

# **TECHNICAL** **SPECIFICATIONS**

## **CHAPTER 8- REACTOR**

*for*

### **PACKAGE KC-6**

*of*

## **KOSHI CORRIDOR 220kV TRANSMISSION LINE PROJECT**

**IFB No.: KOSHI/NEA/KC-6**

**Procurement of Design, Supply, Installation, Testing and**  
**Commissioning of 220kV(GIS)/132kV Substation**  
**Expansion at Dhungesanghu Substation**



**नेपाल विद्युत प्राधिकरण**  
(नेपाल सरकारको स्वामित्व)  
**Nepal Electricity Authority**  
(A Government of Nepal Undertaking)

**CHAPTER 8: SHUNT REACTOR**

| Clause No.  | Description  |
|-------------|--|
| 1.          | General  |
| 2.          | Type of Reactor  |
| 3.          | Transportation   |
| 4.          | Performance  |
| 5.          | Measurable Defects   |
| 6.          | Design review  |
| 7.          | Construction Details   |
| 8.          | Paint system and procedures                                    |
| 9.          | Unused inhibited Insulating Oil                                |
| 10.         | Spare Reactor Units Storage & Connection Arrangement           |
| 11.         | Bushings   |
| 12.         | Neutral Formation and Earthing Arrangement                     |
| 13.         | Cooling Equipment  |
| 14.         | Valves   |
| 15.         | Cabling  |
| 16.         | Individual Marshalling Box and Common Marshalling Box          |
| 17.         | SCADA Integration  |
| 18.         | Current Transformer  |
| 19.         | Surge Arrester   |
| 20.         | Hand Tools   |
| 21.         | Test Kit   |
| 22.         | Fittings   |
| 23.         | Inspection & Testing   |
| Annexure –A | Technical Particulars / Parameters of Reactors & NGR           |
| Annexure –B | Test Plan  |
| Annexure –C | Design Review Document   |
| Annexure –D | Painting Procedure   |
| Annexure –E | Unused inhibited Insulating Oil Parameters                     |
| Annexure –F | Technical Parameters of Current Transformers                   |
| Annexure –G | Gapless Surge Arrester – Technical parameters                  |
| Annexure –H | On load Tap Changing Equipment for Variable Shunt Reactor      |
| Annexure –I | Oil BDV Test Set   |
| Annexure –J | Portable Dissolved Gas Analysis of Oil                         |
| Annexure –K | Online Dissolved Gas (Multi-8 gas) and Moisture Analyser       |
| Annexure –L | Online Dissolved Gas (Multi-4 gas) and Moisture Analyser       |
| Annexure –M | Online Hydrogen and Moisture Measurement Equipment             |
| Annexure –N | Online Bushing monitoring system                               |
| Annexure –O | Nitrogen Injection Type Fire Prevention & Extinguishing System |
| Annexure –P | Oil sampling bottles & Oil Syringe                             |
| Annexure –Q | Oil Storage Tank   |
| Annexure –R | Spare Reactor Units Storage & Connection Arrangement           |



## TECHNICAL SPECIFICATION FOR SHUNT REACTOR, NEUTRAL GROUNDING REACTOR AND SURGE ARRESTER

### 1. General

- 1.1. This specification covers design, engineering, manufacture, testing, delivery at site including all materials, accessories, spares, unloading, handling, proper storage at site, erection, testing and commissioning of the equipment specified.
- 1.2. The Reactor offered by the contractor shall at least conform to the requirements specified under relevant IEC standard. In case of discrepancy between IEC and other international standard, provisions of IEC shall prevail. If the IEC standard is not available, then other applicable Equivalent International standard, as per the specification, shall be accepted.
- 1.3. Any material and equipment not specifically stated in this specification but which are necessary for satisfactory operation of the equipment shall be deemed to be included unless specifically excluded and shall be supplied without any extra cost.
- 1.4. Components having identical rating shall be interchangeable.

### 2. Type of Reactor

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:

- i) Adopting single phase construction in separate tanks.
- ii) Adopting 5 limb core construction, for 3-Phase

In case of coreless construction following requirements are stipulated.

- i) A magnetic shield shall be provided around the coreless coils.
- ii) Non-magnetic material sheet shall form the central core to minimize the vibrations.

The neutral grounding reactors are required for grounding of the neutral point of shunt reactors to limit the secondary arc current and the recovery voltage to a minimum value.

**Note: Variable Shunt Reactor shall be supplied if only specified in Chapter PSR and BPS meeting the additional requirements set in the Annexure-H On load Tap Changing Equipment for Variable Shunt Reactor of this specification.**

### 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 inland transportation of the reactor unit shall be on trailer 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 a load of more than 40 T.
- 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 Employer 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. A dry air pressure testing valve with necessary pressure gauge and adaptor valve shall be provided. The dry air cylinder(s) provided to maintain positive pressure can be taken back by the contractor after oil filling.

In case, turrets are having insulation assembly and is transported separately then the same shall also be filled with dry air.

- 3.6. The Reactor shall also be fitted with at least 2 numbers 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) 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.
- 4.2. The reactors shall be designed for switching surge overvoltage of 2.5 p.u. and temporary overvoltage of the order of 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 dynamic conditions which may cause additional current flow as a result of changed saturation characteristics/slope beyond 1.5 p.u. voltage.



- 4.3. 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 140 Deg Celsius. Maximum ambient temperature shall be considered as 50 Deg C.
- 4.4. 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 140 Deg Celsius. Maximum ambient temperature shall be considered as 50 Deg C.
- 4.5. The reactor shall be designed to withstand the following over-voltages repeatedly without risk of failure (w.r.t. Hotspot temperature & core saturation):
- 1.05 Ur for continuous (for 420kV Class Reactor)
  - 1.10 Ur for continuous (for below 420kV Class Reactor)
  - 1.25 Ur for 1 minute
  - 1.50 Ur for 5 seconds
- 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 windings 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. 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.
- 4.8. Tank hotspot temperature under over voltage condition specified above shall not exceed 110 Deg C considering maximum ambient temperature as 50 Deg C.
- 4.9. The magnetic circuit will be designed such that the reactor is linear upto voltage specified at **Annexure – A**.
- 4.10. **Radio Interference and Noise Level**
- a) 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.
  - b) The noise level of reactor, when energised at rated voltage and frequency shall not exceed the values specified at **Annexure-A** measured under standard conditions.

## 5. Measurable Defects

The following shall constitute as Measureable Defects for the purpose of Defect Liabilities as per relevant clauses of GCC / SCC of the bidding document:



- 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-C57.104-2019, which are given below:

| Fault GAS                   | H2         | CH4        | C2H2      | C2H4       | C2H6       | CO          | CO2          |
|-----------------------------|------------|------------|-----------|------------|------------|-------------|--------------|
| <b>O2/N2 Ratio≤<br/>0.2</b> | <b>200</b> | <b>150</b> | <b>02</b> | <b>100</b> | <b>175</b> | <b>1100</b> | <b>12500</b> |

- 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 for tan delta
- a) The moisture content goes above 12 ppm at any temperature during operation.

## 6. Design review

- 6.1. 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.t. thermal, mechanical, dielectric and electrical stress etc. shall be maintained during design, selection of raw material, manufacturing process etc. The scope of such design review shall include but not limited to the requirement as mentioned at **Annexure – D**.

- 6.2. Design reviews shall be conducted by Employer or by an appointed consultant during the procurement process for Reactors; however, the entire responsibility of design shall be with the manufacturer. Employer may also visit the manufacturers works to inspect design, manufacturing and test facilities.

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 reviews for power transformers*”.

- 6.3. 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 SC 12 shall be applied for short circuit withstand evaluation.

## 6.4. Type test requirement & it's validity

The offered Reactor or the Reactor, the design of which is similar to the offered Reactor, should have been successfully type tested. Manufacturer may use same or different approved make of Bushings and other accessories used in type tested or short circuit tested unit in their Reactor.



Further, type test report of Reactor shall only be acceptable provided the offered Reactor has been manufactured from the same plant. The Reactor Type test validity period shall be as per Technical Specification Chapter-General Technical Requirement (GTR).

## 7. Construction Details

The construction details and features of each Shunt Reactor shall be in accordance with the requirement stated hereunder.

### 7.1. Tank

- a) Tank shall be 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.
- b) 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 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 IS 10801.
- c) Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water.
- d) 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 spatter inside the tank. Proper tank shielding shall be done to prevent excessive temperature rise at the joint.
- e) The tank shall be designed in such a way that it can be mounted on the plinth directly.
- f) 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 and the base plate shall have following minimum thickness:

| Length of tank (m)         | Minimum plate thickness (mm) |
|----------------------------|------------------------------|
| Flat bases                 |                              |
| over 2.5m but less than 5m | 20                           |
| over 5m but less than 7.5m | 26                           |
| exceed 7.5m                | 32                           |

- g) The hotspot temperature in any location of the tank shall not exceed 110 degree Celsius at max. continuous operating voltage. This shall be measured during temperature rise test at manufacturer's works.





- h) 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.
- i) 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.
- j) All pipes connected to Reactor shall follow IS 1239.
- k) 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. Suitable provision (valves, etc.) as required for installation of Nitrogen Injection Fire Protection System in Reactor shall be provided.
- l) 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.

## 7.2. Tank Cover

- a) 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.
- b) 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.
- c) The tank cover shall be provided with pockets for OTI, WTI and RTDs including 2 spare pockets. 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.

- d) 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.
- e) 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
- f) **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.
- g) 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.
- h) **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.

### 7.3. **Gasket for tank & cover**

All gasketed joints in contact with oil shall be designed, manufactured and assembled to ensure long-term leak and maintenance free operation. All gasketed joints unless otherwise approved shall be of the O-ring and groove type. 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.

All tank gaskets used shall be of NBR (Acrylonitrile butadiene Rubber generally known as NBR) and properties of all the above gaskets / O-Rings shall comply with the requirements of IS-11149 (Grade IV) Material selected shall suit temperature conditions expected to be encountered. Neoprene / cork sheets gaskets are not acceptable. The Gaskets and O-rings shall be replaced every time whenever the joints are opened.

### 7.4. **Foundation, Roller Assembly & Anti Earthquake Clamping Device**

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 rollers 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 as per the drawing mentioned at **Annexure-C**.



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.

Foundation bolts and other locking devices shall be in the scope of contractor.

Regarding cooler pipe supports, Buchholz pipe (if required) and fire-fighting pipe supports shall be fixed on concrete block through Anchor Fastener with chemical grouting and no pockets for bolting shall be provided.

All control cubicles shall be mounted at least one meter above FGL (Finished Ground Level) to take care of water logging (if any) during flooding. Suitable arrangement (ladder and platform) shall be provided for safe access to control cubicles.

All fittings (Foundation bolts, supports, embedded plates if any) including anchor fastener with chemical grouting are in the scope of contractor.

#### 7.5. **Conservator**

- a) Conservator shall have air cell type constant oil pressure system to prevent oxidation and contamination of oil due to contact with moisture.

Conservator Protection Relay (CPR)/Air cell puncture detection relay shall be installed to give alarm in the event of lowering of oil in the conservator due to puncture of air cell in service.

Conservator shall be fitted with magnetic oil level gauge with potential free high and low oil level alarm contacts and prismatic oil level gauge and Conservator Protection Relay

- b) 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.
- c) 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.
- d) Conservator shall be positioned so as not to obstruct any electrical connection to Reactor.
- e) 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 150 mm 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 **“Conservator is fitted with an air cell”**.

- f) Contact of the oil with atmosphere is prohibited by using a flexible air cell of nitrile rubber reinforced with nylon cloth. The temperature of oil in the conservator is likely to raise up to 110°C during operation. As such air cell used shall be suitable for operating continuously at this temperature.
- g) 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, and the recommended replacement intervals.
- h) The conservator tank and piping shall be designed for complete vacuum / filling of the main tank and conservator tank. Provision must be made for equalising the pressure in the conservator tank and the air cell during vacuum / filling operations to prevent rupturing of the air cell.
- i) 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 become saturated with oxygen before 10 years. Air cells with well proven long life characteristics shall be preferred.

#### 7.6. Piping works for conservator

- a) Pipe work connections shall be of adequate size for their duty and possibly short and direct. Only radiused elbows shall be used.
- b) 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 for reactor. 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.
- c)
- d) 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 80mm.
- e)
- f) A double flange valve of preferably 50 mm size shall be provided to fully drain the oil from the main tank conservator.



- g)
- h) Pipe work shall neither obstruct the removal of the opening of inspection or manhole covers.

### 7.7. Condition Controlled Maintenance Free Type Breather

7.7.1. The main Transformer 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.

7.7.2. 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 colorless, 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 1200 mm approximately from transformer rail top level.

### 7.7.3. Technical Features:

- a. Material & External Construction of the Breather shall be such that all external parts are suitable for outdoor use & resistive to transformer oil, ultraviolet rays, pollution & salt water and shall work without any trouble for ambient temperature between 0° C to +80° C.
- b. Following LEDs for local display on control unit, and suitable contacts & analog signal shall be provided for wiring to remote location:
  - i) LED for Power of control unit - ON
  - ii) LED for Filter heater- ON
  - iii) LED for Anti-condensation heater (of control unit) - ON
  - iv) LED & relay contact for "Device Error"
  - v) LED & relay contact for Regeneration active (De-humidification in process)
  - vi) Analogue output signal (4-20mA) for the Temperature of air (in filter unit / pipe).

7.7.4. 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.

7.7.5. Control unit shall be equipped with a communication port for downloading the operational data logged by the unit. All necessary software required for downloading and analysing the logger data shall also be provided by the



supplier. Supply of Laptop/PC for above software is not envisaged.

- 7.7.6. 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.
- 7.7.7. The equipment shall operate at input supply of 230V AC, 50 Hz. Any converter if required shall be supplied with the equipment.
- 7.7.8. 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.
- 7.7.9. The control unit shall be equipped with suitable heater to prevent moisture condensation.
- 7.7.10. The size of Condition controlled maintenance free dehydrating breather shall be decided based on the volume of transformer oil during detailed engineering.
- 7.7.11. 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 transformer.
- 7.7.12. Condition Controlled Maintenance Free Type Breather of alternate proven technology shall also be acceptable.

#### 7.8. **Pressure Relief Device**

One PRD of 150 mm 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

#### 7.9. **Sudden Pressure Relay**

One number of Sudden Pressure relay with alarm/trip contacts (**Terminal connection plug & socket type arrangement**) shall be provided on tank of Reactor. Operating features and size shall be reviewed during design review. Suitable canopy shall be provided to prevent ingress of rain water. Pressurized water ingress test for Terminal Box (routine tests) shall be conducted on Sudden Pressure Relay.

Plug & socket type arrangement with factory fitted cable of adequate length shall be supplied by OEM. Connection of plug and socket with cable at site is not acceptable.

#### 7.10. **Buchholz Relay**

One number Double float, reed type Buchholz relay complying to IS 3637 shall be provided in the connecting pipe between the oil conservator and the Reactor tank with minimum distance of five times pipe diameters between them. Any gas evolved in the Reactor shall be collected 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 while the Reactor in service. Suitable canopy shall be provided to prevent ingress of rain water. Each device shall be provided with two potential free contacts (**Plug & socket type arrangement**), one for alarm / trip on gas accumulation and the other for tripping on sudden rise of pressure.

Plug & socket type arrangement with factory fitted cable of adequate length shall be supplied by OEM. Connection of plug and socket with cable is not acceptable at site.

It should be possible to inspect Buchholz relay or Oil surge relay, standing on tank cover and suitable arrangement shall be made to access Buchholz relay safely.

The Buchholz relay shall not operate during starting/stopping of the Reactor oil circulation under any oil temperature conditions. The 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. Pressurised water ingress test for Terminal Box (routine tests) shall be conducted on Buchholz relay.

#### 7.11. **Oil Temperature Indicator (OTI)**

All Reactors shall be provided with a dial type thermometer of around 150 mm diameter for top oil temperature indication with angular sweep of 270°.





It shall have adjustable, potential free alarm and trip contacts besides that required for control of cooling equipment if any. A temperature sensing element suitably located in a pocket on top oil shall be provided. This shall be connected to the OTI instrument by means of flexible capillary tubing with stainless-steel armoured. Temperature indicator dials shall have linear gradations to clearly read at least every 2 deg C. Range of temperature should be 0- 150°C with accuracy of  $\pm 1.5\%$  (or better) of full scale deflection. The setting of alarm and tripping contacts shall be adjustable at site. Adjustable range shall be 20-90% of full-scale range. Heavy duty micro switch of 5A at 240V AC shall be used. The instruments case should be weather proof and having epoxy coating at all sides. Instruments should meet ingress protection class of IP55 as per IS 13947/IEC60529. The instruments should be capable of withstanding line to body high voltage of 2.5kV AC rms, 50Hz for 1 minute.

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

#### **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 ungrounded system. The calibration shall be as per IEC 60751 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 SCADA system. 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 Contractor. 4-20mA signal shall be wired to Digital RTCC panel / BCU for further transfer data to SCADA through IS/IEC 61850 compliant communications.

#### **7.12. Winding Temperature Indicator (WTI)**

All Reactor shall be provided with a device for measuring the hot spot temperature of winding with dial type thermometer of 150 mm diameter for winding temperature indication with angular sweep of 270° and shall have adjustable potential free alarm and trip contacts besides that required for control of cooling equipment if any. The setting of alarm and tripping contacts shall be adjustable at site. 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 capillary tubing with stainless-steel armoured. WTI shall have image coil and auxiliary CTs, if required to match the image coil, shall be mounted in the Marshalling Box / cooler control cabinet. Temperature indicator dials shall have linear gradations to clearly read at least every 2°C. Range of temperature should be 0- 150°C with accuracy of  $\pm 1.5\%$  (or better) of full scale deflection. Adjustable range shall be 20-90% of full-scale range. Heavy duty micro switch of 5A at 240V AC shall be used. The instruments case should be weather proof and having epoxy coating at all sides. Instruments should meet ingress protection class of IP55 as per IS 13947





/IEC60529. The instruments should be capable of withstanding line to body high voltage of 2.5kV AC rms, 50Hz for 1 minute.

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

**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 IEC 60751-2 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 Digital RTCC / BCU panel for further transfer data to SCADA through IS / IEC 61850 compliant communications.

- 7.13. The temperature indicators (OTI & WTI) 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.

7.14. **Earthing Terminals**

- a) Two (2) earthing pads (each complete with two (2) nos. holes, M16 bolts, plain and spring washers) suitable for connection to copper grounding conductor shall be provided each at position close to earth of the two (2) diagonally opposite bottom corners of the tank.
- b) Two earthing terminals suitable for connection to copper grounding conductor shall also be provided on each individual/common marshalling box and any other equipment mounted separately. For the tank-mounted equipment like 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.
- c) To allow for the effect of possible induced and capacitive surge current, good electrical connection is maintained between the tank and turrets. 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.
- d) Each Reactor unit should have provision for earthing and connected to grounding mat when not in service. For this purpose, line Terminals shall also be earthed through neutral by flexible copper connection. Contractor shall provide suitable arrangement for the above. 1.1kV Grade PVC FR type cable of 16 sq.mm (minimum) shall be used for above connection. Neutral shall have provision for connection to ground by a brass/tinned copper grounding bar supported from the



tank by using porcelain insulator. The end of the tinned/brass copper bar shall be brought to the bottom of the tank at a convenient point for making bolted connection to copper grounding conductor connected to station grounding mat. The other end of the tinned/brass copper bar shall be connected to the neutral bushing through flexible conductor/jumper.

#### 7.15. **Core**

- a) The core shall be constructed from non-ageing, cold rolled high permeability grade (HI-B) or better grain-oriented silicon steel laminations.
- b) The leg magnetic packets (cheeses) shall be made from state of the art low loss electrical steel CRGO (conventional/regular grade or better). The “Cheeses” shall be designed to minimize losses and equalize the distribution of flux in the legs.
- c) 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.
- d) 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.
- e) 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.
- f) The yokes shall be designed such that high temperatures resulting from unequal distribution of the flux in the yokes will not occur.
- g) 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.
- h) 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.

#### 7.16. **Internal Structure Design**

- a) 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.



- b) 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.
- c) 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.
- d) 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.

**7.17. Calculation of hot spots**

- a) 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.

**7.18. The hot spot temperature and surface temperatures 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.**

- a) The hot spot for all leads shall be calculated and it shall not exceed the calculated hot spot of the windings.
- b) The hot spot in the windings and magnetic circuit shall be calculated for the over voltage conditions specified.
- c) 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.

**7.19. Earthing of core and clamping structure**

- a) 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.
- b) 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.

- c) Where the core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the laminations, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.
- d) A drawing showing the details of the earthing design and connection shall be furnished during detailed engineering.

#### 7.20. Windings

- a) 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.
- b) The conductors shall be of electrolytic grade copper free from scales and burrs. Oxygen content shall be as per IS 12444/ **IEC 60228 /ISO 1972**.
- c) Epoxy bonded Continuously Transposed Conductor (CTC) shall be used in main winding for rated current of 400 A or more.
- d) The insulation of Reactor windings and connections shall be free from insulating compounds which are liable to soften, ooze out, shrink or collapse and shall be non- catalytic and chemically inactive in Reactor oil during service.
- e) 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.
- f) The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes.
- g) 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.
- h) The windings 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 the fact that the system will not always be in the new factory condition.
- i) The barrier insulation including spacers shall be made from high density pre- compressed pressboard (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  $>0.75$  g/cc.

- j) All spacers shall have rounded edges. Radially stepped spacers between winding disks will not be accepted.
- k) 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.
- l) An electrostatic shield, made from material that will withstand the mechanical forces, will be used to shield the high voltage windings from the magnetic circuit unless otherwise approved.
- m) 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.
- n) Winding paper moisture shall be less than 0.5%.
- o) 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. Windings shall be provided with clamping arrangements which will distribute the clamping forces evenly over the ends of the winding.
- p) The winding current density shall not exceed the limit of 3 Amp/ mm<sup>2</sup> for design rating. The design current density for short circuit current shall be as per IEC. The calculation for the selection of winding cross section shall be furnished by contractor.

Full details of the winding clamping arrangements, and their adjustment in or out of the tank together with relevant drawings and values, shall be submitted during design review.

#### 7.21. **Current carrying connections**

The mating faces of bolted connections shall be appropriately finished and prepared for achieving good long lasting, electrically stable and effective contacts. All lugs for crimping shall be of the correct size for the conductors. Connections shall be carefully designed to limit hot spots due to circulating eddy currents.

#### 7.22. **Winding terminations into bushings**

- a) Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions to ensure the integrity of the Reactor in service.
- b) The winding–end termination, insulation system and transport fixings



shall be so designed that the integrity of the insulation system generally remains intact during repeated work in this area.

- c) Allowances shall be made on the winding ends for accommodating tolerances on the axial dimensions of the set of bushings and also for the fact that bushings may have to be rotated.
- d) In particular, rotation or straining of insulated connections shall be avoided during the fastening of conductor pads (or other methods) on the winding ends onto the termination surfaces of the bushing.
- e) Suitable inspection and access facilities into the tank in the bushing oil-end area shall be provided to minimize the possibility of creating faults during the installation of bushings.

## 8. 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 –**

**D.** 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.

## 9. Unused inhibited Insulating Oil

The insulating oil shall be virgin high grade inhibited, conforming to IEC-60296 & all parameters specified at **Annexure – E**, while tested at oil supplier's premises. The contractor shall furnish test certificates from the supplier against the acceptance norms as mentioned at **Annexure – E**, prior to despatch of oil from refinery to site. The Unused Inhibited Insulating Oil parameters including parameters of oil used at manufacturer's works, processed oil, oil after filtration and settling are attached at **Annexure – E**. The oil test results shall form part of equipment test report.

Sufficient quantity of oil necessary for maintaining required oil level in case of leakage in tank, radiators, conservator etc. till the completion of warranty period shall be supplied.

Oil used for first filling, testing and impregnation of active parts at manufacturer's works shall be of same type of oil which shall be supplied at site and shall meet parameters as per specification.

### 9.1. Particles in the oil

The particle analysis shall be carried out in an oil sample taken before carrying out FAT at manufacturer's works 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 transformer dielectric strength". Particle limit as shown below shall be ensured by manufacturer, implying low contamination, as per CIGRE Brochure 157, Table 8. After filtration the oil is to be flushed and particle count to be measured.





Limiting value for the particle count are 1000 particle/100 ml with size  $\geq 5 \mu\text{m}$ ; 130 particle/100 ml with size  $\geq 15 \mu\text{m}$ .

## 9.2. Oil filling

- a) Procedures for site drying, oil purification, oil filling etc. shall be done as per **EMPLOYER** Field Quality Plan (FQP) approved by employer.
- b) The duration of the vacuum treatment shall be demonstrated as adequate by means of water / dew point measurement with a cold trap or other suitable method. The vacuum shall be measured on the top of the Reactor tank and should be less than 1mbar.
- c) 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.
- d) 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.

## e) Oil treatment plant

The Ultra High Vacuum type oil treatment plant (on returnable basis) of suitable capacity (**minimum 6000** litres per hour) shall be arranged by the contractor at his own cost for treatment of oil in EHV class Reactor in order to achieve properties of treated oil. The plant shall be capable of treatment of oil at rated capacity on single pass basis as follows:

- i) Removal of moisture from 100 ppm to 3 ppm (max.)
- ii) Removal of dissolved gas content from 10% by Vol. to 0.1% by vol.
- iii) Improvement of dielectric strength break down voltage from 20 to 70 KV
- iv) 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.
- v) Filter shall be capable of removing particle size more than 0.5 micron in the filtered oil.
- vi) Processing temperature shall be automatically controlled and have an adjustable range from 40°C to 80°C.

## f) 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, in view of risk involved in balk storage, pilferage and fire hazard. In case this oil is not filled in reactor due to delay in commissioning, same oil shall be used only after testing and ensuring that oil parameters are well within the specified limits.

Insulating oil shall be delivered to the site in returnable oil drums / flexi bag





/ stainless steel 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.

## 10. Spare Reactor Units Storage & Connection Arrangement

Detail procedure for storage of spare reactor unit with and without **isolator switching arrangement** is enclosed at **Annexure-R**.

## 11. Bushings

- 11.1. 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 IEC: 60137/DIN 42530. All details of the bushing shall be submitted for approval and design review.
- 11.2. Bushing for voltage of 145 kV and above shall be RIP (Resin Impregnated paper) condenser type with composite polymer insulator (housing) or RIS (Resin Impregnated Synthetic) condenser type with composite polymer insulator (housing). 52kV Bushing shall of porcelain or composite polymer housing and hermetically sealed Oil filled condenser type or RIP (Resin Impregnated paper) condenser type with composite polymer insulator (housing) or RIS (Resin Impregnated Synthetic) condenser type with composite polymer insulator (housing). 36 kV and below rating bushing shall be solid porcelain or oil communicating type.
- 11.3. RIP/RIS type bushing 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.
- 11.4. 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)
- 11.5. Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.



- 11.6. Bushings of identical rating of different makes shall be interchangeable to optimise the requirement of spares. Mounting dimensions of bushing shall be as approved by employer.
- 11.7. 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.
- 11.8. Polymer / composite insulator shall be seamless sheath of a silicone rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environmental 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 IEC 60815-

3. The weather sheds 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 silicone 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)

- 11.9. Clamps and fittings shall be of hot dip galvanised/stainless steel.
- 11.10. Bushing turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay.



- 11.11. No arcing horns shall be provided on the bushings.
- 11.12. 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. In case of RIP bushing with polymer housing, Bushing oil end portion 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. 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.
- 11.13. The terminal marking and their physical position shall be as per IEC: 60076.
- 11.14. Tan delta at variable frequency (in the range of 20 Hz to 350 Hz) shall be carried out on each condenser type bushing (OIP & RIP) at reactor manufacturing works / bushing manufacturing works as routine test before despatch and the result shall be compared at site during commissioning to verify the healthiness of the bushing.
- 11.15. Tan  $\delta$  value of RIP / RIS condenser bushing shall be 0.005 (max.) in the temperature range of 20°C to 90°C. The measured Tan  $\delta$  value at site of in-service bushing should not exceed by 0.001 w.r.t. factory results (measured at approx. similar temperature conditions) during warrantee period.

Tan delta value of OIP Bushing shall be 0.004 (Max) measured at ambient temperature. The measured Tan  $\delta$  value at site of in-service bushing should not exceed by 0.001 w.r.t. factory results during warrantee period.

## **12. Neutral Formation and Earthing Arrangement.**

### **12.1. For 1-Phase Unit (if specified in BPS)**

The contractor shall connect the neutrals of three (3) 1-phase reactor by overhead connection using IPS Al tube / Cable of suitable size. The neutral formation shall be such that neutral winding of single-phase spare reactor can be disconnected or connected to the three phase banks. The connection from the neutral bushing to neutral bus shall be through IPS Al tube / cable of suitable size and wherever flexible jumper needs to be provided, same shall be through twin conductor. All material like Bus post insulator, Aluminium tube, conductor, clamps & connectors, earthing materials, support structure, hardware etc. required for neutral formation and connection with neutral CT and earthing of neutral shall be provided.

### **12.2. For 3-Phase Unit:**

The neutral of the shunt reactor shall be brought out through neutral bushing. The Contractor shall provide Aluminium clamps & connectors suitable for conductor between neutral of the shunt reactor, surge arrester



and the neutral grounding reactor (NGR) as applicable.

- 12.3. The neutral of shunt reactor shall be grounded either directly or through a neutral grounding reactor (NGR) as the case may be. The neutral terminal of Reactors and NGR 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) earthing copper conductor connected to Employer's grounding mat.

### **13. Cooling Equipment**

- 13.1. The reactor shall be designed for Oil Natural Air Natural Cooling (ONAN)
- 13.2. The radiator bank of the shunt reactor shall be either tank 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. earthing copper conductor.
  - (e) Thermometer pockets with captive screw caps at cooler inlet and outlet.
  - (f) Lifting lugs
- 13.4. Each radiator bank (tank mounted) 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 for separately mounted radiator bank.
- 13.5. If radiators are directly mounted on tank, sufficient number of thermometer pockets fitted with captive screw cap on the inlet and outlet of tank side pipe of radiators shall be provided to record temperature during temperature rise test.
- 13.6. 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.

### **14. Valves**

- 14.1. 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.
- 14.2. Suitable means shall be provided for locking the valves in the open and



close positions. Provision is not required for locking individual radiator valves.

- 14.3. Each valve shall be provided with the indicator to show clearly the position of the valve.
  - 14.4. All valves flanges shall have machined faces.
  - 14.5. All valves in oil line shall be suitable for continuous operation with Reactor oil at 115 deg C.
  - 14.6. Gland packing/gasket material shall be of “O” ring of nitrile rubber for all the valve’s flanges. All the flanges shall be machined.
  - 14.7. 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.
- a) Valves or other suitable means shall be provided to fix various online monitoring systems to facilitate continuous monitoring.

Type of valves shall be used for Reactor as per following table. The location, size of valves for other application shall be finalised during design review.

| Sr. No. | Description of Valve                           | Type            |
|---------|--|-----------------|
| 1       | Drain Valve                                    | Gate            |
| 2       | Filter valve                                   | Gate            |
| 3       | Sampling Valve                                 | Globe           |
| 4       | Radiator isolation valve                       | Butterfly       |
| 5       | Buchholz relay isolation valve                 | Gate            |
| 6       | Sudden pressure relay                          | Gate            |
| 7       | Valve for vacuum application on Tank           | Gate            |
| 8       | Conservator Drain valve                        | Gate            |
| 9       | Aircell equalizing valve                       | Gate/Globe/Ball |
| 10      | Valve for Conservator vacuum (top)             | Gate            |
| 11      | Valve for N2 injection (NIFPS) (If applicable) | Gate            |
| 12      | Valve for NIFPS Drain (if applicable)          | Gate            |

- b) 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.
- 14.8. All hardware used shall be hot dip galvanised / stainless steel.
- 14.9. **Flow sensitive conservator Isolation valve**
- a) In order to restrict the supply of oil in case of a fire in Reactor, flow sensitive valve shall be provided to isolate the conservator oil from the main tank. The valve shall be flow sensitive and shut off when the flow in the pipe is more than the flow expected in the permissible normal operating conditions. It shall not operate when oil pumps are switched



on or off. This valve shall be located in the piping between the conservator and the buchholz relay and shall not affect the flow of oil from and to the conservator in normal conditions.

- b) When the flow from conservator to main tank is more than the normal operating conditions, the valve shall shut off by itself and will have to be reset manually. It shall be provided with valve open/close position indicator along with alarm contact indication in control room during closing operation of valve. This valve shall be provided with locking arrangement for normal position and oil filling / filtration position. A suitable platform or ladder (if required) shall be provided to approach the valve for manual reset. 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.

14.10. 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.

14.11. All hardware used shall be hot dip galvanised / stainless steel.

## **15. Cabling**

15.1. Buchholz Relay, Magnetic Oil Level Gauge, Pressure Relief Device & Sudden pressure relay to be wired through unarmoured cable of 1.5 sq.mm (minimum), inside GI conduit, with no part exposed. Cable shall be protected by flexible stainless steel pipe, at both ends as per requirement. Proper sealing arrangement to be provided at both ends to avoid ingress of water.

The cross section of “control cable” shall be 1.5 sq.mm (minimum) except for CT circuits which should be 2.5 sq.mm (minimum).

All other cables shall be armoured type and shall be routed through covered cable tray or GI conduit and shall be properly dressed.

15.2. Cable terminations shall be through stud type TB and ring type lugs. All cables should be provided from approved sources with valid type test report. 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.

15.3. Cabling of spare unit with isolator switching arrangement 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 be brought in common marshalling box of all the banks. From CMB all the control, protection and indication signals of R, Y, B and Spare units shall be transferred to Purchaser's Control panels / SCADA. Change-over of spare unit signals with faulty unit shall be done through Purchaser's C & R panels / SCADA level.





**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 (for a bank of three single phase unit) Box shall be provided.
- 16.2. Common marshalling box shall be floor mounted and of size, not less than 1600 mm (front) X 650 mm (depth) X 1800 mm (height). Individual Marshalling Box and Cooler Control Box shall be tank mounted.
- 16.3. The Individual Marshalling Box, Common Marshalling Box, Junction box and all other outdoor cubicles shall be made of stainless-steel sheet of minimum grade of SS304 (SS 316 for coastal area) and of minimum thickness of 1.6 mm.
- 16.4. The degree of protection shall be IP: 55 for outdoor and IP: 43 for indoor in accordance with IS 13947/IEC: 60947.
- 16.5. 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.
- 16.6. 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.
- 16.7. 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 Marshalling box. All the CT secondary terminals in the 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 Employer's panel shall be wired upto the Common Marshalling box.
- 16.8. A space heater and cubicle lighting with ON-OFF switch shall be provided in each panel.
- 16.9. 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 Employer's approved scheme.
- 16.10. All the control circuit connections from Individual Marshalling Box and of three single phase units of a bank including spare reactor unit to Employers 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).

- 16.11. Details of station auxiliary power supply are mentioned in Chapter- GTR. Common marshalling box have following arrangement:
- 16.12. Two auxiliary power supplies, 400 volt, three phase four (4) wire shall be provided by the Employer at Common Marshalling Box (for Single Phase unit) or Marshalling Box (for Three Phase unit).
- 16.13. Suitably rated power contactors, MCBs/MCCBs as required for entire auxiliary power supply system including distribution to marshalling boxes, Online DGA monitoring system etc., shall be provided by contractor. For each circuit separate MCBs / MCCBs shall be provided in the Common Marshalling Box.
- 16.14. In case auxiliary power supply requirement is different than station auxiliary AC supply, then all necessary converters shall be provided by the Contractor. Auxiliary power supply distribution scheme shall be submitted for approval.
- 16.15. For 1-Ph Reactor Unit, 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.
- 16.16. All loads shall be fed by one of the two feeders through an electrically interlocked automatic transfer scheme housed in the common marshalling box. Design features of the transfer scheme 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 marshalling box 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. SCADA Integration**

- 17.1.1. All required power & control cables including optical cable, patch chord (if any) upto Common MB shall be in the scope of contractor. Further, any special cable between CMB to switchyard panel room/control room shall be under the present scope.
- 17.1.2. Fiber optic cable, power cable, control cables, as applicable, between CMB to switchyard panel room/control room and power supply (AC & DC) to MB and integration of above said IEC-61850 compliant equipment with Substation Automation System shall be under the scope of EPC contractor.



17.1.3. SCADA Integration of online monitoring equipment (**if applicable**):

All the online monitoring equipment i.e. Online Dissolved Gas (Multi-gas) and Moisture Analyser etc. provided for individual Reactor unit including Spare (if any), are IEC 61850 compliant (either directly or through a Gateway). The monitoring equipment are required to be integrated with SAS through managed Ethernet switch conforming to IEC 61850. This Ethernet switch shall be provided in IMB or CMB. The switch shall be powered by redundant DC supply (110V or as per available Station DC supply). Ethernet switch shall be suitable for operation at ambient temperature of 50 Deg C.

**18. Current Transformer (Bushing & Outdoor Neutral Current Transformer)**

18.1. Current transformers shall comply with IEC 61869 (part 1 & 2).

18.2. It shall be possible to remove the turret mounted current transformers 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.

18.3. Current transformer 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.

18.4. For 1-Phase Reactor, one number single phase current transformer (outdoor) 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.

18.5. Technical Parameters of Bushing CTs and Neutral CTs are enclosed at **Annexure – F**. 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. Bushing Current transformer parameters indicated in this specification are tentative and liable to change within reasonable limits. The Contractor shall obtain Employer's approval before proceeding with the design of bushing current transformers.

18.6. Secondary resistance and magnetising current characteristics of PX/PS class (protection) (as per IS or IEC) CT of same rating shall match. This is applicable for Neutral CT (outdoor) also and shall be reviewed during detail engineering.

**19. Surge Arrester**

**19.1. 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.



## 19.2. **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 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. 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.

## 19.3. **Constructional Features**

- a) 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.
- b) The reference current of the arrester shall be high enough to eliminate the influence of grading and stray capacitance on the measured reference voltage.
- c) The surge arresters shall be fitted with pressure relief devices and arc diverting parts suitable for preventing rupture of polymer housing and providing path for flow of rated fault currents in the event of arrester failure.
- d) 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.
- e) Seals shall be provided in such a way that these are always effectively maintained even when discharging rated lightning current.
- f) Outer insulator shall be polymer / composite insulator housing. Details specification of polymer/composite insulators are given in clause 11.7
- g) The end fittings shall be made of non-magnetic and corrosion proof material.
- h) The name plate shall conform to the requirement of IEC incorporating the year of manufacture.
- i) The arrester shall be supplied with suitable support structure either of tubular GI pipe or lattice steel galvanised.
- j) 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.



- k) Technical parameters of Surge Arrester is enclosed at **Annexure-G**

#### 19.4. **Fittings and Accessories**

- a) 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.
- b) 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.
- c) Suitable milli-Ammeter 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.
- d) Discharge counter and milli-ammeter shall be suitable for mounting on support structure of the arrester with minimum protection class IP 55.
- e) Grading/Corona rings shall be provided on each complete arrester unit as required for proper stress distribution.

#### 19.5. **Tests**

- a) The surge arresters shall conform to type tests and shall be subjected to routine tests as per IEC-60099-4.
- b) Surge arrester shall be subjected to additional acceptance tests.
  - (i) Polymer insulator test as per IEC 61462
  - (ii) Construction check (visual check)
  - (iii) Measurement of insulation resistance by 1kV megger.

#### 20. **Hand Tools (if specified in BPS)**

One set of hand tools of reputed make packed in a carry bag/box broadly comprising of double ended spanners (open jaws, cranked ring, tubular with Tommy bar each of sizes 9mm to 24mm, one set each), adjustable wrenches (8 & 12 inch one set), gasket punches (of different sizes used - 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), bushing handling



and lifting tools with nylon rope/belt, chain block (2 Nos.) and D-Shackle shall be supplied.

## **21. Test Kit (if specified in BPS)**

**BDV Kit as per Annexure-I of specification**

**Portable DGA Kit as per Annexure-J of specification**

## **22. Fittings**

The following fittings & accessories (as applicable) shall be provided with each Reactor & NGR covered in this specification. The fittings listed below are not exhaustive and other fittings, which are required for satisfactory operation of the Reactor, are deemed to be included.

### **22.1. Shunt Reactor**

- i) Conservator for main tank of reactor with aircell, isolating valves, drain valve, magnetic oil level gauge (with canopy) with potential free high and low oil level alarm contacts and prismatic oil level gauge and Condition Controlled Maintenance Free Type Breather.
- ii) Pressure relief devices with trip contact
- iii) Sudden pressure relief relay with alarm contact (for 400kV Reactor only)
- iv) Buchholz relay with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm / trip contacts.
- v) Air release plug
- vi) Conservator air cell rupture detection relay
- vii) Inspection openings and covers
- viii) Bushing of each type with metal parts and gaskets to suit the termination arrangement
- ix) Winding & Oil temperature indicators
- x) Cover lifting eyes, reactor lifting lugs, jacking pads, towing holes and core and winding lifting lugs
- xi) Rating and diagram plates on reactors and auxiliary apparatus
- xii) Roller Assembly (as per clause 7.4)
- xiii) Marshalling Box, Common Marshalling Box (applicable for 1-Ph unit), Fibre optic sensor box as applicable
- xiv) Cooling equipment
- xv) Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently
- xvi) Bushing Current Transformers, Neutral CT (if applicable)
- xvii) Terminal marking plates
- xviii) Valves schedule plate



- xix) Bottom oil sampling valve, Drain valves, Filter valves at top and bottom with threaded male adaptors, Shut off valves on the pipe connection between radiator bank and reactor tank, Shut off valves on both sides of Buchholz relay, Sampling gas collectors for Buchholz relay at accessible height, Valves for Radiators, Valve for vacuum application etc.
- xx) Suitable terminal connectors on bushings and surge arrester
- xxi) Ladder to climb up to the Reactor tank cover with suitable locking arrangement to prevent climbing during charged condition.
- xxii) 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 Reactor top.
- xxiii) Haulage lugs
- xxiv) Two earthing terminals each on shunt reactor tank, radiators & marshalling boxes, SA structures etc.
- xxv) Neutral bus connection arrangement (3-Phase Reactor)
- xxvi) Online Dissolved Gas (Multi- 8 gas) and Moisture Analyser (if specified in Chapter PSR) as per **Annexure-K**
- xxvii) Online Dissolved Gas (Multi- 4 gas) and Moisture Analyser (if specified in Chapter PSR) as per **Annexure-L**
- xxviii) Online Dissolved Gas (Multi- 4 gas) and Moisture Analyser (if specified in Chapter PSR) as per **Annexure-L**
- xxix) On Line Bushing monitoring system (if specified in BPS) as per **Annexure-N**
- xxx) Nitrogen Injection Type Fire Protection System (NIFPS) (if specified in BPS) as per **Annexure-O**
- xxxi) Oil Sampling Bottle & Oil Syringe (if specified in BPS) as per **Annexure- P**
- xxxii) Oil Storage Tank (if specified in BPS) as per **Annexure- Q**
- xxxiii) All Cables (Power, control and shielded / twisted pair for 4-20mA cable from Reactor MB, Cooler control cubicle, etc. (as applicable) to CMB (if applicable) shall be under the present scope. Any special cable if required to be included upto employer's C&R panel.
- xxxiv) Managed Ethernet switch, LIU patch cords etc. (if applicable). shall be provided in CMB/MB (as per clause 17). All IEC 61850 compliant signals from various monitoring equipment/accessories shall be wired upto the Ethernet switch.

## 22.2. NGR

- i) Conservator for NGR main tank with drain valve, isolating valve, vent pipe and prismatic oil level gauge.
- ii) Pressure relief devices with trip contact



- iii) Buchholz relay with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm / trip contacts.
- iv) Air release plug
- v) Inspection openings and covers
- vi) Bushings with metal parts and gaskets to suit the termination arrangement
- vii) Oil temperature indicators
- viii) Cover lifting eyes, reactor lifting lugs, jacking pads, towing holes and core and winding lifting lugs
- ix) Rating and diagram plates
- x) Roller Assembly (if applicable as per clause 7.4)
- xi) Marshalling Box (Tank mounted)
- xii) Cooling equipment as applicable
- xiii) Bushing Current Transformers, Neutral CT (if applicable)
- xiv) Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently
- xv) Terminal marking plates
- xvi) Valves schedule plate
- xvii) Bottom oil sampling valve with threaded male adaptors, Drain valves, Filter valves at top and bottom, shut off valves on both sides of Buchholz relay at accessible height, sampling gas collectors for Buchholz relay at accessible height, Valve for vacuum application etc.
- xviii) Suitable terminal connectors on bushings
- xix) Ladder to climb up to the tank cover with suitable locking arrangement to prevent climbing during charged condition.
- xx) Haulage lugs
- xxi) Two earthing terminals each on tank, marshalling boxes etc.

22.3. All hardware used shall be hot dip galvanised /stainless steel.

## **23. 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 Employer for necessary implementation. All accessories and components of reactor shall be purchased from approved sourced of Employer. All process tests, critical raw material tests and witness / inspection of these testing shall be carried out as per approved manufacturing quality plan (MQP) by Employer.

### **23.1. 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 carry out type & routine tests as per “**Annexure-B & Standard Test Procedure**”. Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the contractor.

23.2. **Type Tests on fittings:**

Type test reports of following Bushing & accessories shall be furnished by the contractor along with drawings.

- a) Bushing Type Test as per IEC:60137 for all voltage class (Seismic test on 400kV Bushings)
- b) Marshalling & Common Marshalling Box and other outdoor cubicle (IP-55)

23.3. **Pre-Shipment Checks at Manufacturer's Works**

- a) Check for inter-changeability of components of similar reactor for mounting dimensions.
- b) Check for proper packing and preservation of accessories like radiators, bushings, dehydrating breather, rollers, buchholz relay, control cubicle, connecting pipes, conservator etc.

23.3.1. Before dispatch of Reactor from factory, following impact recorder settings are to be implemented for graphical analysis:

- >1g: Start recording
- >2g: Warning
- >3g: Alarm

Further, drop-out setting shall be 1g and threshold setting shall be in the range of 3g to 10g.

23.3.2. Check for proper provision for bracing to arrest the movement of core and winding assembly inside the tank.

23.3.3. 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.

23.4. **Inspection and Testing at Site**



The Contractor shall prepare a detailed inspection and testing programme for field activities covering areas right from the receipt of material stage up to commissioning stage i.e. Field Quality Plan (FQP) and get approved from employer and shall follow the same. Testing of oil sample at site shall be carried out as per specification.

**23.5. Receipt and Storage Checks**

- a) Check and record condition of each package, visible parts of the reactor etc. for any damage.
- b) Check and record the gas pressure in the reactor tank as well as in the gas cylinder.
- c) Check and record reading of impact recorder at receipt and verify the allowable limits as per manufacturer's recommendations.

**23.6. Installation Checks**

- a) Visual check for wedging of core and coils before filling up with oil and also check conditions of core and winding in general.
- b) Check whole assembly for tightness, general appearance etc.
- c) Oil leakage test
- d) Capacitance and tan delta measurement of bushing before fixing/connecting to the winding, contractor shall furnish these values for site reference.
- e) Leakage check on bushing before erection.
- f) Measure and record the dew point of gas in the main tank before assembly.

**23.7. Commissioning Checks**

- a) Check the colour of silicagel breather.
- b) Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.
- c) Check the bushing for conformity of connection to the lines etc,
- d) 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 level indication
- e) Check for the adequate protection on the electric circuit supplying the accessories.



- f) Check resistance of all windings. Insulation resistance measurement for the following:
  - i) Control wiring
  - ii) Main windings
  - iii) Bushing Current Transformer
- g) 2 kV for 1 minute test between bushing CT terminal and earth.
- h) Check for cleanliness of the reactor and the surroundings
- i) Measure vibration and noise level
- j) Capacitance and Tan delta measurement of winding and bushing
- k) Frequency response analysis (FRA). FRA equipment shall be arranged by Employer.
- l) DGA of oil just before commissioning and after 24 hours energisation at site.
- m) Contractor shall prepare a comprehensive commissioning report including all commissioning test results and handover to Employer for future record.



**Annexure – A****1.0 Technical Particulars / Parameters of 245kV Shunt Reactor**

| Clause No. | Description  | Unit               | Parameters  |
|------------|--|--------------------|---|
| 2.1        | Rated Voltage, $U_r$ (1p.u)  | kV                 | 245   |
| 2.2        | Rated Capacity at 245 kV   | MVAR               | 25   50   |
| 2.3        | Standard   |                    | IEC 60076-6   |
| 2.4        | Connection (3 Phase)   |                    | Star  |
| 2.5        | Cooling System   |                    | ONAN  |
| 2.6        | Frequency  | Hz                 | 50  |
| 2.7        | No of Phases   |                    | 3 (THREE)   |
| 2.8        | Service  |                    | Outdoor   |
| 2.9        | System Fault Level   | kA                 | 50  |
| 2.10       | Permissible current unbalance among different phases   | %                  | $\pm 2$   |
| 2.11       | Crest value of Third Harmonic content in phase current at rated voltage with sinusoidal wave form                                    | %                  | $\leq 3\%$ of the crest value of fundamental  |
| 2.12       | Range of constant Impedance (However, complete saturation characteristics of the Reactors up to 2.5 p.u. Voltage shall be furnished) |                    | Up to 1.5 p.u. voltage (However, complete saturation characteristics of the Reactors up to 2.5 p.u. Voltage shall be furnished) |
| 2.13       | Tolerance on current   | %                  | 0 to +5%  |
| 2.14       | Ratio of zero sequence reactance to positive reactance ( $X_0/X_1$ )   | Range              | 0.9 - 1.0   |
| 2.15       | Temperature rise over 50 deg C Ambient Temp at rated voltage   |                    |   |
| a)         | Top oil measured by thermometer  | $^{\circ}\text{C}$ | 40  |
| b)         | Average winding measured by resistance method  | $^{\circ}\text{C}$ | 45  |
| c)         | Winding hot spot temperature rise over yearly weighted average temperature of 32 $^{\circ}\text{C}$                                  | $^{\circ}\text{C}$ | 61  |
| d)         | Max. tank surface temperature  | $^{\circ}\text{C}$ | 110   |
| 2.16       | Max. design Ambient temp   | $^{\circ}\text{C}$ | 50  |
| 2.17       | Windings   |                    |   |
| a)         | Lightning Impulse withstand Voltage  |                    |   |
|            | HV   | kV <sub>p</sub>    | 950   |
|            | Neutral  | kV <sub>p</sub>    | 170   |
|            | Chopped Wave Lightning Impulse Withstand Voltage   |                    |   |
|            | HV   | kV <sub>p</sub>    | 1430  |
| b)         | Switching Impulse withstand Voltage  |                    |   |
|            | HV   | kV <sub>p</sub>    | 750   |
| c)         | Power Frequency withstand Voltage  |                    |   |
|            | Line   | kV <sub>rms</sub>  | 395   |



| Clause No. | Description  | Unit              | Parameters   |   |
|------------|--|-------------------|--|---|
|            | Neutral  | kV <sub>rms</sub> | 70   |   |
| d)         | Tan delta of windings  |                   | < 0.005  |   |
| 2.18       | Bushing  |                   |  |   |
| a)         | Rated voltage  |                   |  |   |
|            | HV   | kV                | 145  |   |
|            | Neutral  | kV                | 36   |   |
| b)         | Rated current (Min.)   |                   |  |   |
|            | HV   | A                 | 1250   |   |
|            | Neutral  | A                 | 800  |   |
| c)         | Lightning Impulse withstand Voltage                              |                   |  |   |
|            | HV   | kVp               | 1050   |   |
|            | Neutral  | kVp               | 170  |   |
| d)         | Switching Impulse withstand Voltage                              |                   |  |   |
|            | HV   | kVp               | 850  |   |
| e)         | Power Frequency withstand Voltage                                |                   |  |   |
|            | HV   | kVrms             | 505  |   |
|            | Neutral  | kVrms             | 77   |   |
| f)         | Minimum total creepage distances                                 |                   |  |   |
|            | HV   | mm                | 7595   |   |
|            | Neutral  | mm                | 1116   |   |
| h)         | Partial discharge level at U <sub>r</sub>                        |                   |  |   |
|            | HV   | pC                | < 10   |   |
| 2.19       | Max. Partial discharge level at 1.58 U <sub>r</sub> / $\sqrt{3}$ | pC                | 100  |   |
| 2.20       | Vibration and Tank stress level at rated voltage and frequency   |                   | Max : $\leq 200$ microns peak to peak<br>Average: $\leq 60$ microns peak to peak.<br>Stress: $\leq 2.0$ kg/sq.mm at any point on tank. |   |
| 2.21       | Maximum Noise level at rated voltage and frequency               | dB                | 75   |   |
| 2.22       | Maximum Permissible Losses of Reactor                            |                   | Maximum Total Load Loss at rated Voltage, Frequency and at 75° C (kW)  | Max. I <sup>2</sup> R Loss at rated current and frequency and at 75°C |
| i)         | 25MVAR, 245kV 3-Ph Reactor                                       | kW                | 50   | 28  |
| ii)        | 50MVAR, 245kV 3-Ph Reactor                                       | kW                | 80   | 45  |



## Annexure -B Test Plan

| No. | Item  | Test Category |
|-----|---|---------------|
| 1.  | Measurement of winding resistance   | Routine       |
| 2.  | Reactance and loss measurement<br>(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.  | Core assembly dielectric and earthing continuity test   | Routine       |
| 7.  | High voltage withstand test on auxiliary equipment and wiring after assembly  | Routine       |
| 8.  | Chopped wave lightning impulse test for the line terminals (LIC)  | Routine       |
| 9.  | Lightning impulse test on Neutral   | Routine       |
| 10. | Switching impulse test  | Routine       |
| 11. | Applied voltage test (AV)   | Routine       |
| 12. | Induced Over Voltage Test with Partial Discharge Measurement  | Routine       |
| 13. | Gas-in-oil analysis   | Routine       |
| 14. | 2-Hour excitation test except type tested unit  | Routine       |
| 15. | Vibration & stress measurement in Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units<br>(Measurement shall also be carried out at 1.05Um for reference only on one unit of each type ) | Routine       |
| 16. | Measurement of mutual reactance on 3-phase reactor  | Routine       |
| 17. | Temperature rise test   | Type          |
| 18. | Measurement of harmonic content of current ( Measured in Cold state)  | Type          |
| 19. | Measurement of acoustic noise level (Measured in Cold and Hot state of temperature rise test )  | Type          |
| 20. | Knee point voltage measurement of reactor (Measured in Cold state)  | Type          |
| 21. | Measurement of zero-sequence reactance ( Applicable for three phase shunt reactor only)   | Type          |
| 22. | Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports )   | Routine       |
| 23. | Appearance, construction and dimension check  | Routine       |
| 24. | Oil leakage test on Reactor tank  | Routine       |
| 25. | Tank vacuum test  | Routine       |
| 26. | Tank pressure test  | Routine       |

| Test on NGR                       |         |
|-----------------------------------|---------|
| Item                              | Test    |
| Measurement of winding resistance | Routine |



|   |         |
|---|---------|
| Measurement of Impedance by V/I   | Routine |
| Measurement of insulation resistance  | Routine |
| Measurement of Capacitance & Tan delta of winding insulation to earth and     | Routine |
| Lightning impulse test  | Routine |
| Separate source voltage withstand test  | Routine |
| Isolation Test  | Routine |
| Oil leakage test  | Routine |
| Appearance, construction and dimension check                                  | Routine |
| High voltage with stand test on auxiliary equipment and wiring after assembly | Routine |
| Tank Vacuum test  | Routine |
| Tank Pressure test  | Routine |





**Annexure –C**  
**Design Review Document for Shunt Reactor**

| <b>Sr. No.</b> | <b>Description</b>  |
|----------------|---|
| 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   |

Note: Design review document for NGR shall be decided during detailed engineering.



## Annexure – D

## 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 (30-40µm)   | Epoxy high build Micaceous iron oxide (HB MIO) (75µm) | Aliphatic polyurethane (PU) (Minimum 50µm) | Minimum 155µm                  | 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 30µm                   | Glossy white for paint   |
| Radiator (external surfaces)   | Chemical / Shot Blast cleaning Sa 2 ½* | Epoxy base Zinc primer (30-40µm)   | Epoxy base Zinc primer (30-40µm)                      | PU paint (Minimum 50µm)                    | Minimum 100µm                  | Matching shade of tank/ different shade aesthetically matching to tank |
| <b>contractor may also offer Radiators with hot dip galvanised in place of painting with minimum thickness of 40µm (min)</b> |  |  |   |  |                                |  |
| 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 – E

## UNUSED INHIBITED HIGH GRADE INSULATING OIL PARAMETERS

| Sl. No.  | Property  | Test Method  | Limits  |
|----------|---|--|---|
| <b>A</b> | <b>Function</b>   |  |   |
| 1a.      | Viscosity at 40degC   | IS 1448 Part 25 or ISO 3104 or ASTM D7042  | (Max.)12 mm <sup>2</sup> /s   |
| 1b.      | Viscosity at -30degC  |  | (Max.)1800 mm <sup>2</sup> /s   |
| 2.       | Appearance  | A representative sample of the oil shall be examined in a 100 mm thick layer, at ambient temperature | The oil shall be clear and bright, transparent and free from suspended matter or sediment                                       |
| 3.       | Pour point  | IS 1448 Part 10/Sec 2 or ISO 3016  | (Max.) - 40degC   |
| 4.       | Water content<br>a) for bulk supply<br>b) for delivery in drums             | IEC 60814  | (Max.)<br>30 mg/kg<br>40 mg/kg  |
| 5.       | Electric strength (breakdown voltage)                                       | IS 6792 or IEC 60156   | (Min.) 50kV (new unfiltered oil) / 70 kV (after treatment)  |
| 6.       | Density at 20 deg C   | IS 1448 Part 16 or ISO 12185 or ISO 3675 or ASTM D7042   | Max 0.895 g/ml  |
| 7.       | Dielectric dissipation factor (tan delta) at 90 deg C                       | IS 16086 or IEC 60247 or IEC 61620   | (Max) 0.0025  |
| 8.       | Negative impulse testing KVp @ 25 deg C                                     | ASTM D-3300  | 145 (Min.)  |
| 9.       | Carbon type composition (% of Aromatic, Paraffins and Naphthenic compounds) | IEC 60590 and IS 13155 or ASTM D 2140  | Max. Aromatic:<br>4 to12 %<br>Paraffins: <50%<br>& balance Naphthenic compounds.  |
| <b>B</b> | <b>Refining/Stability</b>   |  |   |
| 1.       | Colour  | ISO 2049   | L0.5 (less than 0.5)  |
| 2.       | Acidity   | IEC 62021-2 or 62021-1   | (Max) 0.01 mg KOH/g   |
| 3.       | Interfacial tension at 27degC   | IEC 62961 or ASTM D971   | 0.043 N/m (min)   |
| 4.       | Total sulphur content   | ISO 14596 or ISO 8754  | 0.05 % (Max.)<br>(before oxidation test)  |
| 5.       | Corrosive sulphur   | DIN 51353  | Not-Corrosive   |
| 6.       | Potentially corrosive sulphur   | IEC 62535  | Not-Corrosive   |
| 7.       | DBDS  | IEC 62697-1  | Not detectable (< 5 mg/kg)  |
| 8.       | Presence of oxidation inhibitor   | IS 13631 or IEC 60666  | 0.08% (Min.) to 0.4% (Max.)<br>Oil should contain no other additives.<br>Supplier should declare presence of additives, if any. |
| 9.       | Metal passivator additives  | IEC 60666  | Not detectable (<5 mg/kg)   |



|   |  |  |  |
|---|--|--|--|
| 10.   | 2-Furfural content and related compound content  | IS 15668 or IEC 61198  | Not detectable (<0.05 mg/kg) for each individual compound  |
| 11.   | Stray gassing under thermooxidative stress   | Procedure in Clause A.4 of IEC 60296-2020 (oil saturated with air) in the presence of copper | Non stray gassing:<br>< 50 µl/l of hydrogen (H2) and < 50 µl/l methane (CH4) and < 50 µl/l ethane (C2H6) |
| C   | Performance  |  |  |
| 1.  | Oxidation stability  | IEC 61125 (method c)<br>Test duration 500 hour   |  |
| 2.  | Total acidity*   | 4.8.4 of IEC 61125:2018  | 0.3 mg KOH/g (Max.)  |
| 3.  | Sludge*  | 4.8.1 of IEC 61125:2018  | 0.05 % (Max.)  |
| 4.  | Dielectric dissipation factor (tan delta) at 90degC  | 4.8.5 of IEC 61125:2018  | 0.05 (Max.)  |
|   | *values at the end of oxidation stability test   |  |  |
| D   | Health, safety and environment (HSE)   |  |  |
| 1.  | Flash point  | IS 1448 Part 21 or ISO 2719  | (Min.)135deg C   |
| 2.  | PCA content  | IP 346   | < 3%   |
| 3.  | PCB content  | IS 16082 or IEC 61619  | Not detectable (< 2 mg/kg)   |
| E   | Oil used (inhibited) for first filling, testing and impregnation of active parts at manufacturer's works shall meet parameters as mentioned below: |  |  |
| 1   | Break Down voltage (BDV)   |  | 70kV (min.)  |
| 2   | Moisture content   |  | 5 ppm (max.)   |
| 3   | Tan-delta at 90°C  |  | 0.005 (max)  |
| 4   | Interfacial tension  |  | 0.04 N/m (min)   |
| F   | Each lot of the oil shall be tested prior to filling in main tank at site for the following:   |  |  |
| 1   | Break Down voltage (BDV)   |  | 70 kV (min.)   |
| 2   | Moisture content   |  | 5 ppm (max.)   |
| 3   | Tan-delta at 90°C  |  | 0.0025 (Max)   |
| 4   | Interfacial tension  |  | 0.04 N/m (min)   |
| G   | After filtration & settling and prior to energisation at site oil shall be tested for following:   |  |  |
| 1   | Break Down voltage (BDV)   |  | 70 kV (min.)   |
| 2   | Moisture content at hot condition  |  | 5 ppm (max.)   |
| 3   | Tan-delta at 90°C  |  | 0.005 (Max)  |
| 4   | Interfacial tension  |  | More than 0.04 N/m   |
| 5   | *Oxidation Stability   |  |  |
|   | a) Acidity   |  | 0.3 (mg KOH /g) (max.)   |
|   | b) Sludge  |  | 0.05 % (max.)  |
|   | c) Tan delta at 90 °C  |  | 0.05 (max.)  |
| 6   | *Total PCB content   |  | Not detectable (less than 2 mg/kg total)   |
| * Separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of EMPLOYER. |  |  |  |
| Note: Supplier shall declare the chemical family and function of all additives and the concentrations in the                          |  |  |  |



cases of inhibitors, antioxidants and passivators.



**Annexure – F****Technical Parameters of Current Transformers -- 245 kV Shunt Reactor On each phase connection**

| <b>(a) Ratio</b>   |   |  |                                   |
|--|---|--|-----------------------------------|
|  | Line Side                               | Neutral Side                                 | Common Neutral Side               |
| CORE 1   | 200/1A                                  | 200/1A                                       | 200/1A                            |
| CORE 2   | 200/1A                                  | 200/1A                                       | -                                 |
| CORE 3   | 200/1A                                  | 200/1A                                       | -                                 |
| CORE 4   | -                                       | To be decided by contractor for WTI          | -                                 |
| <b>(b) Minimum knee point voltage or burden and accuracy class</b> |   |  |                                   |
| CORE 1   | 200V, PX / PS Class                     | 10 VA, 1.0                                   | 200V, PX / PS Class               |
| CORE 2   | 200V, PX / PS Class                     | 200V, PX / PS Class                          | -                                 |
| CORE 3   | 200V, PX / PS Class                     | 200V, PX / PS Class                          | -                                 |
| CORE 4   | -                                       | To be decided by contractor for WTI          | -                                 |
| <b>(c) Instrument security factor (max.)</b>                       |   |  |                                   |
| CORE 1   | -                                       | 20   | -                                 |
| CORE 2   | -                                       | -  | -                                 |
| CORE 3   | -                                       | -  | -                                 |
| CORE 4   | -                                       | -  | -                                 |
| <b>(d) Maximum CT Secondary Resistance</b>                         |   |  |                                   |
| CORE 1   | 1 Ohm                                   | -  | 1 Ohm                             |
| CORE 2   | 1 Ohm                                   | 1 Ohm  | -                                 |
| CORE 3   | 1 Ohm                                   | 1 Ohm  | -                                 |
| CORE 4   | -                                       | -  | -                                 |
| <b>(e) Exciting current(max.) at 50V</b>                           |   |  |                                   |
| CORE 1   | 60mA                                    | -  | 60mA                              |
| CORE 2   | 60mA                                    | 60mA   | -                                 |
| CORE 3   | 60mA                                    | 60mA   | -                                 |
| CORE 4   | -                                       | -  | -                                 |
| <b>(f) Application</b>   |   |  |                                   |
| CORE 1   | Differential protection(High impedance) | Metering                                     | Restricted earth fault protection |
| CORE 2   | Restricted earth fault protection       | Restricted earth fault                       | -                                 |
| CORE 3   | Backup impedance protection             | Differential protection(High impedance)      | -                                 |
| CORE 4   | -                                       | Winding temp. Indication (on one phase only) | -                                 |

**Note:**

- For PX / PS class CT's, Dimensioning parameter "K", Secondary VA shall be considered 1.5 and 20 respectively.
- Rated continuous thermal current rating shall be 200% of rated primary current.
- Parameters of WTI CT for each winding shall be provided by the contractor.
- For estimation of spares, one set of CTs shall mean one CT of each type used in Reactor & NGR.
- 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.

vi) In case of single phase reactor, Common Neutral Side shall be out door type.

vii) reactor, Common Neutral Side shall be out door type.





**ANNEXURE - G****Gapless Surge Arrester – Technical parameters**

| <b>Clause No.</b> | <b>Description</b>  | <b>Parameters</b>                     |
|-------------------|---|---------------------------------------|
| <b>a.</b>         | Rated arrester voltage  | 120 kV                                |
| <b>b.</b>         | Rated system voltage  | 145 kV                                |
| <b>c.</b>         | Rated system frequency  | 50Hz                                  |
| <b>d.</b>         | System neutral earthing   | Earthed through NGR                   |
| <b>e.</b>         | Installation  | Outdoor                               |
| <b>f.</b>         | Nominal discharge current   | 10kA of 8/20 microsec wave.           |
| <b>g.</b>         | Class of arrester   | 10kA heavy duty type                  |
| <b>h.</b>         | Minimum discharge capacity  | 3.5 kJ/kV (referred to rated voltage) |
| <b>i.</b>         | Continuous operating voltage at 50°C                                      | 102 kV                                |
| <b>j.</b>         | Maximum switching surge residual voltage (1kA)                            | 280kVp                                |
| <b>k.</b>         | Maximum residual voltage at   |                                       |
|                   | i) 10kA   | 320kVp                                |
|                   | ii) 20kA nominal discharge current  | 340kVp                                |
| <b>l.</b>         | Long duration discharge class   | 2                                     |
| <b>m.</b>         | High current short duration test value (4/10micro-sec.wave)               | 100kAp                                |
| <b>n.</b>         | Current for pressure relief test  | 40kArms                               |
| <b>o.</b>         | Low current long duration test value (2000microsec.)                      | 1000Apeak                             |
| <b>p.</b>         | Min. total creepage distance  | 3625 mm.                              |
| <b>q.</b>         | One minute dry power frequency withstand voltage of arrester housing      | 275kVrms                              |
| <b>r.</b>         | Impulse withstand voltage of arrester housing with 1.2/50 micro-sec. wave | + 650KVp                              |
| <b>s.</b>         | Pressure relief class   | A                                     |
| <b>t.</b>         | RIV at 92 kVrms.  | Less than 500microvolts               |
| <b>u.</b>         | Partial discharge at 1.05 continuous over voltage                         | Not more than 50pC                    |
| <b>v.</b>         | Seismic acceleration  | As specified in section project       |
| <b>w.</b>         | Reference ambient temperature   | 50 deg C                              |



## ANNEXURE - H

### On load Tap Changing Equipment for Variable Shunt Reactor (If specified at Chapter-PSR & respective BPS)

#### 1. General

The Variable Shunt Reactor (VSR) shall be equipped with a Vacuum type on-load tap changing equipment to regulate the consumed reactive power.

In order to make easier the design and manufacturing of the regulation windings and, on the other hand, to minimize the number of required steps of OLTC in compliance with the commercially available maximum rated step voltage, rated through current and rated switching capacity, it is accepted that the reactive power of the steps can be different depending on tap changer position.

Tapping shall cover range of 40% to 100% and shall not be higher than 33 steps. Percentage variation of each tap shall be decided by manufacturer based on availability of suitable OLTC.

Type of regulation shall be coarse/fine with limited range of regulation. The on load tap changer shall be of motor operated type. The driving motor shall be of adequate type, supplied by 400/230 V, 50 Hz, complete with adequate mechanical and electrical protection, circuit breaker, limit switch, auxiliary contacts, monitoring equipment, etc.

Tap changer, shall consist of a gradient tap selector switch with vacuum interrupter and driving mechanism, position indicators and control devices, complete with all accessories. It shall be designed according to same requirements as respective for the main shunt reactor elements.

OLTC shall be of the type to allow for installing of instrument current transformers inside the tank for differential protection purposes.

OLTC shall have VSR redundant rated current and step voltage and redundant insulation level to ground. The insulation level to ground of the OLTC shall be chosen by the bidder as deemed adequate for the proposed type of regulation, but in any case, the class shall be not lower than that for highest voltage for equipment with test voltages as per the IEC Standards.

OLTC shall comply with IEC 60214 and shall have the below specified characteristics.

The power part of the tap changer unit (diverter switch) will be housed in the main tank but in separate compartments, connected via an oil surge relay to a separate conservator section, without any impact to the oil of the main VSR tank with the windings and with lowest interference in other VSR parts.

The operation of the diverter switches shall be of stored energy and quick release type. The energy storage shall be possible by means of both a hand crank and a 3-phase motor. Use of blade springs will not be accepted. The motor control shall be both remote and local.



Tap selectors may be housed in the main tank. In any case the tap selector shall not be housed in the compartment of the diverter switch. The driving mechanism, local controls and protections shall be housed in a weather-proof, vermin-proof cabinet, ventilated and protected as per, degree IP 55. When the doors of the motor drive unit are opened no voltage-carrying components could be accessible to be touched. The cabinet, equipped with hinged door and provided with padlock facility, with transparent window to see the mark of mechanical position indicator, shall be mounted on a transformer wall and shall comprise:

- totally enclosed driving motor 3-phase, 400 V AC, 50 Hz,
- operating contactors,
- step-by-step interlocks,
- protection breaker with magnetic and thermal over current protection and auxiliary contact wired to terminal board,
- mechanical and electrical end stops,
- local tap position indicator (mechanical),
- local control push buttons or switches,
- auxiliary relays actuated by above push buttons/switches, ensuring full operation of contacts and interlock between rise/lower operations,
- equipment for actuating remote tap position,
- tap position indicator should be supplied loose,
- convenience outlet rated 10 A,
- space heater controlled by a thermostat,
- terminal blocks for all wiring in the cabinet,
- internal lighting,
- terminals allowing connecting of remote controls,
- removable emergency manual operation handle, interlocked with motor control with suitable reduction gear,
- six-digit operation counter.

Tap changer oil expansion tank shall be pipe connected to the power part of the diverter switch. Connecting pipe shall be installed through a separate protection relay. Closing valve in the pipe must be placed on the oil expansion tank side of the oil flow relay. Oil expansion tank compartment must be equipped with its own magnetic oil level measuring device, having a low oil level alarm indication, a charging valve, drainage valve and air dryer in the eye level.

OLTC shall be able to carry out 300,000 switching operations before requiring any maintenance such as greasing of driving mechanism. First maintenance will be required after 300,000 tap changing/switching operations. Change of vacuum interrupter cells shall not be necessary before 600,000 switching operations.

The tap changer shall be designed to withstand same short circuit current and testing voltages as required for the VSR, in any position of the switch.

The maximum operating current at which the tap changer can successfully change taps shall be at least 20 % higher than the highest VSR winding current.

Provisions shall be made to enable hand operation in emergency cases. Motor and hand operation shall be interlocked and protected. The motor operating system shall



be equipped with control system TAPGUARD 260. The control system of OLTC shall provide data to on- line monitoring system

The tap changer operation shall start on the raise or lower after control impulse of short duration and shall complete the step by itself. The longer duration of the control impulse shall not initiate a second operation.

Control panel shall be provided with REMOTE/LOCAL switch and with raise - lower pushbuttons. Tap position indication shall be provided with BCD coding device, signal shall be used for remote indication on the control and protection cubicles in the appertained relay house. Position indicator scale shall be designed in a way that in the »1« position, all windings of the HV winding are included.

In addition to the above, the following two important OLTC-stresses resulting from the arrangement and pertaining to the reactor design have to be checked:

Time span for changing between different reactor power tap positions (power settings) (s)

- a) maximum to minimum position,
- b) maximum to mid position,
- c) minimum to mid position.

Motor drive unit

- a) manufacturer,
- b) type,
- c) motor voltage.

Option: The following equipment shall be supplied loose for mounting in control switchboard:

- tap position indicator (digital type),
- local/remote change over switch,
- lower/raise control switch,
- automatic voltage regulator for individual control of the unit involved, actuated by a voltage input provided by the Customer not included in supply (ratio and burden to be informed in the order).

## References

The selection of a particular OLTC will render optimum technical and economical efficiency if requirements due to operation and testing of all conditions of the associated reactor windings are met. In general, usual safety margins may be neglected in case when OLTC was designed, tested, selected and operated in accordance with the following IEC standards:

- IEC 60214–1, Tap-Changers, Part 1: Performance requirements and test methods,
- IEC 60214–2, Tap-Changers, Part 2: Application Guide.

## **1.1. ON Load Tap Changing (OLTC) Equipment**

### **1.1.1. Main OLTC Gear Mechanism**

1.1.1.1. Each three phase Reactor shall be provided with voltage control equipment of the tap

changing type for varying its effective transformation ratio whilst the Reactors are on load.

- 1.1.1.2. OLTC shall be motor operated suitable for local as well as remote operation. The diverter switch or arcing switch shall be designed so as to ensure that its operation once commenced shall be completed independently of the control relays or switches, failure of auxiliary supplies etc. To meet any contingency which may result in incomplete operation of the diverter switch, adequate means shall be provided to safeguard the Reactor and its ancillary equipment. The current diverting contacts shall be housed in a separate oil chamber not communicating with the oil in main tank of the Reactor. The contacts shall be accessible for inspection without lowering oil level in the main tank and the contacts shall be replaceable.
- 1.1.1.3. Necessary safeguards shall be provided to avoid harmful arcing at the current diverting contacts in the event of operation of the OLTC gear under overload conditions of the Reactor.
- 1.1.1.4. The OLTC oil chamber shall have oil filling and drain valve, oil sampling valve, relief vent and level glass. Oil sampling valve of minimum size, accessible from ground, shall be provided to take sample of oil from the OLTC chamber. It shall also be fitted with an oil surge relay which shall be connected between OLTC oil chamber and OLTC conservator tank.

#### 1.1.2. **Local OLTC Control Cabinet (Drive Mechanism Box)**

Each Reactor unit of OLTC gear shall have following features:

- 1.1.2.1. OLTC shall be suitable for manually handle operated and electrically motor operated. For local manual operation from Local OLTC Control cabinet (Drive Mechanism Box), an external handle shall be provided.
- 1.1.2.2. OLTC's Local control cabinet shall be mounted on the tank in accessible position. The cranking device/handle for manual operation for OLTC gear shall be removable and suitable for operation by a man standing at ground level. The mechanism shall be complete with the following:
  - Mechanical tap position indicator which shall be clearly visible from near the Reactor.
  - mechanical operation counter of at least five digits shall be fitted to indicate the number of operations completed and shall have no provision for resetting.
  - Mechanical stops to prevent over-cranking of the mechanism beyond the extreme tap positions.
  - The manual control considered as back up to the motor operated on load tap changer control shall be interlocked with the motor to block motor start-up during manual operation.
  - The manual operating mechanism shall be labelled to show the direction of operation for raising the voltage and vice-versa.
  - An electrical interlock to cut-off a counter impulse for reverse step change being initiated during a progressing tap change and until the mechanism comes to rest and resets circuits for a fresh position.



- 1.1.2.3. For electrical operation from local as well as remote, motor operated mechanism shall be provided. It shall not be possible to operate the electric drive when the manual operating gear is in use. It shall not be possible for any two controls to be in operation at the same time. Transfer of source in the event of failure of one AC supply shall not affect the tap changer. Thermal device or other means shall be provided to protect the motor and control circuit.
- 1.1.2.4. The Local OLTC Drive Mechanism Box shall house all necessary devices meant for OLTC control and indication. It shall be complete with the followings:
- i. A circuit breaker/contactors with thermal overload devices for controlling the AC Auxiliary supply to the OLTC motor
  - ii. Emergency Push Button to stop OLTC operation
  - iii. Cubicle light with door switch
  - iv. provided with anti-condensation metal clad heaters to prevent condensation of moisture
  - v. Padlocking arrangement for hinged door of cabinet
  - vi. All contactors relay coils and other parts shall be protected against corrosion, deterioration due to condensation, fungi etc.
  - vii. The cabinet shall be tested at least IP 55 protection class.
- 1.1.2.5. All relays and operating devices shall operate correctly at any voltage within the limits specified in Section - GTR. In case auxiliary power supply requirement for OLTC DM Box is different than station auxiliary AC supply, then all necessary converters shall be provided by the Contractor.
- 1.1.2.6. Operating mechanism for on load tap changer shall be designed to go through one step of tap change per command only, until the control switch is returned to the off position between successive operations / repeat commands.
- 1.1.2.7. Limit switches shall be provided to prevent overrunning of the mechanism and shall be directly connected in the control circuit of the operating motor provided that a mechanical de-clutching mechanism is incorporated. In addition, a mechanical stop shall be provided to prevent over-running of the mechanism under any condition. An interlock to cut-out electrical control when it tends to operate the gear beyond either of the extreme tap positions.
- 1.1.2.8. OLTC local control cabinet shall be provided with tap position indication for the Reactor. Drive Mechanism shall be equipped with a fixed resistor network capable of providing discrete voltage steps or provide 4-20mA transducer outputs for tap position indication in CMB (for single phase unit) and input to Digital RTCC/SCADA system.
- 1.1.2.9. 'Local-remote' selector switch shall be provided in the local OLTC control cabinet. In Local mode, all electrical commands from remote (i.e. from CMB, Digital RTCC, SCADA etc.) shall be cut-off/blocked. Electrical operations to change tap positions shall be possible by using raise/lower push buttons under local mode from DM Box. In remote mode electrical commands from CMB/ Digital RTCC/SCADA etc. shall be



executed. The remote-local selector switch shall be having at-least two spare contacts per position.

- 1.1.2.10. Following minimum contacts shall be available in DM Box, which shall be wired to MB. Further these contacts shall be wired to Digital RTCC panel:
- a. INCOMPLETE STEP which shall not operate for momentary loss of auxiliary power.
  - b. OLTC motor overload protection
  - c. Supply to DM Motor fail
  - d. OLTC IN PROGRESS
  - e. Local / Remote Selector switch position
  - f. OLTC upper/lower limits reached
- 1.1.2.11. All relays, switches, fuses etc. shall be mounted in the OLTC local control cabinet and shall be clearly marked / labelled for the purpose of identification.
- 1.1.2.12. A permanently legible lubrication chart if required shall be fitted within the OLTC local control cabinet.

## 1.2. Digital RTCC Panel

- 1.2.1. The digital RTCC relay shall have Automatic Tap Changer control and monitoring relay with Automatic Voltage Regulating features (referred as **Digital RTCC relay**) to remotely control and monitor OLTC.
- 1.2.2. Each Digital RTCC relay shall be used to control 1 No. 3-Phase Reactor unit. Quantity of the Digital RTCC relays shall be as per BPS. Digital RTCC panel, for accommodating/mounting the above Digital RTCC relays shall be supplied within the scope.
- 1.2.3. Digital RTCC relay shall be microprocessor based adopting the latest state of the art design & technology with in-built large display for ease of programming and viewing. The unit supplied shall be field programmable so that in the event of change in Reactor / location, it could be customized to site conditions without sending back to works. The programming shall be menu driven and easily configurable. If it is designed with draw out type modules, it should take care of shorting all CT inputs automatically while drawing out. The CT / VT ratio shall be field programmable and Relay shall display the actual HV Voltage and current considering suitable multiplying factors. The system shall be self-sufficient and shall not require any additional devices like parallel balancing module etc.
- 1.2.4. The RTCC Panel shall be provided with digital RTCC relay having Raise/Lower push buttons, Manual/ Automatic mode selection features, for control of OLTC. Touch screen option in the relay, instead of electrical push button/switch is also acceptable.
- 1.2.5. **In Manual Mode:** In this mode, power system voltage based automatic control from





digital RTCC relay shall be blocked and commands shall be executed manually by raise/lower push buttons.

- 1.2.6. **In Auto Mode:** In Auto mode, digital RTCC relay shall automatically control OLTC taps based on power system voltage or Reactive power set points. However, set points shall be decided during detailed engineering. An interlock shall be provided to cut off electrical control automatically upon recourse being taken to the manual control in emergency.
- 1.2.7. **Raise/Lower control:** The remote OLTC scheme offered shall have provision to raise or lower taps for the complete bank of three 1-phase Reactors / 3-Phase Reactors. Individual 1-phase OLTC operation shall not be possible from the remote-control panel. Tap Position 1 shall be considered as Maximum MVAR Rating.
- 1.2.8. Digital RTCC relays shall communicate with SCADA using IEC 61850 through FO port to monitor, parameterise & control the OLTC. Any software required for this purpose shall be supplied. The supplied software shall not have restriction in loading on multiple computers for downloading and analyzing the data. Software shall indicate the current overview of all measured parameters of the connected Reactor in real time. The digital RTCC Relay shall have multiple set points (Voltage or reactive power) and suitable to operate from SCADA, with a facility to have the possibility of additional set points command from SCADA.
- 1.2.9. The Digital RTCC relay shall have additional programmable Binary Inputs (minimum 7 Nos.) and Binary outputs (minimum 7 Nos.) for Employer's future use. It shall be possible to have additional module for Binary Input / output as well as Analogue input module depending upon requirement.
- 1.2.10. The relays shall ensure positive completion of lowering/raising of the OLTC tap, once the command is issued from the relay. "Step-by-Step" operation shall be ensured for one tap change from each tap changing pulse. If the command remains in the "operate" position, lock-out of the mechanism is to be ensured.
- 1.2.11. Following minimum indications/alarms shall be provided in Digital RTCC relay either through relay display panel or through relay LEDs:
- a. INCOMPLETE STEP alarm
  - b. OLTC motor overload protection alarm
  - c. Supply to DM Motor fail alarm
  - d. OLTC IN PROGRESS alarm
  - e. Local / Remote Selector switch positions in DM Box
  - f. OLTC upper/lower limits reached alarm
  - g. OLTC Tap position indications for Reactor units
  - a. Independent-combined-remote selector switch positions of CMB (In case of single-phase Reactor)
  - b. 400V, AC Mail Supply Fail.
  - c. 400V, AC Standby Supply Fail



**2. Constructional features Digital RTCC Panel**

- 2.1. Digital RTCC panel shall Front door opening type and made of CRCA sheet of minimum thickness of 2.5mm and shall be painted suitably as per respective **Annexure –D** of Chapter – Shunt Reactor.
- 2.2. The degree of protection shall be IP: 43 for indoor in accordance with IS 13947/IEC: 60947.
- 2.3. 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 Digital RTCC panel, 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.
- 2.4. Ventilating Louvers, if provided, shall have screen and filters. The screen shall be fine wire mesh of brass. All the control cabinets shall be provided with suitable lifting arrangement. Thermostat controlled space heater and cubicle lighting with ON-OFF switch shall be provided in each panel.

**All the separately mounted cabinets and panels shall be free standing floor mounted type and have domed or sloping roof for outdoor application**



**ANNEXURE - I****Technical Specification of Oil BDV Test Set (Applicable as per BPS)**

| <b>Item</b>                                | <b>Specification</b>  |
|--|---|
| Functional Requirement                     | <ol style="list-style-type: none"> <li>1. The instrument should be suitable for Automatic Measurement of Electrical Breakdown Strength of Reactor oil as per relevant standards.</li> <li>2. The test results should have repeatability, consistency in laboratory condition.</li> </ol>  |
| Test Output                                | 0-100 kV (Rate of rise: 0.5 to 5KV/Sec)   |
| Accuracy                                   | $\pm 1$ kV  |
| Resolution                                 | 0.1 KV  |
| Switch off Time                            | $\leq 1$ ms   |
| Display/Control                            | LCD/Keypads.  |
| Printer                                    | Inbuilt/External  |
| Measurement Programmes                     | Fully Automatic Pre-programmed/User programmed Test Sequences including as per latest IEC & other national/international standards.   |
| Test Lead/ Accessories                     | One complete set of electrodes, gauge etc. compatible with the instruments should be provided for successfully carrying out the test in EMPLOYER S/S. Additionally all the required accessories, tools, drawing, documents should be provided for the smooth functioning of kit. Further hard carrying case (which should be robust/ rugged enough) for ensuring proper safety of the kit during transportation shall have to be provided.                              |
| Design/Engg.                               | The complete equipment along with complete accessories must be designed / engineered by Original Equipment Manufacturer.  |
| Power Supply                               | It shall work on input supply variations, V: 230 $\pm 10$ %, f: 50 Hz $\pm 5$ % on standard sockets.  |
| Operating Temperature                      | 0 to +50 deg C  |
| Relative humidity                          | Max. 90% non-condensing.  |
| Protection/ Control                        | Against short circuit, over load, transient surges etc. Also the instrument should have facility of stopping automatically on power failure. Also the kit should have facility of HV chamber interlocking as well as zero start interlocking.   |
| Environment                                | The test kit shall be compatible for EMI/EMC/Safety environment requirement as per IEC.   |
| Guarantee                                  | <p>Warranty/Guarantee Period: Min 05 year from the date of successful &amp; complete commissioning at Employer sub-station.</p> <p>All the materials, including accessories, cables, laptops etc. are to be covered under warranty/guaranty period. If the kit needs to be shifted to supplier's works for repairs within warranty/guaranty period, suppliers will have to bear the cost of spares, software, transportation of kit for repair at test lab / works.</p> |
| Calibration Certificate                    | Unit shall be duly calibrated before supply and the date of calibration shall not be older than two month from the date of supply of Kit.   |
| Training                                   | Supplier shall have to ensure that the instrument is made user friendly. Apart from the detailed demonstration at site, the supplier shall also have to arrange necessary training to EMPLOYER engineers.   |
| Commissioning, handing over the Instrument | Successful bidder will have to commission the instrument to the satisfaction of EMPLOYER. The instrument failed during the demonstration shall be rejected and no repairs are allowed.  |



## ANNEXURE - J

**Technical Specification of Portable Dissolved Gas Analysis of Oil (Applicable as per BPS)**

| S.No. | Particulars   | Specification  |
|-------|---|--|
| 01    | Functional Requirement                                | The Portable DGA equipment to extract, detect, analyze and display the dissolved gases in insulating oil as specified in IEEE C 57-104-2008 and IEC 60599-2007.  |
| 02    | Detection of Gases                                    | All the fault gases i.e. H <sub>2</sub> , CH <sub>4</sub> , C <sub>2</sub> H <sub>2</sub> , C <sub>2</sub> H <sub>4</sub> , C <sub>2</sub> H <sub>6</sub> , CO & CO <sub>2</sub> concentrations shall be individually measured and displayed. The minimum detection limits of the instrument for the above gases shall strictly be met the requirement of IEC-60567-2011-Page No. 47-clause 9.2, table-5.  |
| 03    | 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.   |
| 05    | 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.</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 C 57-104-1991 and IEC 60559-1999. Laptop carrying case shall also be provided.</p> <p>c) Internal Memory can capable of store at least 15000 records</p> |



|    |  |  |
|----|--|--|
| 06 | 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 EMPLOYER 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> |
| 07 | Operating Temperature, Relative humidity | <p>01. Temperature 0-50 Deg. C</p> <p>02. 85% non-condensing</p>   |
|    | & Dimensions                             | 03. Portable   |
| 08 | Warranty                                 | The entire test set up shall be covered on warranty for a period of 5 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.   |
| 09 | Service Support                          | The supplier shall furnish the requisite documents ensuring that the equipment manufacturer is having adequate service team and facility to take care of any issues during operation of the instrument.  |
| 10 | Training                                 | The supplier shall provide adequate training for a period of two working days pertaining to the operation and troubleshooting to site personnel.   |



## ANNEXURE - K

### Online Dissolved Gas (Multi- 8 gas) and Moisture Analyser (If Specified in Chapter PSR)

- 1.1. Online Dissolved Gas (Multi-8 gas) and Moisture Analyser along with all required accessories including inbuilt display shall be provided with each reactor for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599-1999.
- 1.2. The equipment shall detect, measure and analyse the following gases:

| Gases & Moisture Parameters   | Typical Detection Range   |
|-------------------------------|---|
| H <sub>2</sub>                | 5 – 5,000 ppm   |
| O <sub>2</sub>                | 5 – 5,000 ppm   |
| CH <sub>4</sub>               | 5 – 5,000 ppm   |
| C <sub>2</sub> H <sub>6</sub> | 5 – 5,000 ppm   |
| C <sub>2</sub> H <sub>4</sub> | 3 – 5,000 ppm   |
| C <sub>2</sub> H <sub>2</sub> | 1 – 3,000 ppm   |
| CO                            | 10 – 10,000 ppm   |
| CO <sub>2</sub>               | 20 – 30,000 ppm   |
| H <sub>2</sub> O              | 2 – 100 % RS should have facility for measurement of moisture in oil in ppm |

- 1.3. 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.
- 1.4. Equipment shall have facility to give SMS alert to at least three users whenever any fault gas violates the predefined limit.
- 1.5. Equipment should work on station auxiliary supply. In case other supply is required for the equipment then suitable converter shall be included. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.
- 1.6. 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 (800kV) 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 °C ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of five (5) years



manufacturer's Warranty.

- 1.7. The equipment shall display all the individual gas and moisture concentration on its display unit and shall have facility to download all the stored the 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
- 1.8. The Equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the Equipment.
- 1.9. 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 <sup>0</sup> C to + 120 <sup>0</sup> C   |
| External Temp. Range  | - 20 <sup>0</sup> C to + 55 <sup>0</sup> C<br>(External temp range of 55 <sup>0</sup> C is important and should not be compromise due to ambient & operating conditions.) |
| Humidity range        | 10 to 95 %  |
| Operating Voltage     | 230 Vac; 50 Hz ( $\pm 20\%$ variation)  |
| Communications        | USB&IEC 61850 compliant   |

- 1.10. 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

- 1.11. 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
- ii) Operation Manual (2 set for every unit),
- iii) Software Manual and
- iv) Compact disc giving operation procedures of Maintenance





Manual & Trouble shooting instructions.

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



## ANNEXURE - L

### Online Dissolved Gas (Multi-4 gas) and Moisture Analyser (If Specified in Chapter PSR)

1.13. Online Dissolved Gas (Multi- 4gas) and Moisture Analyser along with all required accessories including inbuilt display shall be provided with each reactor for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599-1999.

1.14. The equipment shall detect, measure and analyse the following gases:

| Gases & Moisture Parameters   | Typical Detection Range   |
|-------------------------------|---|
| H <sub>2</sub>                | 5 – 5,000 ppm   |
| CH <sub>4</sub><br>Or<br>CO   | 5 – 5,000 ppm   |
| C <sub>2</sub> H <sub>4</sub> | 10 – 10,000 ppm   |
| C <sub>2</sub> H <sub>2</sub> | 3 – 5,000 ppm   |
| H <sub>2</sub> O              | 1 – 3,000 ppm   |
|                               | 2 – 100 % RS should have facility for measurement of moisture in oil in ppm |

1.15. 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 conforming 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.

1.16. Equipment shall have facility to give SMS alert to at least three users whenever any fault gas violates the predefined limit.

1.17. Equipment should work on station auxiliary supply. In case other supply is required for the equipment then suitable converter shall be included. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.

1.18. 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 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 °C ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of five (5) years manufacturer's Warranty.

1.19. The equipment shall display all the individual gas and moisture



concentration on its display unit and shall have facility to download all the stored the 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

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

1.21. 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 <sup>0</sup> C to + 120 <sup>0</sup> C   |
| External Temp. Range  | - 20 <sup>0</sup> C to + 55 <sup>0</sup> C<br>(External temp range of 55 <sup>0</sup> C is important and should not be compromise due to ambient & operating conditions.) |
| Humidity range        | 10 to 95 %  |
| Operating Voltage     | 230 Vac; 50 Hz ( $\pm 20\%$ variation)  |
| Communications        | USB&IEC 61850 compliant   |

1.22. 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:

- iv) Key gases
- v) Ratios (Rogers, IEC. etc.)
- vi) Duval"s Triangle

1.23. 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
- ii) Operation Manual (2 set for every unit),
- iii) Software Manual and
- iv) Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.

1.24. The installation and commissioning at site shall be done under the



supervision of OEM representative or OEM certified representative.



## ANNEXURE - M

### On Line Dissolved Hydrogen and Moisture Monitor (If Specified in Chapter PSR)

- 1.0 Online Dissolved Hydrogen and Moisture Analyser along with all required accessories including inbuilt display shall be provided with each Reactor for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599-1999
- 2.0 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
- 3.0 Equipment should work on station auxiliary supply. In case other supply is required for the equipment then suitable converter shall be included. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier
- 4.0 Equipment 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 (800kV) 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 °C ambient temperature and EMI and EMC compatibility. The Equipment must carry a minimum of five (5) years manufacturer's Warranty
- 5.0 The equipment shall display H<sub>2</sub> and moisture concentration on its display unit and shall have facility to download all the stored the 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. All the consumable (if any) upto warrantee period shall be included in the scope of supply
- 6.0 The monitor shall also be suitable to detect Water Content measured in ppm or % RS (Relative Saturation). The sensors shall be able to withstand pressure from vacuum to 10 psi.
- 7.0 Technical Parameters:

| Sr. No. | Parameters                           | Requirements                         |
|---------|--------------------------------------|--------------------------------------|
| a)      | The measurement range / Output:      |                                      |
|         | Hydrogen Dissolved in oil            | 0 to 2000 ppm, with 4 – 20 mA output |
|         | Water Dissolved in oil               | 0 to 95% RS, with 4 – 20 mA output   |
| b)      | Alarms/Indication (High & Very High) |                                      |



|    |                                |                              |
|----|--------------------------------|------------------------------|
|    | Hydrogen                       | Programmable NO/NC contacts, |
|    | Water                          | Programmable NO/NC contacts, |
| c) | Environment                    |                              |
|    | Operating Ambient Temperature  | – 20 to + 55 deg C           |
|    | Operating Oil Temperature      | – 20 to + 105 deg C          |
| d) | Pressure Withstand, (Oil side) | Full Vacuum to 10 psi.       |
| e) | Communications                 | USB&IEC 61850 compliant      |

Equipment shall be mounted separately to avoid effect of vibration. Suitable arrangement shall be provided support and protect the inlet and outlet piping arrangement.

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

- iii) IEEE, IEC or user configurable levels of dissolved gases
- iv) Rate of change trending

9.0 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.

- v) Software
- vi) Operation Manual (2 set for every unit),
- vii) Software Manual and
- viii) Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.

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



**ANNEXURE - N****Online Bushing Monitoring System (If specified in Chapter PSR)**

- 1.1. Online Bushing Monitoring System along with all required accessories including inbuilt display shall be provided with each Transformer for bushing capacitance and Tan Delta. Interpretations shall be as per IEC.
- 1.2. Bushing Monitoring system shall have:
  - i) By direct measurement of bushing capacitance and Tan Delta by Schering bridge principle.
  - ii) be connected at the bushings Test Tap, through properly designed adaptors, including protections in order to disallow the Test Tap pin to remain floating, even with the signal cable disconnected from the adaptors.
  - iii) Provide hourly summary, indicating:
    - Transformer Status (ON/OFF)
    - Current Polar Plot
    - Relative (%) and Referenced (pf) Capacitance, Relative (%) and Referenced (%) Power Factor
- 1.3. The monitoring system should measure (not calculate) all above data 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.
- 1.4. Equipment shall have facility to give SMS alert to at least three users whenever any fault violates the predefined limit.
- 1.5. Equipment should work on station auxiliary supply. In case other supply is required for the equipment then suitable converter shall be included. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.
- 1.6. Bushing Monitoring System shall be installed out door on Transformer 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 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 °C ambient temperature and EMI and EMC compatibility.
- 1.7. The equipment shall display all the individual bushing data on its display unit and shall have facility to download all the stored the 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.

1.8. The Equipment must have an automatic Calibration facility at fixed intervals.

1.9. The technical feature of the equipment shall be as under:

|                        |  |
|------------------------|--|
| Input channels         | 2 sets of 3 phases, simultaneous acquisition on all channels |
| Simultaneous channels  | 3 (up to 6)  |
| Sensors                | Bushing Tap Adaptors   |
| Input measuring range  | 0 - 200mA  |
| Accuracy               | Amplitude: 0.1%,<br>Relative Phase Angle: 0.05°              |
| Resolution             | 12 bit   |
| Sampling rate          | >10 kS/s   |
| Power system frequency | 50 - 60Hz, $\pm 0.01$ Hz                                     |

1.10. DATA- Bushing

|                  |                                |
|------------------|--------------------------------|
| Acquisition mode | Continuous                     |
| Trending         | Hourly, daily, weekly, monthly |
| Storage          | > 1 year                       |

1.11. Software for bushing monitoring shall include following:

- i) IEEE, IEC or user configurable levels of Capacitances & ten delta
- ii) Rate of change

1.12. The equipment shall be supplied with all necessary accessories required for carrying out bushing monitoring complete in all respect as per the technical specification. The following shall be also forming a part of supply.

- i) Software
- ii) Operation & Software Manual (2 set for every unit),
- iii) Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.

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

1.14. The equipment 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. Further supplier shall make alternate arrangement for smooth operation of the transformer.



**ANNEXURE - O****Nitrogen Injection Type Fire Prevention & Extinguishing System (If specified in BPS)**

1. Nitrogen Injection Type Fire Protection System (NIFPS) shall be designed to prevent explosion of transformer/reactor tank and the fire during internal faults/arc.

The system shall work on the principle of Drain & stir. On activation, it shall drain a pre- determined quantity of oil from the tank top through drain valve to reduce the tank pressure, isolate conservator tank oil and inject nitrogen gas at high pressure from the bottom side of the tank through inlet valves to create stirring action and reduce the temperature of oil below flash point to extinguish the fire. On operation, the quantity of oil removed from the tank shall be such that adequate amount of oil shall remain to cover active part (i.e. core coil assembly).

Electrical isolation of transformer shall be an essential pre-condition for activating the system.

2. Operational Controls

The system operation shall be fully automatic and activate from the required fire and other trip signals. In addition to automatic operation, remote operation from control room/ remote centre and local manual control in the fire extinguishing cubicle shall also be provided. System shall operate on following situations:

- 2.1 Prevention of transformer from explosion and fire

To prevent transformer from explosion and fire in case of an internal fault, signals given by operation of Electrical protection relays (Differential / Restricted earth fault) and tripping of circuit breaker of transformer and operation of either Buchholz relay or pressure relief valve (PRV) shall be used to activate the system. The exact logic for system activation shall be finalized during detailed engineering.

- 2.2 Prevention of transformer from fire in case of fire, sensed by fire detectors, the system shall be activated only after electrical isolation of the transformer, confirmed by breaker trip. If the fire detection is not associated with any other fault, the system activation shall be only manual. Manual operation switch shall be provided in the control room with a cover to avoid accidental operation of it.

3. Operation of System

On receiving activation signal, the following shall take place:

- i) Open the quick opening drain valve to drain the top layer oil
- ii) Shut off the conservator isolation valve to prevent flow of oil from the Conservator tank to the main tank
- iii) Open the valve to inject Nitrogen into the transformer tank to create stirring of oil.

There shall be interlock to prevent activation of the system if the transformer is not electrically isolated.

There shall also be provision for isolating the system during maintenance and/or testing of the transformer.

4. Technical Particulars

The contractor shall be responsible for the design of the complete system and shall



submit the drawings and design calculations for the number of fire detectors, pipe sizing of drain pipe and Nitrogen injection pipe, Nitrogen cylinder capacity, number of injection points, etc. and get approval from Employer.

Facility shall be provided to test the system when the transformer is in service, without actually draining the oil and injecting Nitrogen.

The Nitrogen regulator valve shall be designed in such a way that the Nitrogen shall not enter the transformer tank even in case of passing/ leakage of valve.

Owner shall provide two distinct station auxiliary DC feeders for control purposes. The system shall work on station DC supply with voltage variation defined in GTR. The control box of fire protection system shall have facility to receive these feeders for auto changeover of supply. It shall be the contractor's responsibility to further distribute power to the required locations. In case auxiliary DC power supply requirement is different than station auxiliary DC supply, then all necessary DC-DC converters shall be provided by the Contractor.

Following minimum indications and alarms shall be provided in the local cubicle as well as in the control box: -

- Nitrogen cylinder pressure indication - manometer with sufficient number of adjustable NO contacts
- Nitrogen cylinder pressure low
- Fire in Transformer/ Reactor
- Oil drain started
- Conservator oil isolation valve closed
- Nitrogen injection started
- DC supply fail
- Oil drain valve closed
- Gas inlet valve closed

#### 5. Details of Supply of System Equipment and Other Related Activities:

The scope of supply shall include the following items and any other items required for safe and trouble-free operation of the system.

- i) Fire extinguishing cubicle with base frame and containing at least the following:
  - Nitrogen gas cylinder of sufficient capacity with pressure regulator and manometer with sufficient number of adjustable NO contacts.
  - Oil Drain Assembly including oil drainpipe extension of suitable size for connecting pipes to oil pit
  - Mechanical release device for oil drain and nitrogen release
  - Limit switches for monitoring of the systems
  - Panel lighting
  - Flanges on top of the panel for connecting oil drain and nitrogen injection pipes for transformer
  - Back up pressure switch to operate nitrogen gas valve
  - Pressure indicators for Nitrogen pressure of the cylinder and actual injection through Nitrogen regulator



- Fire Extinguishing Cubicle shall have oil leakage detection arrangement for detecting oil leakage from drain valve. In case of any oil leakages, alarm to be provided.
  - shall have minimum IP55 degree of protection
- ii) Control box to be installed in the control room of the station for monitoring system operation, automatic control and remote operation, with alarms, indications, switches, push buttons, audio signal, suitable for tripping and signalling.
  - iii) Required number of fire detectors to be located in strategic locations to be finalized during detailed engineering. Fire detectors shall have minimum IP-67 class degree of protection.
  - iv) All controls, alarms, panels, cables, cable trays (if required), junction boxes etc.
  - v) Flow sensitive conservator Isolation valve to isolate the conservator oil from the main tank is being provided by the transformer/reactor supplier. This valve shall be located in the piping between the conservator and the Buchholz relay.
6. Under Ground Oil Storage Tank
- Each transformer unit shall be provided with an underground oil storage tank. The oil storage tank shall have Non-Corrosive, waterproof, epoxy coated (from Inside) mild steel (minimum thickness 5 mm) to store drained out oil on operation of NIFPS. The tank shall be painted from outside as per **table below**:

| Painting         | Surface preparation         | Primer coat                      | Intermediate undercoat                                | Finish coat                                | Total dry film thickness (DFT) | Colour shade |
|------------------|-----------------------------|----------------------------------|---|--|--------------------------------|--------------|
| Oil Storage Tank | Shot Blast cleaning Sa 2 ½* | Epoxy base Zinc primer (30-40µm) | Epoxy high build Micaceous iron oxide (HB MIO) (75µm) | Aliphatic polyurethane (PU) (Minimum 50µm) | Minimum 155µm                  | RAL 7035     |

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

The total capacity of storage tank shall be at least 10% of transformer tank oil to avoid overflowing of oil considering that drained oil volume shall be around 10% of transformer tank oil. Necessary arrangement shall be made on underground storage tank so as to take out the drained oil from the tank for further processing and use. All the pipe and physical connection from transformer to oil pit shall be in the scope of contractor.

This storage tank shall be placed in the pit made of brick walls with PCC (1:2:4) flooring with suitable cover plates to avoid ingress of rainwater. The design of tank and pit shall be finalised during detailed engineering.



7. 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 system.
8. Installation and pre-commissioning test After installation the system pre-commissioning tests shall be carried out jointly with the Owner's representative before the system is put in service.



**ANNEXURE - P****Oil sampling bottles (Applicable as per BPS)**

Oil sampling bottles (if specified in BPS) 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.

The scope of oil sampling bottles shall be included in the bid price as per the quantity indicated in the bid price schedule.

**Oil Syringe (Applicable as per BPS)**

If specified in BPS, the glass syringe of capacity 50ml (approx) and three way stop cock valve shall be supplied. 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 fitting shall be leak proof and shall meet the requirement of IEC- 60567. Plunger shall be grounded 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.



**ANNEXURE - Q****Oil Storage Tank (Applicable as per BPS)**

1. Oil storage tank shall be of minimum capacity (as per BPS) along with complete accessories. The oil storage tank shall be designed and fabricated as per relevant Indian Standards e.g. IS 10987 (1992). Transformer oil storage tanks shall be towable on pneumatic tyres and rested on manual screw jacks of adequate quantity & size. The tank shall be cylindrical in shape and mounted horizontally and made of mild steel plate of thickness as per standard. Diameter of the tank shall be 2.0 meter approximately. The tank shall be designed for storage of oil at a temperature of 100°C.
2. The maximum height of any part of the complete assembly of the storage tank shall not exceed 4.0 metres above road top.
3. The tank shall have adequate number of jacking pad so that it can be kept on jack while completely filled with oil. The tank shall be provided with suitable saddles so that tank can be rested on ground after removing the pneumatic tyres.
4. The tank shall also be fitted with manhole, outside & inside access ladder, silica gel breather assembly, inlet & outlet valve, oil sampling valve with suitable adopter, oil drainage valve, air vent etc. Pulling hook on both ends of the tank shall be provided so that the tank can be pulled from either end while completely filled with oil. The engine capacity in horse power to pull one tank completely fitted with oil shall be indicated. Oil level indicator shall be provided with calibration in terms of litre so that at any time operator can have an idea of oil in the tank. Solenoid valve (Electro-mechanically operated) with Centrifugal pump shall be provided at bottom inlet so that pump shall be utilised both ways during oil fill up and draining. Suitable arrangement shall also be provided to prevent overflow and drain form the tank.
5. The following accessories shall also form part of supply along with each Oil storage tank.
  - 5.1 Four numbers of 50NB suitable rubber hoses for Reactor oil application up to temperature of 100°C, full vacuum and pressure up to 2.5 Kg/ cm<sup>2</sup> with couplers and unions each not less than 10 metre long shall be provided.
  - 5.2 Two numbers of 100NB suitable for full vacuum without collapsing and kinking vacuum hoses with couplers and unions each not less than 10 metre long shall also be provided.
  - 5.3 One number of digital vacuum gauge with sensor capable of reading up to 0.001 torr, operating on 240V 50Hz AC supply shall be supplied. Couplers and unions for sensor should block oil flow in the sensor. Sensor shall be provided with at-least 8 meter cable so as to suitably place the Vacuum gauge at ground level.
  - 5.4 The painting of oil storage tank and its control panel shall be as per technical specification.





- 5.5 The tank shall contain a self mounted centrifugal oil pump with inlet and outlet valves, with couplers -suitable for flexible rubber hoses and necessary switchgear for its control. There shall be no rigid connection to the pump. The pump shall be electric motor driven, and shall have a discharge of not less than 6.0 kl/hr. with a discharge head of 8.0m. The pump motor and the control cabinet shall be enclosed in a cubicle with IP-55 enclosure.



### **Annexure–R Spare Reactor Unit Storage & Connection Arrangement**

- 1.1. **Reactor with Isolator switching arrangement:** Employer intends to replace any of the Reactor unit by the spare Reactor unit using isolator switching arrangement so as to avoid physical shifting the Reactor.

Connection of spare unit of Reactor with other units shall be made by isolator switching arrangement. Neutral formation for spare unit of Reactor shall be done by manual connection. The spare Reactor unit shall be completely erected and commissioned similar to the other Reactor units. The contractor shall carry out all pre- commissioning tests on the spare Reactor similar to the unit kept in service.

For this purpose if specified in BPS, HV and Neutral Connections of spare unit shall be extended upto the other unit(s) by forming auxiliary buses connection through flexible/rigid conductor. All associated materials like Bus post insulators, Aluminium tube, conductors, clamps & connectors, insulator strings, hardware, cables, support structures, required for the above-mentioned arrangement shall be provided by the contractor. However, the detail configuration and hardware shall be finalised during detailed engineering and shall be subject to Employer's approval.

Any special maintenance procedure required shall be clearly brought out in the instruction manual.

- 1.2. **Reactor without isolator switching arrangement:** Employer intends to keep the spare Reactor unit without isolator switching arrangement due to space limitation. In case of failure of any of the running unit, this spare reactor shall be physically shifted to replace faulty reactor.

The spare Reactor shall be placed on the elevated foundation block to facilitate quick movement. The Reactor unit may be required to be stored for long duration. The spare Reactor unit shall be completely erected and commissioned similar to the other Reactor units. However, erection of separate cooler bank is not envisaged. In case conservator is cooler bank mounted, suitable arrangement for mounting of conservator on tank top cover shall be provided. The contractor shall carry out all pre- commissioning tests on the spare Reactor similar to the unit kept in service.

All other items shall be suitably packed in reusable boxes. Arrangement shall be made to minimize moisture ingress inside the boxes. All pipes and radiators shall be provided with blanking plates during long duration storage to prevent entry of foreign material/ water.

In case spare Reactors needs to be commissioned in switchyard bay (as advised by Engineer in-charge), the contractor shall erect, test and commission the spare reactor unit similar to other units in service. However packaging material as above for long-term storage shall be included in the scope of bidder.

