brought out through 145kV class Oil filled condenser bushing. The neutral of shunt reactor connected to a line shall be grounded through a neutral grounding reactor. The Contractor shall provide Aluminium connectors suitable for moose conductor between neutral of the shunt reactor, surge arrester and the neutral grounding reactor.

The neutral terminals of Reactors (without NGR) and Neutral grounding reactors shall be brought to the ground level by a brass/tinned copper grounding bar, supported from the tank by using porcelain insulators. The end of the brass/tinned copper bar shall be brought to the bottom of the tank, at a convenient point, for making bolted connection to two (2) 75 x 12 mm galvanised steel flats connected to Employer's grounding mat.

- 11.3 Neutral of Reactors, where neutral grounding reactor is not provided, shall be grounded directly.

12.0 SPARE UNIT CONNECTION ARRANGEMENT

If specified in BPS, connection arrangement of spare unit of reactor with other units shall be made by isolator switching. Neutral formation for spare unit of reactor shall be done by manual connection. Necessary conductors and clamps & connectors for this purpose shall be provided by the contractor.

The contractor shall make connection arrangement as well as control scheme in such a way that spare unit of reactor can be connected in place of faulty unit without physically shifting it from its location. For this purpose, Line, and Neutral Connections of spare unit are to be extended upto the other unit by forming auxiliary buses and shall be supported by structure mounted bus post insulators at suitable intervals to enable spare unit connection through flexible/rigid conductor and suitable connector in place of existing unit to be replaced. . However, the detail configuration and actual sizes of various items shall be finalised during detailed engineering and shall be subject to Employer's approval.

All associated materials like Bus post insulators, Aluminium tube, clamps & connectors, insulator strings, hardware, cables, support structures, required for the above mentioned arrangement shall be provided by the contractor.

13 COOLING EQUIPMENT

- 13.1 The reactor shall be designed for Oil immersed with natural cooling (ONAN)
- 13.2 The radiator bank of the shunt reactor shall be separately mounted. For neutral grounding reactor, the radiator, if required, may be tank mounted.
- 13.3 Design of cooling system shall satisfy the performance requirements. The radiator shall be of sheet steel in accordance with IS 513 and minimum thickness 1.2 mm. Each radiator bank shall be provided with the following accessories:
 - (a) Top and bottom shut off valve
 - (b) Drain Valve and sampling valve
 - (c) Air release plug
 - (d) Two grounding terminals for termination of two (2) Nos. 75x12 mm galvanised steel flats.
 - (e) Thermometer pockets with captive screw caps at cooler inlet and outlet.
 - (f) Lifting lugs
- 13.4 Each radiator bank shall be detachable and shall be provided with flanged inlet and outlet branches. Expansion joint shall be provided on top and bottom cooler pipe connection.
- 13.5 The cooler pipes, support structure including radiators and its accessories shall be hot dip galvanised or corrosion resistant paint should be applied to external surface of it.
- 13.6 Air release device and oil plug shall be provided on oil pipe connections. Drain valves shall be provided in order that each section of pipe work can be drained independently.

14 WIRING & CABLING:

All interconnecting control and power cables between various parts of Reactors like turret CT, MBs, Fans, pumps, Buchholz, PRD etc shall be routed through covered cable tray or GI conduit and shall be properly dressed. All cables shall be armoured type. Un-armoured cables (if provided) in any circuitry, shall be through GI conduit and no part shall be exposed. Cable terminations shall be through stud type TB and

ring type lugs. Type tested cables from approved sources shall be provided. Both ends of all the wires (Control & Power) shall be provided with proper ferrule numbers for tracing and maintenance. Further, any special cables (if required) shall also be considered included in the scope. All cable accessories such as glands, lugs, cable tags/numbers, etc. as required shall be considered included in the scope of supply.

- 14.1 Cable box / sealing end shall be suitable for following types of cables:-

| | |
|----------------------|--|
| i). 415volts Power | 1100 volt grade PVC insulated 1 X 4 core, 4/6 sq mm, stranded copper conductor cable |
| ii) Control | 1100 volt grade PVC insulated 19 core 2.5 sq mm & 10 core 2.5 Sq.mm stranded copper conductor cable. |
| iii) Signaling cable | 1Px0.5Sq.mm screened cable for 4-20mA signals |

- 14.2 Compression type cable connector shall be provided for termination of power and control cables.
- 14.3 Not more than 2 wires shall be connected to one terminal. Each terminal shall be suitable for connecting two 2.5 sq. mm stranded copper conductor control cable from each side.
- 14.4 All internal wiring shall be securely supported, neatly arranged, readily accessible and connected to equipment terminals and terminal blocks.
- 14.5 Engraved code identification plastic Alpha numeric ferrules marked to correspond with schematic diagrams shall be fitted at both ends of wires. Alpha Numeric ferrules shall fit tightly on wires and shall not fall off when the wire is disconnected from terminal block.

15 VALVES

- 15.1 All valves upto and including 100 mm shall be of gun metal or of cast steel/ cast iron. Larger valves may be of gun metal or may have cast iron bodies with gun metal fittings. They shall be of full way type with internal screw and shall open when turned counter clock wise when facing the hand wheel.
- 15.2 Suitable means shall be provided for locking the valves in the open and close positions. Provision is not required for locking individual radiator valves.
- 15.3 Each valve shall be provided with the indicator to show clearly the position of the valve.

- 15.4 All valves flanges shall have machined faces.
- 15.5 All valves in oil line shall be suitable for continuous operation with Reactor oil at 115 deg C.
- 15.6 The oil sampling point for main tank shall have two identical valves to be put in series. Oil sampling valve shall have provision to fix rubber hose of 10 mm size to facilitate oil sampling.
- 15.7 Valves or other suitable means shall be provided to fix the on line DGA monitoring systems to facilitate continuous monitoring. The location & size of the same shall be finalised during detailed design review.
- 15.8 After testing, inside surface of all cast iron valves coming in contact with oil shall be applied with one coat of oil resisting paint/varnish with two coats of red oxide zinc chromate primer followed by two coats of fully glossy finishing paint conforming to IS:2932. Outside surface except gasket setting surface of butterfly valves shall be painted with two coats of red oxide zinc chromate conforming to IS:2074 followed by two coats of fully glossy finishing paint.
- 15.9 All valves shall be painted with a shade (preferably red or yellow distinct and different from of main tank surface and as per the painting system and procedure specified.
- 15.10 All hardware used shall be hot dip galvanised / stainless steel.

16 INDIVIDUAL MARSHALLING BOX AND COMMON MARSHALLING BOX

- 16.1 Each single phase reactor unit shall be provided with Individual Marshalling Box and Common Marshalling Box (for a bank of three single phase unit) whereas each three phase shunt reactor shall be provided with Individual Marshalling Box.

All control cabinets shall be made of stainless steel sheet of at least 1.6 mm thick. The degree of protection shall be at least IP: 55 for outdoor and IP: 43 for indoor in accordance with IS: 13947/IEC: 60947.

All doors, removable covers and plates shall be gasketed all around with suitably profiled. All gasketed surfaces shall be smooth straight and reinforced if necessary to minimize distortion to make a tight seal. For Control cubicle / Marshalling Boxes etc. which are outdoor type, all the sealing gaskets shall be of EPDM rubber or any better approved quality, whereas for all indoor control cabinets, the sealing gaskets shall be of neoprene rubber

or any better approved quality. The gaskets shall be tested in accordance with approved quality plan, IS: 1149 and IS: 3400. Ventilating Louvers, if provided, shall have screen and filters. The screen shall be fine wire mesh of brass. All the separately mounted cabinets and panels shall be free standing floor mounted type and have domed or sloping roof. All the control cabinets shall be provided with suitable lifting arrangement. Individual Marshalling Box shall be tank mounted only.

- 16.1.1.1 All the contacts of various protective devices mounted on the reactor and all the secondary terminals of the bushing CTs shall also be wired upto the terminal board in the Individual Marshalling box. All the CT secondary terminals in the Individual Marshalling box shall have provision for shorting to avoid CT open circuit while it is not in use. All the necessary terminations for remote connection to Purchaser's panel shall be wired upto the Common Marshalling box.
- 16.2 A space heater and cubicle lighting with ON-OFF switch shall be provided in each panel.
- 16.2.1 Control and power supplies are to be given after suitable selection at Common Marshalling Box. Necessary isolating switches and protective devices shall be provided at suitable points as per Purchaser's approved scheme.
- 16.2.2 The temperature indicators shall be so mounted that the dials are about 1200 mm from ground level. Glazed door of suitable size shall be provided for convenience of reading.
- 16.2.3 All the control circuit connections from individual marshalling box and of three single phase units of a bank including spare reactor unit to Purchasers Control panels shall be routed through common marshalling box. Common marshalling box shall be floor mounted and of size not less than 1600mm (front) X 650mm (depth) X 1800mm (height).
- 16.2.4 Connection arrangement for spare unit shall be in such a way that spare unit of reactor can be connected in place of faulty unit without physically shifting, and all the control, protection, indication signals of spare unit shall also be brought in common marshalling box of all the banks. Necessary arrangement in schematic of Common marshalling box is required to facilitate changeover of all the signals of faulty units to spare unit of reactor, to ensure flow of control, protection and indication signals between Purchasers Control panels and individual units under operation (i.e. any designated unit for bank or spare unit, if it replace any designated unit). The control and monitoring terminations of a spare Reactor unit shall be brought to CMB. The necessary switching arrangement

through male-female plug-in TB assembly shall be provided for replacing spare unit with any one of the faulty phase unit for monitoring & control from CMB.

- 16.2.5 Common marshalling box shall have following arrangement in addition to schematic arrangement. Details of stationed auxiliary power supply are mentioned in GTR specification.
- 16.2.6 Two auxiliary power supplies, 415 volt, three phase four (4) wire shall be provided by the Purchaser at common marshalling box (for Single Phase unit) or Individual Marshalling Box (for Three Phase unit). Suitably rated power contractors, MCBs/MCCBs as required for entire auxiliary power supply system including distribution to individual marshalling boxes, Online Moisture & Hydrogen monitoring system, Online drying system and Fibre optic sensor Box etc., shall be provided by contractor. In case auxiliary power supply requirement for is different than station auxiliary AC supply, then all necessary converters shall be provided by the Contractor. For each circuit separate MCBs / MCCBs shall be provided in the Common Marshalling Box. Auxiliary power supply distribution scheme shall be submitted for approval. Supply and laying of Power, Control and special cables from common marshalling box to individual units (including spare unit) is in the scope of the contractor.
- 16.2.7 All loads shall be fed by one of the two feeders through an electrically interlocked automatic transfer switch housed in the common marshalling box.
- 16.2.8 Design features of the transfer switch shall include the following:
- a) Provision for the selection of one of the feeder as normal source and other as standby.
 - b) Upon failure of the normal source, the loads shall be automatically transferred after an adjustable time delay to standby sources.
 - c) Indication to be provided at cooler control cabinet for failure of normal source and for transfer to standby source and also for failure to transfer.
 - d) Automatic re-transfer to normal source without any intentional time delay following re-energization of the normal source.
 - e) Both the transfer and the re-transfers shall be dead transfers and AC feeders shall not be paralleled at any time.

17 CURRENT REACTOR (BUSHING & OUTDOOR NEUTRAL CURRENT REACTOR)

- 17.1 Current Reactors shall comply with IS: 16227/IEC-61869 1& 2.
- 17.2 It shall be possible to remove the turret mounted current Reactors from the Reactor tank without removing the tank cover. Necessary precautions shall be taken to minimize eddy currents and local heat generated in the turret.
- 17.3 Current Reactor secondary leads shall be brought out to a weatherproof terminal box near each bushing. These terminals shall be wired out to common marshalling box using separate cables for each core.
- 17.4 Bushing Current Reactor parameters indicated in this specification are tentative and liable to change within reasonable limits. The Contractor shall obtain Purchaser's approval before proceeding with the design of bushing current Reactors.
- 17.5 One number single phase current Reactor for earth fault protection shall be provided for each bank of reactor and shall be located in the neutral conductor connecting common neutral point with earth.
- 17.6 Technical Parameters of Bushing CTs and Neutral CTs (outdoor type) are enclosed at Annexure – H. The CT's used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
- 17.7 Secondary resistance and magnetising current characteristics of TPS class (protection) (as per IEC) CT of same rating shall be identical. This is applicable for Neutral CT (outdoor) also and shall be reviewed during detail engineering.

18 SURGE ARRESTER

18.1 General

The surge arresters (if specified in BPS) shall conform in general to IEC-60099-4 except to the extent explicitly modified in the specification.

The bidder shall offer surge arresters of gapless type without any series or shunt gap. Arresters shall be hermetically sealed units, of self supporting construction, suitable for mounting on structures.

18.2 Duty Requirements

The surge arresters shall be of heavy duty station class type. It shall be physically located between the neutral of shunt reactor (brought out at 145kV class bushing) and neutral grounding reactor and shall be electrically in parallel with the

latter.

The surge arresters shall be capable of discharging over voltage occurring during switching of unloaded Reactors and reactors. It shall be capable of spark over on severe switching surges and multiple strokes. It shall be able to withstand wind load calculated at 195 kg/sq.m.

18.3 **Constructional Features**

- 18.3.1 The non linear blocks shall be of sintered metal oxide material. These shall be provided in such a way as to obtain robust construction, with excellent electrical and mechanical properties even after repeated operations.
- 18.3.2 The reference current of the arrester shall be high enough to eliminate the influence of grading and stray capacitance on the measured reference voltage.
- 18.3.3 The surge arresters shall be fitted with pressure relief devices and arc diverting parts suitable for preventing shattering of porcelain housing and providing path for flow of rated fault currents in the event of arrester failure.
- 18.3.4 The arresters shall incorporate anti-contamination feature to prevent arrester failure consequent to uneven voltage gradient across the stack in the event of contamination of the arrester housing.
- 18.3.5 Seals shall be provided in such a way that these are always effectively maintained even when discharging rated lightning current.
- 18.3.6 Outer insulator shall be porcelain used shall be homogenous, free from laminations, cavities and other flaws or imperfection that might affect the mechanical or dielectric quality and shall be thoroughly vitrified, tough and impervious to moisture. Glazing of porcelain shall be uniform brown colour, free from blisters, burrs and other similar defects. Porcelain housing shall be so coordinated that external flashover will not occur due to application of any impulse or switching surge voltage upto the maximum design value for arrester

Outer insulator shall be polymer/composite insulator housing. Details of specification of polymer/composite insulator are given below:

Polymer/composite insulator shall be seamless sheath of a silicon rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environment influences, external pollution and

humidity. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core. The technique being followed with detailed procedure and sampling shall be finalized during finalization of MQP.

The weather sheds of the insulators shall be of alternate shed profile as per IS/IEC 60815-3. The weather shed shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections. The vulcanization for extrusion process shall be at high temperature and for injection moulding shall be at high temperature & high pressure. Any seams/burrs protruding axially along the insulator, resulting from the injection moulding process shall be removed completely without causing any damage to the housing. The track resistance of housing and shed material shall be class 1A4.5 according to IEC60587. The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. The composite insulator shall be capable of high pressure washing.

End fittings shall be free from cracks, seams, shrinks, air holes and rough edges. End fittings should be effectively, sealed to prevent moisture ingress, effectiveness of sealing system must be supported by test documents. All surfaces of the metal parts shall be perfectly smooth with the projecting points or irregularities which may cause corona. All load bearing surfaces shall be smooth and uniform so as to distribute the loading stresses uniformly.

The hollow silicon composite insulators shall comply with the requirements of the IEC publications IEC 61462 and the relevant parts of IEC 62217. The design of the composite insulators shall be tested and verified according to IEC 61462 (Type & Routine test).

- 18.3.7 The end fittings shall be made of non-magnetic and corrosion proof material.
- 18.3.8 The name plate shall conform to the requirement of IEC incorporating the year of manufacture.
- 18.3.9 The arrester shall be supplied with suitable support structure either of tubular GI pipe or lattice steel galvanised.
- 18.3.10 The heat treatment cycle details along with necessary quality checks used for individual blocks along with insulation layer formed across each block to be furnished. Metallised coating

thickness for reduced resistance between adjacent discs to be furnished along-with procedure for checking the same.

- 18.3.11 Technical specification of Surge Arrester is enclosed at **Annexure-I**

18.4 **Fittings and Accessories of Surge Arrester**

- 18.4.1 Each arrester shall be complete with insulating base, support structure and terminal connector. The height of the support structure shall not be less than 2500 mm. The structure would be made of galvanized steel generally conforming to IS: 802. The surge arrester can also be mounted on the neutral grounding reactor in lieu of separate support structure.
- 18.4.2 Self contained discharge counter, suitably enclosed for outdoor use and requiring no auxiliary or battery supply for operation along with necessary connection, shall be provided for each unit. The counter shall be visible through an inspection window from ground level. The counter terminals shall be robust and of adequate size and shall be so located that incoming and outgoing connections are made with minimum possible bends. One no. potential free change over type contacts (rated for 220V DC) shall be provided for monitoring of surge counter operation in substation automation system.
- 18.4.3 Suitable milliammeter on each arrester with appropriate connections shall be supplied to measure the resistor grading leakage current. The push buttons shall be mounted such that it can be operated from ground level.
- 18.4.4 Discharge counter and milliammeter shall be suitable for mounting on support structure of the arrester with minimum protection class IP 55.
- 18.4.5 Grading/Corona rings shall be provided on each complete arrester unit as required for proper stress distribution.

18.5 **Tests**

- 18.5.1 The surge arresters shall conform to type tests and shall be subjected to routine tests as per IEC-60099-4.
- 18.5.2 Surge arrester shall be subjected to additional acceptance tests.
- (i) Construction check (visual check)
 - (ii) Measurement of insulation resistance by 1kV megger.

19 Fittings & Accessories of Reactor

- 19.1 The following fittings and accessories shall be provided with

each shunt reactor and for neutral grounding reactor (whichever are applicable) covered under this specification.

- 19.2 Conservator for main tank with aircell, oil filling hole and cap, isolating valves, drain valve, magnetic oil level gauge with low level alarm contacts prismatic oil level gauge and condition controlled maintenance free type breather.
- 19.3 Pressure relief devices with trip contacts and with special shroud to direct the hot oil.
- 19.4 Sudden pressure relief relay with alarm/trip contacts
- 19.5 Buchholz relay double float, reed type with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm / trip contacts.
- 19.6 Air release plug
- 19.7 Inspection openings and covers
- 19.8 Bushing of each type with metal parts and gaskets to suit the termination arrangement.
- 19.9 Winding & Oil temperature indicators (local and remote).
- 19.10 Cover lifting eyes, reactor lifting lugs, jacking pads, towing holes and core and winding lifting lugs
- 19.11 Protected type alcohol in glass thermometer or magnetic or micro-switch type dial type temperature indicator as applicable (mercury should not be used).
- 19.12 Top & bottom oil sampling valve, Drain valves, Filter valves at top and bottom with threaded male adaptors, Shut off valves on the pipes connection between radiator bank and Reactor tank, Shut off valves on both sides of the Buchholz relay, Sampling gas collectors for Buchholz relay at accessible at height, Valves for radiators, Valve for vacuum application, Valve for online DGA, Valves for drying out system, Flow sensitive conservator isolation valve, Gate Valve (4 Nos. of min. 50NB) for UHF sensors for PD measurements, Valves for NIFPES system and other valves as specified in the specification
- 19.13 Rating and diagram plates on reactors and auxiliary apparatus
- 19.14 Roller Assembly (Flanged bi-directional wheels)
- 19.15 Individual marshalling box, Common Marshalling Box, Fibre optic sensor box

- 19.16 Cooling equipment
- 19.17 Bushing current Reactors, Neutral CT (if applicable)
- 19.18 Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently
- 19.19 Terminal marking plates
- 19.20 Valves schedule plate, oil filling instruction plate of conservator.
- 19.21 Minimum four jacking pads
- 19.22 Suitable terminal connectors on bushings and surge arrester
- 19.23 Ladder (suitably placed to avoid fouling with bushing or piping) to climb up to the Reactor tank cover with suitable locking arrangement to prevent climbing during charged condition. Additional ladder for conservator in case it is not tank mounted.
- 19.24 Haulage lugs
- 19.25 On line insulating oil drying system (cartridge type)
- 19.26 On line dissolved gas (multi-gas) and moisture monitor
- 19.27 Fibre optic sensor based temperature measuring system.
- 19.28 Flow sensitive conservator isolation valve.
- 19.29 Lifting lugs/ eyes for the cover.
- 19.30 Two earthing terminals each on shunt reactor tank, radiators & marshalling boxes, SA structures etc.
- 19.31 Suitable neutral bus connection arrangement
- 19.32 Suitable platform or ladder for safe access of flow sensitive non-return valve and buchholz relay shall be provided, in case these are not accessible from the Reactor top
- 19.33 All hardware used shall be hot dip galvanised / stainless steel
- 19.34 Lifting Jacks of suitable capacity (1 set per station)
- 19.35 Oil Sampling bottles made of stainless steel having a capacity of one litre.
- 19.36 Oil Syringe.
- 19.37 Conservator air cell rupture detection relay.
- 19.38 One complete set of all metal blanking plates & covers.

- 19.39 All necessary provision required for NIFPS.
- 19.40 Suitable galvanized Iron or Stainless steel tray for cabling on main tank for better aesthetics.
- 19.41 The fittings listed above are only indicative and any other fittings which are generally required for satisfactory operation of the reactors are deemed to be included.
- 19.42 a) The accessories required with the Reactor shall be SCADA/ SAS compatible. For OTI, WTI, etc. dual output of 4-20mA shall be provided.
- b) All the microprocessor based IEDs such as Online DGA, FOTMS, Online Drying system, etc. shall be interfaced with the SAS of the sub-station in co-ordination with the SAS supplier. Necessary files such as ICD, CID and PICS, MICS and PIXIT documents shall be provided in soft copy for integration with third party HMI.
- c) The required communication cables for the above is in the scope of the bidder/ supplier.
- d) The auxiliary supply to all the IEDs shall be 220V, DC.
- e) Warranty for the “Products and Solutions” for the IEDs as per International Standards shall be furnished. Also, guarantee for the availability of spares and solutions for all the IEDs for at least 10 years from the date of supply of products to be furnished.
- f) KPTCL Engineers shall be trained for operation of Fibre optic temperature monitoring system, online DGA & online drying system.
- 19.43 All IEC 61850 compliant signals from various monitoring equipments /accessories shall be wired upto the SAS Ethernet switch provided in the C&R panel and shall be interfaced with the SAS system.

20 ONLINE DISSOLVED GAS (MULTI-GAS) AND MOISTURE ANALYSER

- 20.1 Online Dissolved Gas (Multi-gas) and Moisture Analyser along with all required accessories shall be provided with each Reactor for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599 (2007-05 or latest version).
- 20.2 The equipment shall detect, measure and analyse the following gases:

| Gases & Moisture | Typical Detection Range |
|-------------------------------|-------------------------|
| H ₂ | 5 – 5,000 ppm |
| CH ₄ | 5 – 5,000 ppm |
| C ₂ H ₆ | 5 – 5,000 ppm |

| | |
|-------------------------------|---|
| C ₂ H ₄ | 3 – 5,000 ppm |
| C ₂ H ₂ | 1 – 3,000 ppm |
| CO | 10 – 10,000 ppm |
| CO ₂ | 20 – 30,000 ppm |
| O ₂ | 500 – 25,000 ppm |
| H ₂ O | 2 – 100 % RS should have facility for measurement of moisture in oil in ppm |

- 20.3 The analyser should measure (not calculate) all above gases and should have 100% sensitivity. The equipment shall be capable of transferring data to sub-station automation system confirming to IEC 61850. Necessary interface arrangement shall be provided by the contractor for integration with automation system. The necessary type test report for such confirmation shall be submitted during detailed engineering.
- 20.4 Equipment shall have facility to give SMS alert to at least three users whenever any fault gas violates the predefined limit.
- 20.5 Equipment should work on 220V DC supply. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.
- 20.6 Online DGA shall be installed out door on Reactor in harsh ambient and noisy condition (Electromagnetic induction, Corona, and capacitive coupling). Equipment shall be mounted separately on ground. Suitable arrangement shall be provided to support and protect the inlet and outlet piping arrangement. The connecting oil lines must be of Stainless Steel rigid pipes or flexible hoses. The equipment shall be suitable for proper operation in EHV substation (400kV) environment where switching takes place in the EHV/HV System. The suitable indications for power On, Alarm, Caution, normal operation etc. shall be provided on the front panel of the equipment. The equipment shall have IP55 Stainless Steel enclosure, suitable for 55 OC ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of Five (5) years manufacturer's Warranty.
- 20.7 The equipment shall display all the individual gas and moisture concentration on its display unit and shall have facility to download all the stored data from the unit for further analysis. The sampling rate shall be selectable as 2 or 4 or 6 or 12 hours etc. The equipment shall have inbuilt memory to store these results for complete one year even if sampling is done at the lowest interval. The carrier and calibration gas (if applicable) shall have minimum capacity to work for at least three years without replacement. All the consumable (if any) upto warrantee period shall be included in the scope of supply.

20.8 The equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the Equipment.

20.9 The Equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the Equipment.

20.10 The technical feature of the equipment shall be as under:

| | |
|-----------------------|--|
| Accuracy | $\pm 10\%$ |
| Repeatability | $\pm 3\%$ to 10% depending upon gases |
| Oil temperature range | - 20° C to + 120° C |
| External Temp. Range | - 20° C to +55° C (External temp range of 55° C is important and should not be compromise due to Indian ambient & |
| Humidity range | 10 to 95 % |
| Operating Voltage | 220V DC |
| Communications | USB & IEC 61850 compliant |

20.11 Software for fault indication and fault diagnostics shall include following: Fault indication:

- i) IEEE, IEC or user configurable levels of dissolved gases
- ii) Rate of change trending

Fault Diagnosis:

- i) Key gases
- ii) Ratios (Rogers, IEC. etc.)
- iii) Duval's Triangle

20.12. The equipment shall be supplied with all necessary accessories required for carrying out DGA of oil sample complete in all respect as per the technical specification. The following shall be also form a part of supply.

- i) Software running on PC under the latest version of windows shall be provided in duplicate
- ii) Operation Manual (2 set for every unit),
- iii) Software Manual and
- iv) Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.

20.13 The installation and commissioning at site shall be done under the supervision of representative or OEM certified representative.

21 ON-LINE INSULATING OIL DRYING SYSTEM (CARTRIDGE TYPE)

In addition to provision of air cell in conservators for sealing of the oil system against the atmosphere, each Reactor shall be provided with an on line insulating oil drying system of adequate rating with proven field performance. This system shall be separately ground mounted and shall be housed in metallic (stainless steel) enclosure. The bidder shall submit the mounting arrangement. This online insulating oil drying system shall be

- i. Designed for very slow removal of moisture that may enter the oil system or generated during cellulose decomposition. Oil flow to the equipment shall be controlled through pump of suitable capacity (at least 5LPM).
- ii. The equipment shall display the moisture content in oil (PPM) of the inlet and outlet oil from the drying system.
- iii. In case, drying system is transported without oil, the same shall be suitable for withstanding vacuum to ensure that no air/contamination is trapped during commissioning.
In case, drying system is transported with oil, the oil shall conform to EMPLOYER specification for unused oil. Before installation at site, oil sample shall be tested to avoid contamination of min tank oil.
- iv. Minimum capacity of moisture extraction shall be 10 Litres before replacement of cartridge. Calculation to prove the adequacy of sizing of the on line insulating oil- drying system along with make and model shall be submitted for approval of purchaser during detail engineering.
- v. The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.
- vi. The equipment shall be capable of transferring data to substation automation system confirming to IEC 61850 through FO port. Necessary interface arrangement shall be provided by the contractor for integration with automation system.
- vii. The entire test set up shall be covered on warranty for a period of 5 years from the last date of complete commissioning and taking over the test set up. During this period, if the kit needs to be shifted to suppliers works for repairs, supplier will have to bear the cost of spares, software, transportation, etc. of kit for repair at test lab/works.

Note: For operation of the On-line insulating oil drying system breaker open status shall be considered. The scheme shall be finalized during detailed engineering.

The equipment shall be supplied with Operation Manual (2 set for every unit), Software (if any), and Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.

22 OIL SAMPLING BOTTLE

Oil sampling bottles shall be suitable for collecting oil samples from Reactors and shunt Reactors, for Dissolved Gas Analysis. Bottles shall be robust enough, so that no damage occurs during frequent transportation of samples from site to laboratory.

Oil sampling bottles shall be made of stainless steel having a capacity of 1litre. Oil Sampling bottles shall be capable of being sealed gas-tight and shall be fitted with cocks on both ends.

The design of bottle & seal shall be such that loss of hydrogen shall not exceed 5% per week. An impermeable oil-proof, transparent plastic or rubber tube of about 5 mm diameter, and of sufficient length shall also be provided with each bottle along with suitable connectors to fit the tube on to the oil sampling valve of the equipment and the oil collecting bottles respectively.

23 OIL SYRINGE

The glass syringe and three way stop cock valve shall meet the following specification

The tentative dimensions are given below

Dimensions

Volume 50 ml \pm 1.5

% Piston outside diameter

| | | | | | |
|--------|-------|---------|--------|------------|-----------|
| 27.45 | \pm | 0.20mm | Barrel | Diameter | (OD) |
| 32.35 | \pm | 0.55 mm | Barrel | Diameter | (OD) |
| 44.00 | \pm | 0.75 mm | Barrel | Diameter | (OD) |
| 34.05 | \pm | 0.65 mm | | Length (L) | |
| 178.00 | mm | \pm | 0.50 | mm | Increment |
| 2.0 ml | | | | | |

The syringe shall be made from Heat resistant borosilicate Glass. The material and construction should be resistant to breakage from shock and sudden temperature changes. Reinforced at luer lock tip Centre and barrel base.

The cylinder-Plunger fit is leak proof and shall meet the requirement of IEC- 60567.Plunger shall be individually ground and fitted to barrel for smooth movement with no back flow. Barrel rim should be flat on both sides to prevent rolling and should be wide enough for convenient finger tip grip. The syringe shall be custom fit and uniquely numbered for matching. The syringe shall be clearly marked with

graduations of 2.0 ml and 10.0 ml and shall be permanently fused for life time legibility.

24.0 **Guaranteed Losses:**

- i) The bidder while quoting should clearly indicate the guaranteed value of the Total losses which **shall be firm and without any tolerance limit** as required in GTP.
- ii) Void
- iii) Void
- iv) The Maximum permissible total loss at rated voltage & frequency (at 75 deg C) have been specified in Technical particulars/parameters. Following penalties shall be levied on the manufacturer/contractor/bidder (as the case may be) if losses measured during routine test are found to be within +2% tolerance of the Guaranteed losses **declared by the manufacturer/contractor/bidder (as the case may be)**, beyond which the Reactor shall be liable for rejection. No benefit shall be given for supply of Reactor, with losses (measured during routine tests) less than the **guaranteed losses declared by the manufacturer/contractor/bidder (as the case may be)**.

| Sl. No. | Differential of specified losses vs Measured losses | RATE (in INR per KW) |
|---|---|----------------------|
| 1 | Total Losses | Rs. 10,00,000/KW |
| Note: For a fraction of a kW, the penalty shall be applied on pro rata basis. | | |

25 **HAND TOOLS**

Each Reactor shall be supplied with a full kit of tools & spanners of required sizes; bushing handling & lifting tools with nylon rope/belt, with a rack for holding them; hydraulic jacks of suitable capacity (one set per station) for lifting the Reactors and for changing the plane of rotation of wheels. All spanners shall be single ended and case hardened. Tirfors with wire rope and slings with grippers etc. for hauling the Reactor to the plinth are to be supplied along with each Reactor.

One set of hand tools of reputed make packed in a carry bag/box broadly comprising of single ended spanners (one set), Adjustable wrenches (8 & 12 inch one set), pliers (flat nose, round nose & side cutting one of each type), hammer with handle (one), files with handle (two), knife with handle (one), adjustable hacksaw (one), and cold chisel (one) shall be supplied per Substation.

26 **TEST KIT**

BDV Kit (if specified in BPS) as per **Annexure- K** of specification
Portable DGA Kit (if specified in BPS) as per **Annexure- K** of specification

27 INSPECTION AND TESTING

The Contractor shall carry out a comprehensive inspection and testing programme during manufacture of the equipment. The inspection envisaged by the Purchaser is given below. This is however not intended to form a comprehensive programme as it is Contractor's responsibility to draw up and carry out such a programme in the form of detailed quality plan duly approved by Purchaser for necessary implementation.

27.1.1 Bought Out Items

The make of all major bought out items shall be subject to Purchaser's approval. The Contractor shall also prepare a comprehensive inspection and testing programme for all bought out/sub-contracted items and shall submit the same to the Purchaser for approval. Such programme shall include the following components:

- a. Buchholz Relay
- b. Axles and wheels
- c. Winding temperature indicators
- d. Oil temperature indicators
- e. Bushings
- f. Bushing current Reactors
- g. Marshalling box
- h. Radiators
- i. Pressure relief device
- j. Terminal connectors
- k. On-line DGA, online drying system, Fibre optic temperature & monitoring system.

The above list is not exhaustive and the Contractor shall also include other bought-out items in his programme.

27.2 Factory Tests

The manufacturer shall be fully equipped to perform all the required tests as specified. Bidder shall confirm the capabilities of the proposed manufacturing plant in this regard when submitting the bid. Any limitations shall be clearly stated in.

The contractor shall bear all additional costs related to tests which are not possible to carry out at his own works.

The contractor shall submit an Inspection and test plan (ITP) for

approval. A typical test plan is indicated in “Annexure-B”.

All tests shall be done in line with IEC: 60076 and the test procedures as mentioned in “Annexure-C”. Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the contractor.

27.3 Type Test:

Type test reports of the Reactor shall be furnished. The type test reports shall not be older than TEN (10) years as on the last date of submission of bid.

a) For Reactors manufactured in India:

- i). The type tests on indigenous equipment for which testing facility is available in India, should have been conducted in any independent laboratories approved by the Government or the laboratories accredited by the National accreditation body of the country like Central Power Research Institute (CPRI), Electrical Research and Development Association (ERDA), etc.
- ii). The type tests on indigenous equipment, for which testing facility is not available in India, should have been conducted in a laboratory of foreign country accredited by National accreditation body of that country.
- iii). The type tests conducted in-house by a manufacturer shall also be acceptable provided the laboratory is accredited by National accreditation body of the country and the tests has been conducted in the presence of a representative of NABL accredited laboratory or any of the purchasing utilities or CEA in that order. Such type test reports shall record the details of such witness including the signature/authentication in the type test report.

b) For Reactors manufactured Abroad:

- i). Type tests on imported equipment should have been conducted in an Indian Laboratory or foreign laboratory accredited by National accreditation body of the country where the Type test has been conducted.
- ii). The type tests conducted in-house by a manufacturer shall also be acceptable provided the laboratory is accredited by National accreditation body of the country and the tests has been conducted in the presence of a representative of accredited laboratory or any of the purchasing utilities or CEA in that order. Such type test reports shall record the details of such witness including the signature/authentication in the type test report.

In case of in-house type tested imported equipment of foreign OEM, the term “Purchasing Utility” covers the foreign Utility who has purchased that equipment

27.4 Type Tests on fittings:

All the following fittings shall conform to type tests and the type test reports shall be furnished by the contractor along with the drawings of equipment/ fittings as per the Section – GTR and during inspection. The list of fittings and the type test requirement is:

- 1) Bushing (Type Test as per IEC:60137 including Snap back/Seismic test for 400 kV and above voltage class bushing)
- 2) Buchholz relay
- 3) Marshalling & common marshalling box (IP-55 test)
- 4) Pressure Relief device Test (including IP 55 test in terminal box)
- 5) Sudden Pressure Relay Test (including IP 55 test in terminal box)
- 6) Magnetic Oil Level gauge & Terminal Box for IP-55 degree of protection as per IS: 13947/IEC: 60529.
- 7) Air Cell (Flexible air separator) - Oil side coating, Air side under Coating, Air side outer coating and coated fabric as per IS: 3400/ BS: 903/ IS: 7016
- 8) OTI & WTI – Switch setting & operation, switch differential , switch rating.

27.5 Pre-Shipment Checks at Manufacturer's Works

- 27.5.1 Check for inter-changeability of components of similar reactor for mounting dimensions.
- 27.5.2 Check for proper packing and preservation of accessories like radiators, bushings, dehydrating breather, rollers, buchholz relay, fans, control cubicle, connecting pipes, conservator etc.
- 27.5.3 Ensure following setting of impact recorder at the time of installation with Reactor unit before dispatch from factory:
1g: Start recording
2g: Warning
3g: Alarm
- 27.5.4 Further, drop-out setting shall be 1g and threshold setting shall be in the range of 5g to 10g.
- 27.5.5 Check for proper provision for bracing to arrest the movement of core and winding assembly inside the tank.
- 27.5.6 Gas tightness test to confirm tightness and record of dew point of gas inside the tank. Derivation of leakage rate and ensure the adequate reserve gas capacity.

27.6 Inspection and Testing at Site

The Contractor/Manufacturer shall carry out a detailed

inspection and testing programme for field activities covering areas right from the receipt of material stage up to commissioning stage. An indicative programme of inspection as envisaged by the Purchaser is given below. However, it is contractor's responsibility to draw up and carry out such a programme duly approved by the Purchaser. Testing of oil sample at site shall be carried out as per specification. Contractor shall follow KPTCL Field Quality Plan (FQP).

27.7 Receipt and Storage Checks

- 27.7.1 Check and record condition of each package, visible parts of the reactor etc. for any damage.
- 27.7.2 Check and record the gas pressure in the reactor tank as well as in the gas cylinder.
- 27.7.3 Visual check for wedging of core and coils before filling up with oil and also check conditions of core and winding in general.
- 27.7.4 Check and record reading of impact recorder at receipt and verify the allowable limits as per manufacturer's recommendations.

27.8 Installation Checks

- 27.8.1 Check whole assembly for tightness, general appearance etc.
- 27.8.2 Oil leakage test
- 27.8.3 Capacitance and tan delta measurement of bushing before fixing/connecting to the winding, contractor shall furnish these values for site reference.
- 27.8.4 Leakage check on bushing before erection.
- 27.8.5 Measure and record the dew point of gas in the main tank before assembly.

27.9 Commissioning Checks

- 27.9.1 Check the colour of silicagel breather.
- 27.9.2 Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.
- 27.9.3 Check the bushing for conformity of connection to the lines etc,
- 27.9.4 Check for correct operation of all protection devices and alarms/trip :
 - i) Buchholz relay

- ii) Excessive winding temperature
- iii) Excessive oil temperature
- iv) Low oil flow
- v) Low oil level indication

27.9.5 Check for the adequate protection on the electric circuit supplying the accessories.

27.9.6 Check resistance of all windings on all steps of the tap changer. Insulation resistance measurement for the following:

- i) Control wiring
- ii) Main windings
- iii) Bushing current Reactor

27.9.7 2 kV/minute test between bushing CT terminal and earth.

27.9.8 Check for cleanliness of the reactor and the surroundings

27.9.9 Measure vibration and noise level

27.9.10 Capacitance and Tan delta measurement of winding and bushing.

27.9.11 The manufacturer shall carry out the Sweep Frequency Response Analysis (SFRA) Test at their works and also during pre-commissioning at site. The values / data shall be furnished to KPTCL for future reference. The required instruments / equipments for conducting the SFRA test at Site shall be arranged by Reactor manufacturer/Contractor.

27.9.12 DGA of oil just before commissioning and after 24 hours energisation at site.

27.9.13 Contractor shall prepare a comprehensive commissioning report including all commissioning test results as per Pre-Commissioning Procedures enclosed at Annexure – C and forward to Purchaser.

28.0 Nitrogen Injection type fire prevention & extinguishing system.

The reactors shall be supplied with Nitrogen injection fire protection system.

The details of the same are explained in Section – Fire Protection System of Bid document.

All the necessary provisions required for Nitrogen injection Fire protection system shall be made in reactor.

Annexure – A

1.0 Technical Particulars / Parameters of 400kV Shunt Reactor

| Clause No. | Description | Unit | Parameters | Parameters | Parameters |
|------------|---|-------|--|---------------------|---------------------|
| 1.1 | Rated Voltage (1p.u) | kV | 420 | 420 | 420 |
| 1.2 | Rated Capacity | MVAR | 63 at 420kV | 80 at 420kV | 125 at 420 kV |
| 1.3 | Standard | | IEC 60076-6 | IEC 60076-6 | IEC 60076-6 |
| 1.4 | Connection | | Star | Star | Star |
| 1.5 | Cooling System | | ONAN | ONAN | ONAN |
| 1.6 | Frequency | Hz | 50 | 50 | 50 |
| 1.7 | No of Phases | | 3 (THREE) | 3 (THREE) | 3 (THREE) |
| 1.8 | Service | | Outdoor | Outdoor | Outdoor |
| 1.9 | System Fault Level | kA | 63 | 63 | 63 |
| 1.10 | Duty | | Continuous at 441kV | Continuous at 441kV | Continuous at 441kV |
| 1.11 | Permissible current unbalance among different phases | % | ±2 | ±2 | ±2 |
| 1.12 | Crest Value of Third Harmonic content in phase current at rated voltage at sinusoidal waveform. | | ≤ 3% of the crest value of fundamental | | |
| 1.13 | Range of constant Impedance (Linearity) | | Up to 1.5 p.u. voltage (However, complete saturation characteristics of Reactors upto 2.5 p.u. voltage shall be furnished. | | |
| 1.14 | Tolerance on current | % | 0 to +5% | 0 to +5% | 0 to +5% |
| 1.15 | Ratio of zero sequence reactance to positive reactance (X0/X1) | Range | Between 0.9 - 1.0 | Between 0.9 - 1.0 | Between 0.9 - 1.0 |
| 1.16 | Temperature rise over 50 deg C Ambient Temp at Rated voltage | | | | |
| | Top oil measured by thermometer | °C | 40 | 40 | 40 |
| | Average winding measured by resistance method | °C | 45 | 45 | 45 |

| | | | | | |
|------|--|-----------------------------------|---------|---------|---------|
| 1.17 | Winding hot spot temperature rise over yearly weighted average temperature of 32°C | °C | 61 | 61 | 61 |
| 1.18 | Max. tank surface temperature | °C | 110 | 110 | 110 |
| 1.19 | Max. design Ambient temp | °C | 50 | 50 | 50 |
| 1.20 | Windings | | | | |
| a) | Lightning Impulse withstand voltage | | | | |
| | HV | kVp | 1300 | 1300 | 1300 |
| | Neutral | kVp | 550 | 550 | 550 |
| b) | Chopped wave lightning Impulse withstand voltage | | | | |
| | HV | kVp | 1430 | 1430 | 1430 |
| c) | Switching Impulse withstand Voltage | | | | |
| | HV | kVp | 1050 | 1050 | 1050 |
| d) | One Minute Power | | | | |
| | HV | kVrms | 570 | 570 | 570 |
| | Neutral | kVrms | 230 | 230 | 230 |
| e) | Tan delta of windings | | < 0.005 | < 0.005 | < 0.005 |
| 1.21 | Neutral earthing | Solidly earthed | | | |
| 1.22 | Whether neutral brought out | Yes (through 145kV class bushing) | | | |
| 1.23 | Bushing | | | | |
| a) | Rated voltage | | | | |
| | HV | kV | 420 | 420 | 420 |
| | Neutral | kV | 145 | 145 | 145 |
| b) | Rated current (Min.) | | | | |
| | HV | A | 1250 | 1250 | 1250 |
| | Neutral | A | 1250 | 1250 | 1250 |
| c) | Lightning Impulse withstand Voltage | | | | |
| | HV | kVp | 1425 | 1425 | 1425 |
| | Neutral | kVp | 650 | 650 | 650 |
| d) | Switching Impulse withstand Voltage | | | | |
| | HV | kVp | 1050 | 1050 | 1050 |
| | Neutral | kVp | - | - | - |
| e) | One Minute Power Frequency withstand voltage | | | | |
| | HV | kVrms | 695 | 695 | 695 |
| | Neutral | kVrms | 305 | 305 | 305 |

| | | | | | |
|------|--|----|---|---------|---------|
| f) | Tan delta of bushings at ambient temperature | | < 0.005 | < 0.005 | < 0.005 |
| g) | Minimum creepage distance | | | | |
| | HV | mm | 13020 | | |
| | Neutral | mm | 4495 | | |
| h) | Partial discharge of bushings at U_r (Line end and neutral) | pC | < 10 | < 10 | < 10 |
| 1.24 | Max Partial discharge level at $1.58 U_r / \sqrt{3}$ | pC | < 100 | < 100 | < 100 |
| 1.25 | Vibration and stress level at rated voltage | | Maximum amplitude ≤ 200 microns (peak to peak) Average amplitude ≤ 60 microns (peak to peak) Tank stress: ≤ 2.0 Kg/Sq.mm at any point of tank. | | |
| 1.26 | Maximum Noise level at rated voltage and frequency | dB | <80dB | <80dB | <80dB |
| 1.27 | Maximum Permissible Losses of Reactor at rated voltage and Frequency and at 75°C | | | | |
| | Total Loss | kW | 100 | 115 | 160 |

Notes:

Tan delta of Winding & Bushing shall be measured at ambient temperature. No temperature correction factor shall be applied

Technical Particulars / Parameters of Neutral Grounding Reactor

| Clause No. | Description | Unit | Parameters |
|------------|--|-------|---|
| 1. | Technical Parameters | | |
| | Rated voltage from insulation | kV | 145 |
| 1.1. | Connection | | Between neutral of reactor and ground |
| 1.2. | Cooling System | | Natural oil cooling (ONAN) |
| 1.3. | Cooling medium | | Insulating oil |
| 1.4. | Frequency | Hz | 50 |
| 1.5. | No of Phases | | 1 (SINGLE) |
| 1.6. | Service | | Outdoor |
| 1.7. | Type | | Oil filled outdoor application |
| 1.8. | Insulation | | Graded |
| 1.9. | Max. continuous | | 10 A |
| 1.10. | Rated short time current (rms) (10secs.) | | 60A |
| 1.11. | Rated impedance at rated short time and continuous current | | 600-2500 Ohms (this is an indicative value – Actual Value will be finalized during engineering) |
| 1.12. | Max. temperature rise over ambient temperature of | | |
| i) | of winding measured by | Deg C | 50 |
| ii) | of top oil measured by thermometer | Deg C | 45 |
| 1.13. | Insulation level for winding | | |
| i) | Lightning Impulse | | |
| | Line side | kVp | 550 |
| | Ground side | kVp | 95 |
| ii) | Chopped wave lightning impulse withstand voltage | | |
| | Line side | kVp | 605 |

| | | | |
|-------|--|-----------------|---|
| iii) | One Minute Power Frequency withstand | | |
| | Line side | kVrms | 230 |
| | Ground side | kVrms | 38 |
| 1.14. | Bushing | | |
| i) | Rated Voltage | | |
| | Line side | kV | 145 |
| | Ground side | kV | 24 |
| ii) | Lightning Impulse withstand Voltage | kV _p | |
| | Line side | | 650 |
| | Ground side | | 125 |
| iii) | One Minute Power Frequency withstand Voltage | | |
| | Line side | kVrms | 305 |
| | Ground side | kVrms | 55 |
| iv) | Creepage (total minimum) | | 31mm/kV |
| | Line side | mm | 4495 |
| | Ground side | mm | 744 |
| v) | Tan delta of Bushing at ambient temperature | % | ≤ 0.5 |
| 1.15. | Method of grounding | | Solidly connected between neutral of shunt reactor and earth. |
| 1.16. | Whether neutral is to be brought out | | Yes (through 24kV Porcelain bushing) |

**Annexure -B
Test Plan**

| No. | Item | Test category |
|------------|---|----------------------|
| 1. | Measurement of winding resistance | Routine |
| 2. | Reactance and loss measurement (Measured in Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units) | Routine |
| 3. | Measurement of insulation resistance & Polarization Index | Routine |
| 4. | Measurement of insulation power factor and capacitance between winding and earth | Routine |
| 5. | Measurement of insulation power factor and capacitance of bushings | Routine |
| 6 | Tan-delta of bushing at variable frequency (frequency Routine domain spectroscopy) | Routine |
| 7. | Chopped wave lightning impulse test for the line terminals (LIC) | Routine |
| 8. | Lightning impulse test on Neutral | Routine |
| 9. | Switching impulse test | Routine |
| 10. | Applied voltage test (AV) | Routine |
| 11. | Induced over voltage test with Partial Discharge measurement | Routine |
| 12. | Gas-in-oil analysis | Routine |
| 13. | Oil leakage test on Reactor tank | Routine |
| 14. | Appearance, construction and dimension check | Routine |
| 15. | Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports) | Routine |
| 16. | High voltage with stand test on auxiliary equipment and wiring after assembly | Routine |
| 17 | Measurement of mutual reactance on 3- Φ reactor | Routine |
| 18. | 2-Hour excitation test except type tested unit | Routine |
| 19. | Tank vacuum test | Routine |
| 20 | Tank pressure test | Routine |

| | | |
|-----|---|---------|
| 21. | Vibration & stress measurement at $U_m/\sqrt{3}$ level (Measured in Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units) (Measurement shall be carried out at $1.05U_m$ for reference purpose) | Routine |
| 22. | Core assembly dielectric and earthing continuity test | Routine |
| 23. | Temperature rise test | * Type |
| 24. | Measurement of harmonic content of current (Measured in Cold state) | * Type |
| 25. | Measurement of acoustic sound / noise level (Measured in Cold and Hot state of temperature rise test) | * Type |
| 26. | Knee point voltage measurement of reactor (Measured in Cold state and Hot state of temperature rise test) | * Type |
| 27. | Measurement of zero-sequence reactance (For three phase shunt reactor only) | Routine |

| | Test on NGR | |
|----|---|------------------|
| | Item | Test Category |
| 1 | Measurement of winding resistance | Routine |
| 2 | Measurement of Impedance at rated continuous current | Routine |
| 3 | Measurement of insulation resistance | Routine |
| 4 | Measurement of Capacitance & Tan delta of winding insulation to Earth and bushing | Routine |
| 5 | Lightning impulse test | Routine |
| 6 | Separate source voltage withstand test | Routine |
| 7 | Isolation Test | Routine |
| 8 | Oil leakage test | Routine |
| 9 | Appearance, construction and dimension check | Routine |
| 10 | High voltage with stand test on auxiliary equipment and wiring after assembly | Routine |
| 11 | Tank Vacuum test | Routine |
| 12 | Tank Pressure test | Routine |
| 13 | Temperature rise test | Type |
| 14 | Measurement of vibration at rated continuous current | Routine |
| 15 | Measurement of loss | Routine |
| 16 | Short time current test and measurement of impedance at short time current | Type |
| 17 | Measurement of acoustic sound/noise level | Type |

Annexure – C

Test Procedures

1. Measurement of winding resistance

After the Reactor has been under oil without excitation for at least 3h the average oil temperature shall be determined and the temperature of the winding shall be deemed to be the same as the average oil temperature. The average oil temperature is taken as the mean of the top and bottom oil temperature.

In measuring the cold resistance for the purpose of temperature – rise determination, special efforts shall be made to determine the average winding temperature accurately. Thus, the difference in temperature between the top and bottom oil shall not exceed 5 K. To obtain this result more rapidly, the oil may be circulated by a pump.

2. Reactance and loss measurement.

- The type tested unit shall be measured in the cold and hot state.
- In other units, measurement shall be carried out in the cold state and corrected as per factors derived from the type tested unit.
- Measurement shall also be carried out during 2-hour excitation test.

The following details shall be recorded under the heading of losses on the test certificate:

- Voltage reading
- Current reading
- CT & PT Ratio
- Tan delta
- The power reading
- Total losses measured
- Total losses corrected to 75°C winding temperature.
- The frequency reading
- The instrument constants and corrections (if any)
- The magnetization curve of the reactor (Type tested unit)

3. Measurement of insulation resistance & Polarization Index.

Measurement of D.C. insulation resistance between each winding to earth and between windings shall be carried out at 5000V DC. The polarization index is a ratio of insulation resistance value at the end of 10 min test to that at the end of 1 min test at a

constant voltage. It is recommended that PI value shall be better than 1.3.

4. Measurement of insulation power factor and capacitance of between winding and earth.

Reactor shall be tested in GST mode only between winding to tank for the measurement of capacitance & tan delta of winding to earth by applying 2kV and 10kV. Tan delta of winding shall not exceed 0.5% if measured between 10°C and 40°C temperature. If tan-delta is measured at a temperature beyond the above mentioned limit, necessary correction factor as per IEEE shall be applicable.

5. Measurement of insulation power factor and capacitance of bushings.

Bushing shall be tested in UST mode by applying 10kV and 2kV. Tan delta of bushing shall not exceed 0.5% if measured between 10°C to 40°C temperature. If Tan delta is measured at a temperature beyond the above mentioned limit necessary correction factor as per IEEE shall be applicable.

6. Core assembly dielectric and earthing continuity tests.

The insulation of the magnetic circuit and between the magnetic circuit and the core clamping structure, including core-belts, bands and or buckles shall withstand the application of a test voltage of either 2kV AC or 3kV DC for 60 seconds.

The insulation of core to tank, core to yoke clamp (frame) and yoke clamp (frame) to tank shall be able to withstand a voltage of 2kV (DC) for 1 minute. Insulation resistance shall be minimum 1 GΩ for all cases mentioned above.

The continuity of the single-point earthing shall be verified before dispatch. The results of the works tests shall be recorded on the test certificate, and shall include the resistance reading obtained from a measurement made between the core and core clamping structure by means of at least 1.5kV ac or 2kV dc. During erection, the contractor shall repeat this measurement at site. The records of these tests shall also be included in the test report.

7. Dielectric Tests.

Following Tests (as applicable) shall be performed in the sequence given below as per IEC 60076-3:2013 clause 7.2.3 shall be followed:

- a) Lightning impulse test (LIC, LIN)
- b) Switching impulse (SI)

- c) Applied voltage test (AV)
- d) Induced voltage test with partial discharge measurement.

Testing shall be performed in line with IEC, DGA tests shall be performed before and after Dielectric Tests.

8. Two hours excitation test.

- Each reactor to be excited at 1 p.u. for 2 hours except type tested unit.
- Measure reactance, loss and vibration.
- DGA rate interpretation shall be as per IEC/CIGRE/IEEE guidelines.
- Test shall be performed before partial discharge test.

9. Vibration & Stress measurement.

After all dielectric tests, reactor shall be energized at rated voltage and mark atleast 4 points on each side wall where vibration is more. Stress will be measured on the same points. Similar process shall be followed for 1.05Ur voltage.

10. Temperature rise test (As per IEC-60076)

Temperature rise shall be guaranteed and tested at rated voltage (1 p.u). The tests shall be done for a minimum of 24 hours with saturated temperature for at least 4 hours. DGA tests shall be performed before and after heat run and DGA results shall generally conform to IEC-61181.

During this test the following shall be measured.

- Voltage
- Current
- Reactance and loss
- Audible sound
- Vibration
- Colour photographs of the four sides and top of the reactor together with the corresponding series of thermal images (colour) during starting and end of the test. It is also recommended to take thermal images 4 more times to take care of any unforeseen situation.
- Temperature measurement with internal probes during test.

The heat run type test results shall serve as a “finger print” for the other units to be routine rested.

Specified winding hotspot temperatures shall not be exceeded.

The temperature rises recorded by infra red shall not be more than 10°C above top oil temperature or 15°C above the local oil

temperature.

Full details of the test arrangements, procedures and conditions shall be provided with the test certificates and the following shall at least be included.

- Purchaser's order number and reactor site designation.
- Manufacturer's name and reactor serial number
- Ratings of reactor
- MVA
- Voltage
- Frequency
- Rated currents
- Class of cooling
- Measured load losses at 75°C.
- Altitude of test bay.

Top oil temperature rise test.

A log of the following parameters taken at 30 minutes intervals:

- Time
- Voltage
- Current
- Total Power
- Ambient temperature measured on not less than three thermometers.
- Top oil temperature
- Cooler inlet and outlet oil temperatures.
- Infra red pictures during the heating up phases.

Winding temperature rise test.

- Record the weight of conductor in each winding, and the losses in watts per kilogram, the 'cold' resistance of each winding and the simultaneous top oil and ambient air temperatures, together with the time required for the effect to disappear.
- Record the thermal time constant of the winding.
- Log the half-hourly readings of the parameters as for the top oil temperature rise test.
- Provide a table of readings, after shut-down of power, giving the following information:
 - Time after shut-down:
 - Time increment:
 - Winding resistance: Record the resistance values of minimum 20 minutes.

- Resistance increment:
 - X , where x is the time after shut-down divided by the thermal time constant of the winding; and
 - Y , where $Y = 100 (1 - e^{-x})$
- (Any graphical/computer method used to determine the temperature of a winding by extrapolation to the instant of power shut-down shall produce a linear curve).
 - Provide a record of all calculations, corrections and curves leading to the determination of the winding temperatures at the instant of shut-down of power.
 - Record any action taken to remedy instability of the oil surge device during initiation of the oil circulating pumps.

Temperature measurements as per special probes or sensors placed at various locations shall also be recorded.

11. Measurement of harmonic content of current (Measured in cold state).

The harmonics of the current in all three phases are measured at rated voltage, by means of a harmonic analyzer. The magnitude of the relevant harmonics is expressed as a percentage of the fundamental component. For more information on the magnetic characteristic, see Annex B of IEC 60076-6. The harmonics of the applied voltage shall be adequately measured at the same time.

12. Measurement of acoustic noise level (Measured in cold state and hot state of temperature rise test).

Test shall be performed as per clause 7.8.12 of IEC 60076-6 and IEC 60076-10. The measured value shall not exceed the limit as specified at Annexure-A of this specification.

13. Knee point voltage measurement of reactor (Measured in Cold state)

The test shall be carried out as per IEC 60076-6 clause B.7.1 “DC current charging- discharging method (theory)” or applying AC voltage from 0.7p.u, 0.8p.u, 0.9p.u. and so on upto the level as per specification and measure the current at various voltages and calculate the tolerance of reactance as per annexure- A of this specification.

14. Measurement of Zero-sequence reactance (applicable for three

phase shunt reactor only).

The test shall be generally performed as per IEC 60076-1. This measurement shall be carried out at a voltage corresponding to a neutral current equal to the rated phase current.

15. Frequency Response analysis.

The test shall be performed on each phase of the Reactor by tanking open circuit response of complete winding as HV to neutral terminal and vice versa. The response shall be compared with order units of same design for reference.

FRA shall also be carried out without oil in main tank for reference purpose.

16. Oil leakage test on reactor tank & NGR.

All tanks and oil filled compartments shall be completely filled with air or oil of a viscosity not greater than that of insulating oil conforming to IEC 60296 at the ambient temperature and subjected to a pressure equal to normal head of oil plus 35kN/Sq.m (5 psi) measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours for oil and 1 hour for air during which no leakage shall occur.

17. Tank Vacuum Tests.

All shunt reactor & NGR tanks shall be subjected to the specified vacuum. The tank designed for full vacuum shall be tested at an internal pressure of 3.33kN/Sq.m absolute (25 torr) for one hour. The permanent deflection of flat plates after the vacuum has been released shall not exceed the values specified below:

| Horizontal length of flat plate (in mm) | Permanent deflection (in mm) |
|---|------------------------------|
| Upto and including 750 | 5.0 |
| 751 to 1250 | 6.5 |
| 1251 to 1750 | 8.0 |
| 1751 to 2000 | 9.5 |
| 2001 to 2250 | 11.0 |
| 2251 to 2500 | 12.5 |
| 2501 to 3000 | 16.0 |
| Above 3000 | 19.0 |

18. Tank Pressure Test.

All shunt reactor & NGR tanks of each size, its radiator, conservator

vessel and other fittings together or separately shall be subjected to a pressure corresponding to twice the normal head of oil or normal oil head pressure plus 35 KN/Sq. whichever is lower, measured at the base of the tank and maintained for one hour. The permanent deflection of the flat plate after the excess pressure has been released shall not exceed the figures specified above for vacuum test.

19. Routine tests on neutral grounding reactor.

In addition to the routine tests listed in the IEC- 60076 & Annexure – C of this specification, the volt-current characteristics test shall also be carried out on each neutral grounding reactor preferably at least upto short time rated current. Calculated value of hot spot temperature shall be furnished by the Contractor. Further, Lighting impulse voltage withstand test and ohmic value measurement shall also be carried out.

20. Routine Tests on Bushings: Routine test on bushings shall be done as per IEC 60137.

Annexure -D - VOID

Annexure – E
Design Review Document

| Sr. | Description |
|------------|---|
| 1. | Core and Magnetic Design |
| 2. | Over-fluxing and Linear characteristics |
| 3. | Inrush-current characteristics while charging |
| 4. | Winding and winding clamping arrangements |
| 5. | Short-circuit withstand capability considering inrush current. |
| 6. | Thermal design including review of localised potentially hot area |
| 7. | Cooling design |
| 8. | Overload capability |
| 9. | Eddy current losses |
| 10 | Seismic design, as applicable |
| 11 | Insulation co-ordination |
| 12 | Tank and accessories |
| 13 | Bushings |
| 14 | Protective devices |
| 15 | Radiators |
| 16 | Sensors and protective devices– its location, fitment, securing and level of redundancy |
| 17 | Oil and oil preservation system |
| 18 | Corrosion protection |
| 19 | Electrical and physical Interfaces with substation |
| 20 | Earthing (Internal & External) |
| 21 | Processing and assembly |
| 22 | Testing capabilities |
| 23 | Inspection and test plan |
| 24 | Transport and storage |
| 25 | Sensitivity of design to specified parameters |
| 26 | Acoustic Noise |
| 27 | Spares, inter-changeability and standardization |
| 28 | Maintainability |
| 29 | PRD and SPR (number & locations) and selection |
| 30 | Conservator capacity calculation |
| 31 | Winding Clamping arrangement details with provisions for taking it “in or out of tank” |
| 32 | Conductor insulation paper details |
| 33 | Location of Optical temperature sensors |
| 34 | The design of all current connections |
| 35 | Location & size of the Valves |

Annexure – F
Painting Procedure

| PAINTING | Surface preparation | Primer coat | Intermediate undercoat | Finish coat | Total dry film thickness (DFT) | Colour shade |
|---|--|--|--|---|---------------------------------------|--|
| Main tank, pipes, conservator tank, oil storage tank & DM Box etc. (external surfaces) | Shot Blast cleaning Sa 2 ½* | Epoxy base Zinc primer (30-40 μ m) | Epoxy high build Micaceous iron oxide (HB MIO) (75μ m) | Aliphatic polyurethane (PU) (Minimum 50μ m) | Minimum 155μ m | RAL 7035 |
| Main tank, pipes (above 80 NB), conservator tank, oil storage tank & DM Box etc. (Internal surfaces) | Shot Blast cleaning Sa 2 ½* | Hot oil proof, low viscosity varnish or Hot oil resistant, non-corrosive Paint | -- | -- | Minimum 30μ m | Glossy white for paint |
| Radiator (external surfaces) | Chemical / Shot Blast cleaning Sa 2 ½* | Epoxy base Zinc primer (30-40 μ m) | Epoxy base Zinc primer (30-40μ m) | PU paint (Minimum 50 μ m) | Minimum 100μ m | Matching shade of tank/ different shade aesthetically matching to tank |
| Manufacturer may also offer Radiators with hot dip galvanised in place of painting with minimum thickness of 40μ m (min) | | | | | | |
| Radiator and pipes up to 80 NB (Internal surfaces) | Chemical cleaning, if required | Hot oil proof, low viscosity varnish or Hot oil resistant, non-corrosive Paint | -- | -- | -- | -- |
| Control cabinet/ Marshalling box/ Common marshalling box – No painting is required. | | | | | | |

Note: (*) indicates Sa 2 ½ as per Swedish Standard SIS 055900 of ISO 8501 Part-1.

Annexure – H
Technical Parameters of Current Reactors - 420 kV Line Shunt
Reactor
On each phase connection & Neutral Grounding Reactor

| (a) Ratio | | | | |
|--|--------------------|--|----------------------|-------------------|
| | Line Side | Neutral Side | Comm on | Earth Side |
| CORE 1 | 200/1A | 2000-1000- 500/1A | 200/1A | 200/1A |
| CORE 2 | 200/1A | 2000-1000- 500/1A | | |
| CORE 3 | 200/1A | 200/1A | | |
| CORE 4 | 200/1A | Applicable for WTI (to be decided by contractor for WTI) | | |
| (b) Minimum knee point voltage or burden and accuracy class | | | | |
| CORE 1 | 200V, PS Class | 2000V-1000V- 500V, PS Class | 200V, PS Class | 200V, PS Class |
| CORE 2 | 200V, PS Class | 2000V-1000V- 500V, PS Class | | |
| CORE 3 | 200V, PS Class | 200V, PS Class | | |
| CORE 4 | 10VA, Class 1.0 | Applicable for WTI (to be decided by contractor for WTI) | | |
| (c) Maximum CT Secondary Resistance | | | | |
| CORE 1 | 1 Ohm | 10-5-2.5 Ohm | 1 Ohm | 1 Ohm |
| CORE 2 | 1 Ohm | 10-5-2.5 Ohm | | |
| CORE 3 | 1 Ohm | 1 Ohm | | |
| CORE 4 | - | Suitable for WTI | | |
| (d) Existing current (max.) | | | | |
| CORE 1 | 250mA @ Vk/4 | 30mA@ 2000/1A 120mA@ 500/1A | | |
| CORE 2 | 250mA @ Vk/4 | 30mA@ 2000/1A 120mA@ 500/1A | | |
| CORE 3 | 250mA @ Vk/4 | 250mA @ Vk/4 | | |
| CORE 4 | - | - | | |

| (e) Application | | | | |
|------------------------|--------------------------|---|-------|------------------------|
| CORE 1 | Spare | Spare | Spare | Restricted earth fault |
| CORE 2 | Restricted earth Fault | Reactor differential Protection | | |
| CORE 3 | Reactor Backup Impedance | spare | | |
| CORE 4 | Metering | Temperature Indicator (on one phase only) | | |

Note:

- a. The CT used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
- b. Rated continuous thermal current rating shall be 200% of rated primary current.
- c. Parameters of WTI CT for each winding shall be provided by contractor/manufacturer.

Technical Parameters of Current Reactors - 420 kV Bus Reactor

| | Line Side | Neutral Side |
|--|------------------------|---|
| CORE 1 | 200/1A | 200/1A |
| CORE 2 | 200/1A | 200/1A |
| CORE 3 | 200/1A | 2000-1000-500/1A |
| CORE 4 | 200/1A | To be decided by contractor for WTI |
| (b) Minimum knee point voltage or burden and accuracy class | | |
| CORE 1 | 200V, PS Class | 200V, PS Class |
| CORE 2 | 200V, PS Class | 200V PS class |
| CORE 3 | 200V, PS Class | 2000-1000-500V, PS Class, |
| CORE 4 | 10VA, Class 1.0 | To be decided by contractor for WTI |
| c) Maximum CT Secondary Resistance | | |
| CORE 1 | 1 Ohm | 1 Ohm |
| CORE 2 | 1 Ohm | 1 Ohm |
| CORE 3 | 1 Ohm | 10-5-2.5 Ohm |
| CORE 4 | - | - |
| d) Exciting Current (Max.) | | |
| CORE 1 | 250mA @ $V_k/4$ | 250mA @ $V_k/4$ |
| CORE 2 | 250mA @ $V_k/4$ | 250mA @ $V_k/4$ |
| CORE 3 | 250mA @ $V_k/4$ | 30mA @ 2000/1 120mA @ 500/1 |
| CORE 4 | - | - |
| e) Application: | | |
| CORE 1 | Spare | Spare |
| CORE 2 | Restricted earth fault | Restricted earth fault |
| CORE 3 | Spare | Overall Reactor differential Protection |
| CORE 4 | Metering | Temperature Indicator (on one phase only) |

Note:

- The CT used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
- Rated continuous thermal current rating shall be 200% of rated primary current.
- Parameters of WTI CT for each winding shall be provided by contractor/manufacturer.

ANNEXURE – I
Gapless Surge Arrester – Technical parameters

| | | |
|------|---|---------------------------------------|
| a | Rated arrester voltage | 120 kV |
| b | Rated system voltage | 145 kV |
| c | Rated system frequency | 50Hz |
| d | System neutral earthing | Earthed through NGR |
| e | Installation | Outdoor |
| f | Nominal discharge current | 10kA of 8/20 microsec wave. |
| g | Class of arrester | 10kA heavy duty type |
| h | Minimum discharge capacity | 3.5 kJ/kV (referred to rated voltage) |
| i | Continuous operating voltage at 50 ^o C | 102 kV |
| j. | Maximum switching surge residual voltage (1kA) | 280kVp |
| k | Maximum residual voltage at | |
| (i) | 10kA | 320kVp |
| (ii) | 20kA nominal discharge current | 340kVp |
| l | Long duration discharge class | 2 |
| m | High current short duration test value (4/10micro- sec.wave) | 100kAp |
| n | Current for pressure relief test | 40kArms |
| o | Low current long duration test value (2000microsec.) | 1000Apeak |
| p | Min. total creepage distance | 4495 mm. |
| q | One minute dry power frequency withstand voltage of arrester housing | 275kVrms |
| r | Impulse withstand voltage of arrester housing with 1.2/50 micro-sec. wave | + 650KVp |
| s | Pressure relief class | A |
| t | RIV at 92 kVrms. | Less than 500microvolts |
| u | Partial discharge at 1.05 continuous over voltage | Not more than 50pC |
| v | Seismic acceleration | As specified in section project |
| w | Reference ambient temperature | 50 deg C |

ANNEXURE – J - VOID

ANNEXURE – K

Technical Specification of Reactor Oil BDV Test Set

1. Technical Specifications of BDV kit (Automatic Electric Strength Apparatus)

1. SCOPE

This specification is regarding Automatic Electric Strength Apparatus used for testing of Electric Strength of Reactor oil as per IEC – 156 , IS 6792-1992 and other International Standards up to 100kV. The Instrument should carry out the sequence of tests without supervision.

The bidder shall provide:

- a) Operation and maintenance manual including drawings in English language.
- b) Software in a CD in English language.
- c) Training to KPTCL personnel on all aspects of operation, maintenance and calibration.
- d) Continued technical support during guarantee period (2 years) and also during extended warranty period (3 years).
- e) The bidder must have trained Engineers dedicated for trouble shooting and Technical support, permanently posted in India preferably in Bangalore.

2. APPLICABLE STANDARDS

Unless otherwise specified separately in this specification, the equipment shall comply with the requirements of IEC 156, IS 6792-1992 and any other standards relevant IEC, BS, ASTM etc. Over and above to this, all special requirements specified in the specification shall be complied.

3. OPERATING CONDITIONS:

- a) Voltage (Mains) : 90 to 264V AC (-10% to +10%)
- b) Frequency (Mains) : 50 Hz \pm 5%
- c) Environment : Laboratory use. Indoor
- d) Operating Temperature : 0 deg C to +50 deg C
- e) Storage Temperature : -20 deg C to +65 deg C
- f) Humidity 80% RH 40 deg C Operation.

4. INTERFACE and PRINTER

- i) Inbuilt Printer
- ii) Unit should have internal memory to store results and should be transferable to a USB drive or PC.

5. ESSENTIAL FEATURES

- a) Type:** Fully Automatic Onboard Control Interface.
Fully Automatic to set the following option
- Stand time
 - Stir Time
 - Rate of Rise of voltage 0.5kV to 5kV adjustable
 - No. of Tests carried out.

b) Out put Rating: 0 – 100 kV @ 61.8 Hz with 0.1 kV resolution.

c) Accuracy: 0.1 kV $\pm 1\% \pm 2$ digits.

d) Reactor: Voltage applied to the electrodes of the oil filled test-cell should be nearly sinusoidal and the peak factor should be within the limits of 1.34 and 1.48.

e) Method: The unit shall have automatic voltage increase as per the various testing standards. Provision should also be available for user settable tests. The unit shall be automatic and completer with test cell, stirrer and 'GO' and 'NO GO' gauge for adjusting the gap.

f) Additional Features: Facility of manual operation, recalling of Breakdown.

- The equipment shall have provision for automatic oil temperature measurement.
- Instrument should be light weight, Portable and should not exceed 30 kgs.
- Instrument should be supplied with a suitable calibrator which allows the actual applied voltage to be quickly and easily checked against the displayed value giving immediate confidence in the calibration of the oil test set.
- The instrument shall trip the high voltage with direct measurement of Voltage and current.

g) Breakdown Indication: The test set should display individual and avg BDV with mean and standard deviation with date and time. The instrument should have an internal built in printer for printing the test results.

h) Display : 320 X 240 QVGA colour display with back light

i) Protection: Safety Interlock on Cover

Instrument should meet the safety requirements of IEC 61010-1
Instrument should meet the EMC requirements of IEC 61326-1

5.10.Test Vessel

5.10.a. Material: Cell made of glass of rigid oil resistant plastic shall be transparent and covered Volume: 350ml to 500ml

5.10.b. Electrodes:-

Type : all types including Spherical (As per IS.6792-1992).

Material: Brass, Copper, Bronze or Stainless Steel. The two electrodes should be mounted on a horizontal axis and should be 2.5 mm apart. The gap between them should be set to an accuracy of $\pm 0.01\text{mm}$ by guage. The axis of the electrodes should be immersed to a depth of approximately 40mm.

5.11. Interlocking System:-

Safety Interlock on High Voltage test Chamber. Open ground & Interlock indication & protection on front panel. Zero start interlocking.

5.12. Circuit Protection:-

The instrument shall have fast HV switch off time less than 10 micro seconds.

6. GUARANTEE PERIOD

The whole equipment along with accessories shall be guaranteed for a period of minimum 42 months from date of successful demonstration at site/Laboratory.

7. INSTALLATIONS AND TRAINING

The bidder shall install the equipment at the location specified by the KPTCL and provide training to at least 2 personnel about the operation, maintenance and calibration of the equipment. Two sets of Instruction Manual with circuit diagrams shall be provided.

8. TEST CERTIFICATES:

The equipment shall be supplied along with the valid calibration certificate and Test certificate.

9. Recommended Spares and Consumables:

The bidder shall supply the following spares and consumables required for the satisfactory and trouble free operation of the equipment for 2 years.

| | | | |
|---------|------------------------------------|---|--------|
| Spares: | a) Test Vessel | - | 2 Nos. |
| | b) Electrode set | - | 2 Nos. |
| | c) Electrode gauge set | - | 2 Nos. |
| | d) Magnetic Stirrer with retriever | - | 3 Nos. |
| | e) Software CD | | |
| | f) Mains supply Cable | | |

**Technical Specification of Portable Dissolved Gas Analysis of
Reactor Oil**

| S.No | Particulars | Specification | | | | |
|------|------------------------|---|---------------------------------|----------------------|-----------------------------|--|
| 01 | Functional Requirement | The Portable Gas Chromatograph equipment to extract, detect, analyze and display the dissolved gases in Reactor oil as specified in IEEE C 57-104-2008 and IEC 60559-2007. | | | | |
| 02 | Extraction of Gases | Gases shall be extracted from insulating oil either of the mercury free extraction method <ul style="list-style-type: none">- Shake test method as described in IEC-60567-2005-Annexure C- Head space method- Partial Degassing toepler pump method | | | | |
| 03 | Detection of Gases | All the fault gases ie H2, CH4, C2H2, C2H4, C2H6, CO & CO2 concentrations shall be individually measured and displayed. It is preferable that instrument also displays N2 and O2 content individually. The minimum detection limits of the instrument shall strictly meet the requirement of IEC-60567-2011-Page No.47-clause 9.2, table-5. | | | | |
| 04 | Performance Parameters | Gases | Minimum Detection Limits in ppm | Working Range in ppm | Accuracy | |
| | | Hydrogen-H2 | 5 | 0-5000 | +/- 2 ppm or | |
| | | Hydrocarbons-CH4, C2H2, C2H4, C2H6 | 1 | 0-10000 | +/- 5% whichever is greater | |
| | | Carbon Monoxide-CO | 25 | 0-10000 | | |
| | | Carbon dioxide-CO2 | 25 | 0-50000 | | |
| 05 | Power Supply | It shall be operated with AC single phase,50 Hz +/- 5%, 230 V +/- 10% supply. All power cable and necessary adaptors shall be provided by supplier. | | | | |

| | | |
|----|---|--|
| 06 | Calibration | <p>a). Instrument shall have facility to perform calibration check using GAS-IN-OIL standards as well as calibration gas mixtures. This GAS- IN-OIL standard shall be prepared in syringes in accordance with IEC-60567-2005-Page No.35-clause 6.2.</p> <p>b). The calibration shall be demonstrated by supplier at the time of installation / commissioning at our lab and KPTCL will provide only the insulating oil for testing.</p> <p>c). All necessary requirement like Glass syringes, 3 way cock and any other consumable required for calibration check shall include in the scope of supply.</p> |
| 07 | Instrument control and Data handling, Internal Memory | <p>a) Instrument shall be having in built control for all the functions, data acquisitions and data storage, it shall have a facility for communication with computer for downloading the data from instrument via USB port. Licensed copy of the software required to download data to computer shall be provided.</p> <p>b) Laptop shall be provided for communication with the instrument. It shall be of latest specification along with licensed preloaded OS and software as well as software for interpreting DGA results accordance with IEEE C57-104-1991 and IEC 60559-1999 along with laptop with carrying case included.</p> <p>c) Internal Memory can be capable of storing 15000 records, if inbuilt functions</p> |

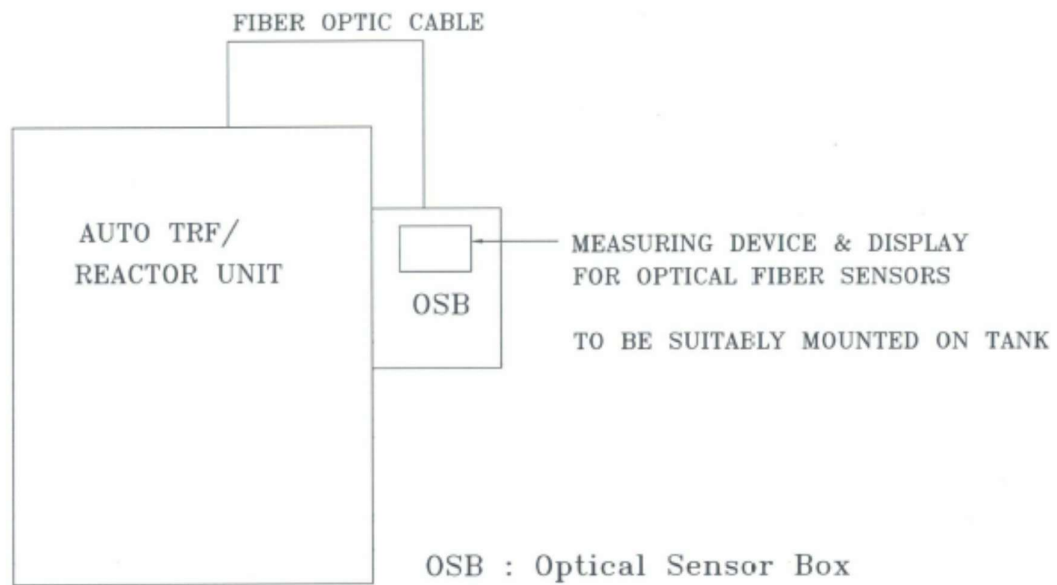
| | | |
|----|--|---|
| 08 | General Conditions | <p>a) Performance Parameters like- Minimum Detection Limits, working range, Accuracy, repeatability etc. shall be finalized during detailed engineering.</p> <p>b) The portable DGA equipment supplier shall demonstrate during commissioning of the kit that the results shown by the kit are within the specified accuracy and repeatability range and KPTCL will provide only the insulating oil/GAS-IN-OIL standard for testing.</p> <p>c) All required items/instruments /spares / consumable /connecting cables/ communication cables/instruments/manuals/Certificates/ training materials/original software/original licensed data /station operating software/education CD/DVDs that are essential to understand and operate the instrument shall be supplied at no extra cost.</p> |
| 09 | Operating Temperature , Relative humidity & Dimensions | <p>01. Temperature 0-40 Deg. Centigrade</p> <p>02. 85% non condensing</p> <p>03. Portable</p> |
| 10 | Receipt, Storage | It shall be the responsibility of the supplier to ensure proper receipt and storage before commissioning the kit. |
| 11 | Warranty | The entire test set up shall be covered on warranty for a period of five year from the last date of complete commissioning and taking over the test set up. If the kit needs to be shifted to suppliers works for repairs, supplier will have to bear the cost of, spares, software, transportation etc of kit for repair at test lab/works. |
| 13 | Application Note | An application note/principle document from original manufacturer compliance with standard test method shall be submitted along with the kit. |
| 14 | Service Support | The supplier shall furnish the detailed organization structure of the service team, who has acquired qualification and regular training records from manufacturer. Mode of attending service calls shall be given in details. |

| | | |
|----|------------------------|--|
| 15 | Training | The supplier shall provide adequate training for a period of two working days pertaining to the operation and troubleshooting to site personnel. |
| 16 | Spares and consumables | All the necessary spares and consumables including carrier gas bottles if required, calibration gas mixture, septa, syringes, 3 way valves etc to run the equipment for AMC period with sample load of around 500 samples per year shall be offered items and quantity wise. |

ANNEXURE – L - VOID

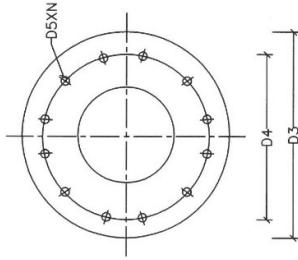
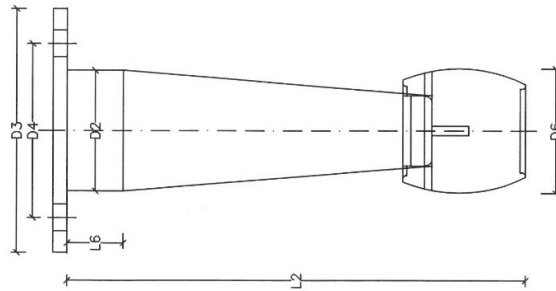
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CONCEPTUAL DRAWING FOR OPTICAL FIBER SENSOR

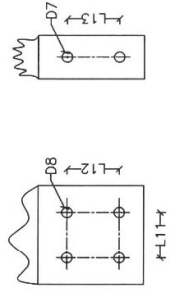


STANDARD DIMENSION FOR LOWER PORTION OF CONDENSER BUSHINGS
(FOR 420KV AND BELOW VOLTAGE CLASS BUSHINGS)

BUSHING MOUNTING FLANGE DETAILS

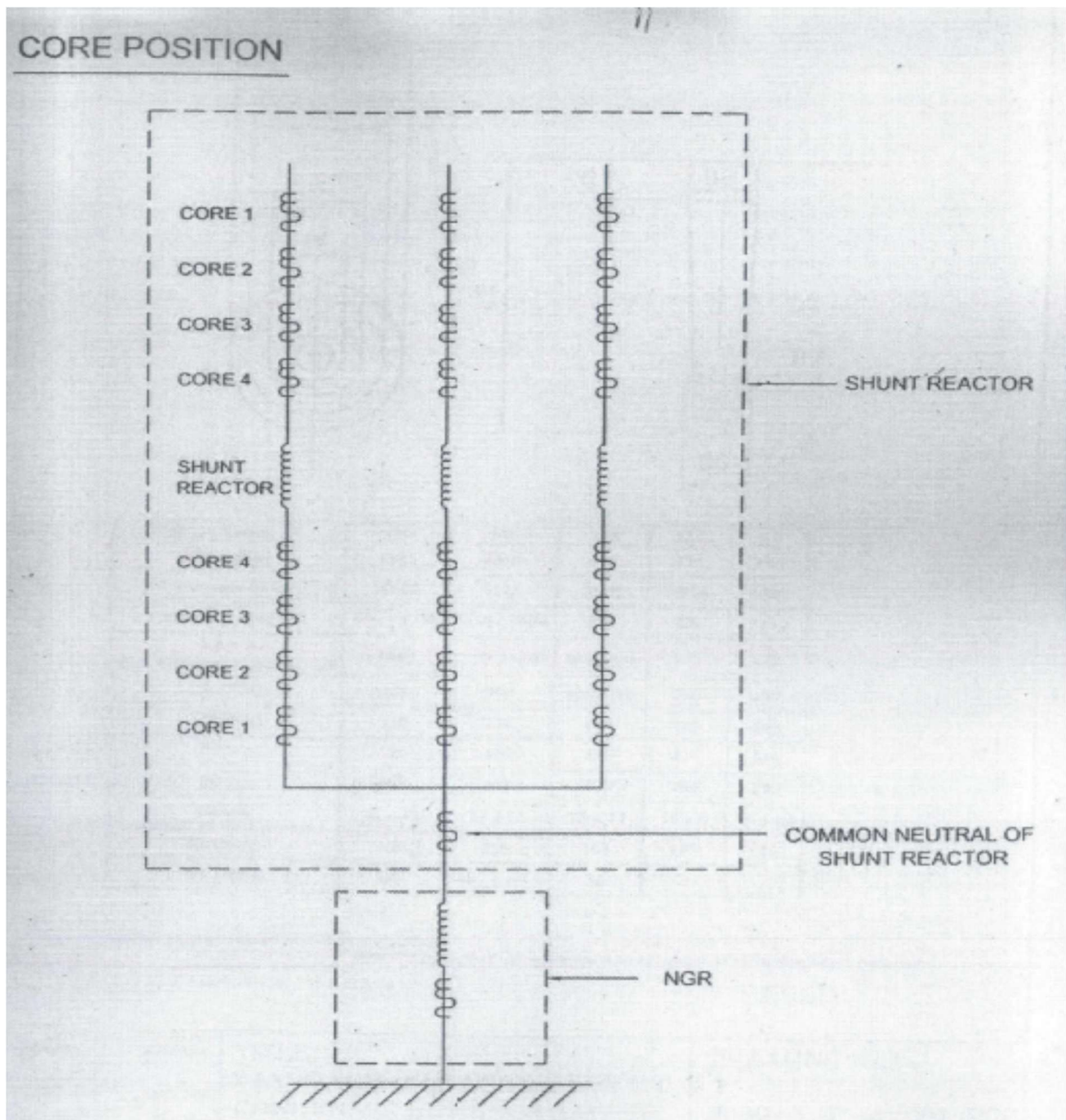


BOTTOM CONNECTION DETAILS

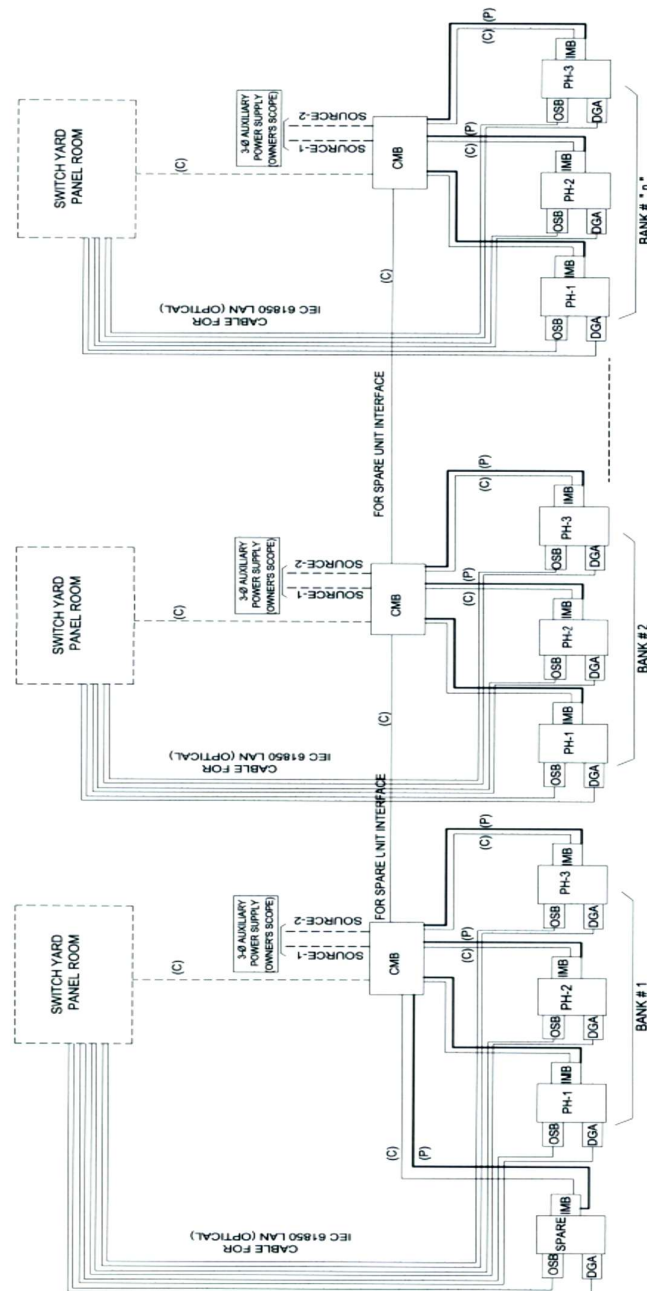


| SYMBOL | DESCRIPTION |
|--------|--|
| L2 | LENGTH BETWEEN BOTTOM SEAT OF FLANGE AND BOTTOM OF THE OIL END SHIELD/STRESS RELIEVING ELECTRODE/ OIL END TERMINAL WHICHEVER IS THE LONGEST. |
| L6 | LENGTH FOR ACCOMMODATING BUSHING CURRENT TRANSFORMER (BCT) |
| D2 | MAXIMUM DIAMETER OF OIL IMMERSED END |
| D3 | OUTSIDE DIAMETER OF FIXING FLANGE |
| D4 | PITCH CIRCLE DIAMETER OF FIXING HOLES OF FLANGE |
| D5 | DIAMETER OF FIXING HOLE |
| N | NUMBER OF FIXING HOLES |
| D6 | MAXIMUM DIAMETER OF OIL END SHIELD/STRESS RELIEVING ELECTRODE |
| L11 | HORIZONTAL DISTANCE BETWEEN HOLES FOR BUSHING BOTTOM CONNECTION FOR 4 HOLE CONNECTION |
| L12 | VERTICAL DISTANCE BETWEEN HOLES FOR BUSHING BOTTOM CONNECTION FOR 4 HOLE CONNECTION |
| L13 | VERTICAL DISTANCE BETWEEN HOLES FOR BUSHING BOTTOM CONNECTION FOR 2 HOLE CONNECTION |
| D7 | DIAMETER OF HOLE FOR BUSHING BOTTOM CONNECTION FOR 2 HOLE CONNECTION |
| D8 | DIAMETER OF HOLE FOR BUSHING BOTTOM CONNECTION FOR 4 HOLE CONNECTION |

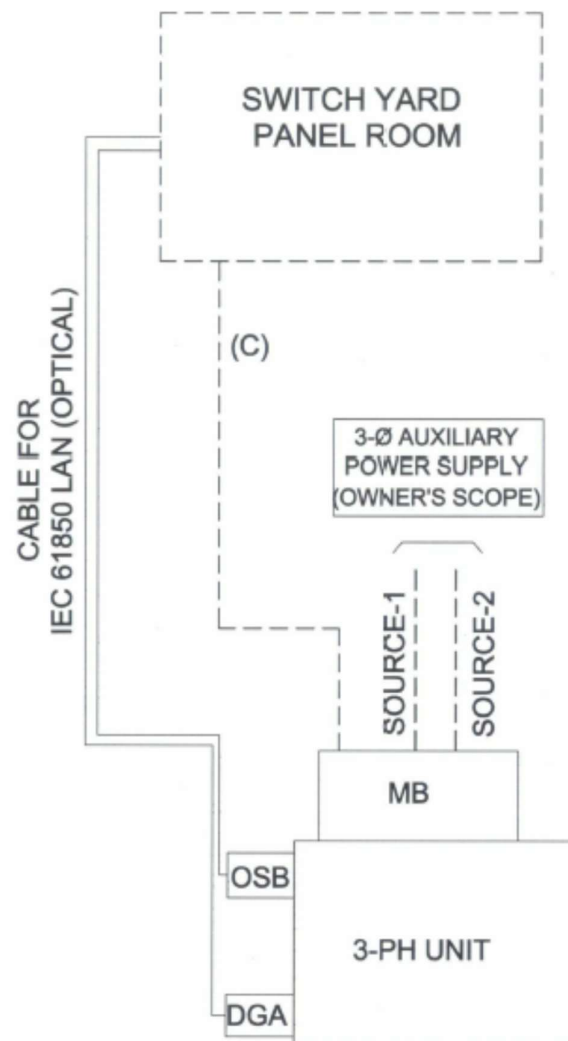
ARRANGEMENT OF CURRENT REACTOR ON SHUNT REACTOR AND NGR

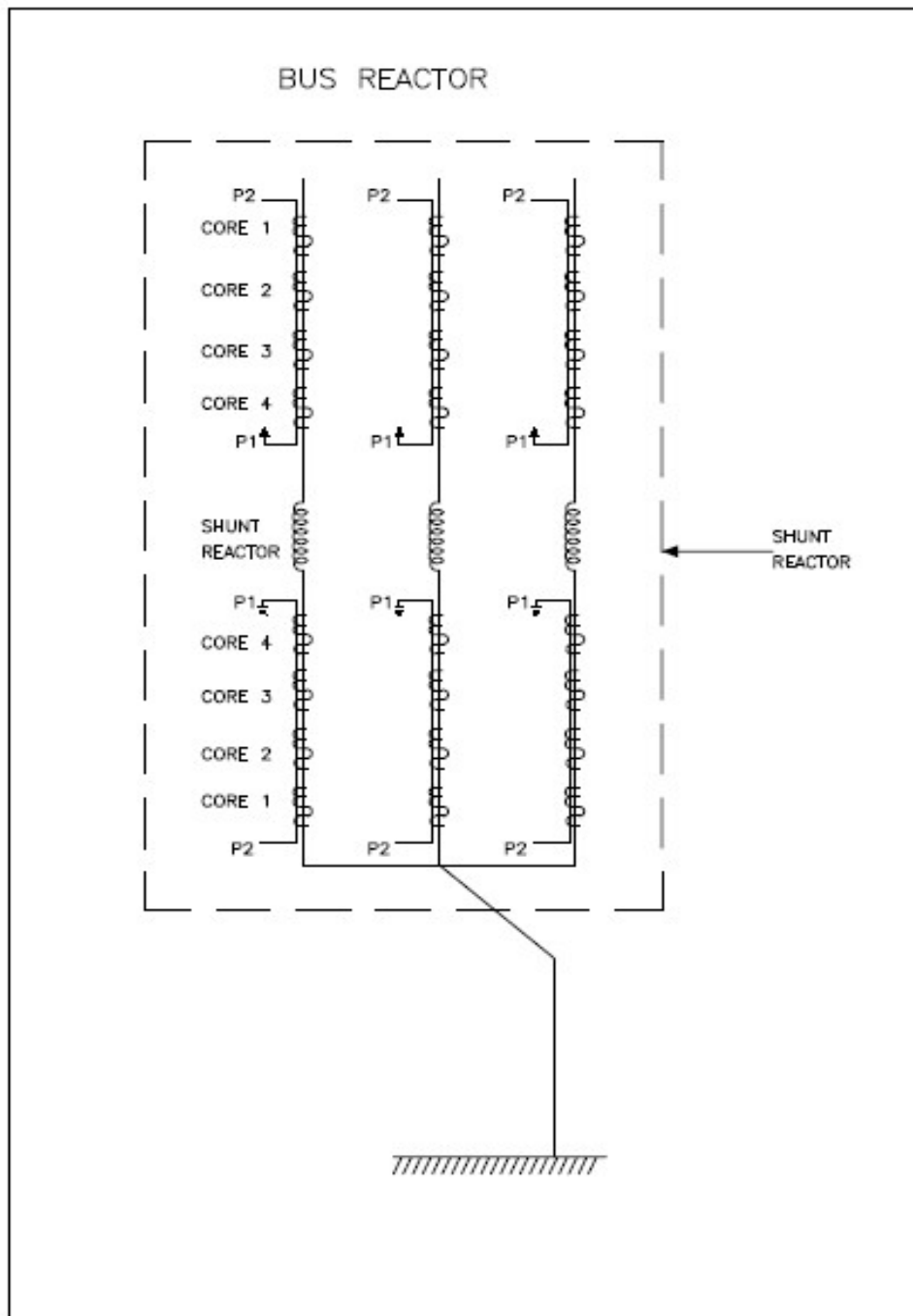


CONCEPTUAL DRAWING FOR SHOWING POWER AND CONTROL CABLE CONNECTION FOR OPERATION WITH SPARE UNIT



CONCEPTUAL DRAWING FOR SHOWING POWRE & CONTROL CABLE
FOR OPERATION OF 3-PH REACTOR





ARRANGEMENT OF CURRENT REACTOR IN REACTOR