

# TECHNICAL SPECIFICATIONS

## CHAPTER 7-TRANSFORMER

*for*

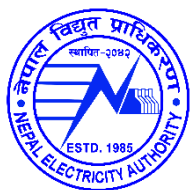
### PACKAGE KC-6

*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  
Dhangesanghu Substation**



**नेपाल विद्युत प्राधिकरण**

*(नेपाल सरकारको स्वामित्व)*

**Nepal Electricity Authority**

*(A Government of Nepal Undertaking)*

## CHAPTER 7- TRANSFORMER

### CONTENTS

Clause No.	Description
1.	General
2.	Transportation
3.	Performance
4.	Measurable Defects
5.	Design review
6.	Construction Details
7.	Paint system and procedures
8.	Insulating Oil
9.	Spare Transformer Units Connection Arrangement
10.	Bushings
11.	Neutral Formation and Earthing Arrangement.
12.	Cooling Equipment and its Control
13.	Cabling
14.	Tap Changing Equipment
15.	SCADA Integration and Interconnection
16.	Constructional features of Cooler Control Cabinet/ Individual Marshalling Box/ Common Marshalling Box/ Junction Box / Outdoor cubicle and Digital RTCC Panel
17.	Current Transformer
18.	Oil Storage Tank
19.	Oil Sampling Bottle
20.	Oil Syringe
21.	Hand Tools
22.	Test Kit
23.	Fittings & accessories
24.	Inspection and Testing
Annexure –A	Technical Particulars / Parameters of Transformers
Annexure –B	Test Plan
Annexure –C	Design Review Document
Annexure –D	Painting Procedure
Annexure –E	Insulating Oil Parameters
Annexure –F	Technical parameters of Current Transformers
Annexure –G	Spare Transformer Units Connection Arrangement
Annexure–H	BDV Test Set
Annexure–I	Portable Dissolved Gas Analysis of Oil
Annexure–J	Online Dissolved Gas (Multi-8 gas) and Moisture Measuring Equipment
Annexure–K	Online Dissolved Gas (Multi-4 gas) and Moisture Measuring Equipment
Annexure–L	Online Hydrogen and Moisture Measuring Equipment
Annexure–M	Nitrogen Injection Type Fire Prevention & Extinguishing System
Annexure–N	Online Bushing Monitoring System
Annexure –O	Transformer Oil Filtration Plant



## TECHNICAL SPECIFICATION TRANSFORMER

### 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 Transformer offered by the contractor shall at least conform to the requirements specified under relevant IEC standard. However, in case of parallel operation with the existing transformer,
  - a) The percentage impedance, vector group, OLTC connection & range etc. of the transformer is to be matched with that of the existing transformer.
  - b) Necessary provision is to be kept in the transformer control scheme for parallel operation with the existing OLTC control scheme having provision of Master/Follower/Independent /off operation etc.
  - c) External or internal reactors shall not be used to achieve the specified HV/LV and IV/LV impedances.
- 1.3. Further, matching of physical orientation, mounting rail gauge etc. shall be done to facilitate inter-changeability. Components having identical rating shall be interchangeable.
- 1.4. 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.

### 2. Transportation

- 2.1. 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 transformer for all the stages from the manufacturer's work to site.
- 2.2. The contractor shall carry out the route survey along with the transporter and finalise the detail methodology for transportation of transformer and based on route survey; any modification/ extension/ improvement to existing road, bridges, culverts etc. if required, shall be in the scope of the contractor.
- 2.3. The inland transportation of the Transformer shall be on trailers equipped with GPS system for tracking the location of transformer at all



times during transportation from manufacturer works to designated site. Contractor shall monitor / track the location of the trailer on regular basis and also provide tracking details to respective site/RHQ at the time of despatch of Transformer from factory to designated site. Requirement of Hydraulic trailer is envisaged for a load of more than 40 T.

- 2.4. All metal blanking plates and covers which are specifically required to transport and storage of the transformer shall be considered part of the transformer and handed over to the Purchaser after completion of the erection. Bill of quantity of these items shall be included in the relevant drawing/document.
- 2.5. The Contractor shall dispatch the transformer 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. Generally, the duration of the storage of transformer at site with dry air, shall preferably be limited to three months, after which the Transformer shall be processed as per the recommendation of manufacturer if not filled with oil. The dry air cylinder(s) provided to maintain positive pressure can be taken back by the contractor after oil filling.

In case turret, having insulation assembly, is transported separately then positive dry air pressure shall be ensured.

- 2.6. The Transformer shall also be fitted with sufficient number of electronic impact recorders (at least 2 numbers) 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. The Contractor shall comply with the relevant **CIGRÉ technical documents**, including the "*Guide on Transformer Transportation*", to ensure the safe transportation of the transformer up to the Site.

### 3. Performance

- 3.1. The transformers shall be used for bi-directional flow of rated power. The major technical parameters of single phase and three phase transformer units are defined at **Annexure - A**.
- 3.2. Transformers shall be capable of operating under natural cooled condition up to the specified load. The forced cooling equipment shall come into operation by pre-set contacts of winding temperature indicator and the transformer shall operate as a forced cooling unit initially ONAF (or ONAF1, as specified) up to specified load and then as OFAF (ONAF2 or ODAF or ODWF, as specified in data sheet). Cooling shall be so designed that during total failure of power supply to cooling fans and oil pumps, the transformer shall be able to operate at full load for at



least ten (10) minutes without the calculated winding hot spot temperature exceeding 140° C. If the Transformer is fitted with two coolers, each capable of dissipating 50 per cent of the loss at continuous maximum rating, it shall be capable of operating for 20 minutes in the event of failure of the oil circulating pump or blowers associated with one cooler without the calculated winding hot spot temperature exceeding 140° C at continuous max rating. The contractor shall submit supporting calculations for the above and the same shall be reviewed during design review.

- 3.3. The transformer shall be free from any Electrostatic Charging Tendency (ECT) under all operating conditions and when all oil circulation systems are in operation. In general, maximum oil velocity shall be such that it does not lead to static discharges inside the transformer while all coolers are in operation.
- 3.4. The transformers shall be capable of being continuously operated at the rated MVA without danger, at any tapping with voltage variation of  $\pm 10\%$  corresponding to the voltage of that tapping.
- 3.5. The transformers shall be capable of being over loaded in accordance with IEC-60076-7. There shall be no limitation imposed by bushings, tap changers etc. or any other associated equipment.
- 3.6. Tank hotspot shall not exceed 110 Deg. Celsius. Maximum ambient temperature shall be considered as per as Chapter-PSR. The above condition shall be verified during temperature rise test.
- 3.7. The transformer and all its accessories including bushing/ built in CTs etc. shall be designed to withstand without damage, the thermal and mechanical effects of any external short circuit to earth and of short circuits at the terminals of any winding for a period of 2 secs. The short circuit level of the HV & IV System to which the transformers will be connected is as follows:

400kV system	- 63kA for 1 sec (sym, rms, 3
phase fault)	220kV system - 50 kA for 1 sec
(sym, rms, 3 phase fault)	132kV system - 40 kA
for 1 sec (sym, rms, 3 phase fault)	66kV system
	- 40 kA for 1 sec (sym, rms, 3
phase fault)	33kV system - 31.5 kA for 1 sec
(sym, rms, 3 phase fault)	
11kV system	- 25 kA for 3 sec (sym, rms, 3
phase fault)	

However, for transformer design purpose, the through fault current shall be considered limited by the transformer self-impedance only (i.e.  $Z_s = 0$ ).

- 3.8. Transformer shall be capable of withstanding thermal and mechanical stresses caused by symmetrical or asymmetrical faults on any terminals. Mechanical strength of the transformer shall be such that it can withstand 3-phase and 1- phase through fault for transformer rated voltage applied



to HV and / or IV terminals of transformer. The short circuit shall alternatively be considered to be applied to each of the HV, IV and tertiary (LV) transformer terminals as applicable. The tertiary terminals shall be considered not connected to system source. For short circuit on the tertiary terminals, the in-feed from both HV & IV system shall be limited by the transformer self-impedance only and the rated voltage of HV and IV terminals shall be considered. The maximum short circuit output current at the tertiary terminals shall be limited to a safe value to make the transformer short circuit proof.

The transformer shall be designed to withstand for short circuit duration of 2 seconds for Thermal stress and the same shall be verified during design review.

3.9. The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be such that under 10 % continuous over-voltage condition it does not exceed 1.8 Tesla at all tap positions.

3.10. Transformers shall withstand without damage, heating due to the combined voltage and frequency fluctuations which produce the following over fluxing conditions:

110 % for continuous  
125 % for 1 minute  
140 % for 5 seconds

Withstand time for 150% & 170% over fluxing condition shall be indicated. Over fluxing characteristics up to 170 % shall be submitted.

3.11. The air core reactance of HV winding of transformer of 400 kV voltage class shall not be less than 20%.

3.12. **Tertiary Windings (if applicable as per Annexure - A)**

The tertiary windings shall be suitable for connection of reactors or capacitors which would be subjected to frequent switching and shall be suitable for connection to LT Transformer for auxiliary supply. All the windings shall be capable of withstanding the stresses which may be caused by such switching. The tertiary winding shall be designed to withstand mechanical and thermal stresses due to dead short circuit on its terminals and for 1/3<sup>rd</sup> of the MVA capacity of the transformer although the cooling for

continuous thermal rating of the tertiary winding shall be for 5MVA capacity. Tertiary, if not loaded, i.e. not connected to reactor, capacitor or LT transformer etc., its terminals shall be insulated to avoid any accidental short circuiting.

If required, the surge arrester (with polymer housing) shall be provided externally in proximity with bushings mounted suitably on the transformer tank. Alternatively, if required, the surge arrester may be mounted internally (as per standard practice of manufacturer), in order to limit the transfer surge within the BIL specified. Further, in case



external surge arresters are required, same shall be mounted on Transformer tank.

### 3.13. Radio Interference and Noise Level

The transformers 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.

The noise level of transformer, when energised at normal voltage and frequency with fans and pumps running shall not exceed the values specified at **Annexure - A**, when measured under standard conditions.

## 4. Measurable Defects

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

- a) Repair, inside the Transformer and OLTC (including oil migration) either at site or at factory is carried out after commissioning.
- b) The concentration of any fault gas is more than the respective values as per table-2 of IEEE C57.104-2019, which are as detailed below.

Fault GAS	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>
<b>O<sub>2</sub>/N<sub>2</sub> Ratio ≤ 0.2</b>	<b>20 0</b>	<b>150</b>	<b>02</b>	<b>100</b>	<b>175</b>	<b>1100</b>	<b>12500</b>

If fault gases except CO and CO<sub>2</sub> are well below the limit as specified above during warranty period, furan test may be carried out to ascertain the degree of degradation of transformer paper insulation. Based on measured furan values CO & CO<sub>2</sub> levels may be re-evaluated.

- 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.
- d) The moisture content goes above 12 ppm at any temperature during operation including full load.

## 5. Design review

- 5.1. The transformer 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. The manufacturer will be required to demonstrate the 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. in order to achieve long life of transformer with least maintenance and to take into account the





uncertainties of his design and manufacturing processes. The scope of such design review shall include but not limited to the requirement as mentioned at Annexure – C.

- 5.2. Design reviews shall be conducted by Purchaser or an appointed consultant during the procurement process for transformers; however, the entire responsibility of design shall be with the manufacturer. Purchaser may also visit the manufacturer's works to inspect design, manufacturing and test facilities at any time.

The design review will commence after placement of award and shall be finalized before commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the transformer under the scope. It shall be conducted generally following the "CIGRE TB 529: Guidelines for conducting design reviews for power transformers".

- 5.3. The manufacturer shall provide all necessary information and calculations to demonstrate that the transformer meets the requirements for short circuit strength and durability. The latest recommendations of IEC and CIGRE SC 12 shall be applied for short circuit withstand evaluation.

- 5.4. Raw material and sub-vendors used by transformer manufacturer shall be declared before commencement of manufacturing.

5.5. **Type test requirement & it's validity**

The offered transformer or the transformer, the design of which is similar to the offered transformer, 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 transformer. Further, type test report of transformer shall only be acceptable provided the offered transformer has been manufactured from the same plant. The Transformer Type test validity period shall be as per Technical Specification Chapter-General Technical Requirement (GTR).

**6. Construction Details**

The construction details and features of transformer shall be in accordance with the requirement stated hereunder. The components and fittings associated with transformers are subject to the Employer's approval.

**6.1. Tank**

- 6.1.1. Tank shall be of welded or bolted construction and fabricated from tested quality low carbon steel of adequate thickness. Unless otherwise approved, metal plate, bar and sections for fabrication shall comply with BS-4360 / IS 2062. Material Samples, technical literature, drawings, test reports and list of the names of the principal users with experience gained shall be supplied on request.





- 6.1.2. All seams and joints which are 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/ ISO 15614-1/ AWS D1.1. 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/ ISO 17663.
- 6.1.3. Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water.
- 6.1.4. The tank shall be of proven design either bell type with bolted /welded joint or conventional type with welded / bolted top cover. Bell type tank shall be provided with joint at about 500 mm above the bottom of the tank. The welded joint shall be provided with flanges suitable for repeated welding. The joint shall be provided with a suitable gasket to prevent weld splatter inside the tank. Proper tank shielding shall be done to prevent excessive temperature rise at the joint.
- 6.1.5. The tank shall be designed in such a way that it can be mounted either on the plinth directly or on rollers, as per manufacturer's standard practice.
- 6.1.6. The base of each tank shall be so designed that it shall be possible to move the complete transformer 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 2.5 m but less than 5m	20
Over 5 m but less than 7.5m	26
Over 7.5 m	32

- 6.1.7. Tank shall be capable of withstanding, without damage, severe strains that may be induced under normal operating conditions or forces encountered during lifting, jacking and pulling during shipping and handling at site or factory. Tank, tank cover and associated structure should be adequately designed to withstand, without damage or permanent deflection / deformation, the forces arising out of normal oil pressure, test pressures, vacuum, seismic conditions and short circuit forces specified.
- 6.1.8. Tank MS plates of thickness >12 mm should undergo Ultrasonic Test (UT) to check lamination defect, internal impurities in line with ASTM 435 & ASTM 577.
- 6.1.9. Tank shall be provided with:
- Lifting lugs: Four symmetrically placed lifting lugs shall be provided so that it will be possible to lift the complete transformer when filled with oil without structural damage to any part of the transformer. 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 transformer 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 transformer filled with oil allowing in addition to 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 transformer shall be provided (if applicable).
- e. Suitable provisions of pockets for OTI, WTI & RTDs including two spare pockets.

6.1.10. All pipes connected to Transformer shall follow IS 1239/ ISO 65.

## 6.2. Tank Cover

6.2.1. The tank cover shall be designed to prevent retention of water and shall not distort when lifted. The internal surface of the top cover shall be shaped to ensure efficient collection and direction of free gas to the Buchholz relay.

6.2.2. At least two adequately sized inspection openings one at each end of the tank, shall be provided for easy access to bushings and earth connections. The inspection covers shall not weigh more than 25 kg. Handles shall be provided on the inspection cover to facilitate lifting.

6.2.3. The tank cover shall be provided with pockets for 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.

6.2.4. Bushing turrets, covers of inspection openings, thermometer pockets etc. shall be designed to prevent ingress of water into or leakage of oil from the tank.

6.2.5. To allow for the effect of possible induced and capacitive surge current flow, the tank cover and bushing turret shall be fixed to the transformer in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.

6.2.6. The transformer shall be provided with a suitable diameter pipe flange, butterfly valve, bolted blanking plate and gasket shall be fitted at the highest point of the transformer for maintaining vacuum in the tank.

6.2.7. **Gas venting** - The transformer cover and generally the internal spaces of the transformer and all pipe connections shall be designed so as to provide efficient venting of any gas in any part of the transformer 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 transformer is being mounted.

### 6.3. **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 ISO 4633/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.

### 6.4. **Foundation of Roller Assembly, Cooler Banks other supports**

Transformer shall be rested on foundation on roller assembly. The rollers are to be provided with flanged bi-directional wheels and axles. This set of wheels and axles shall be suitable for fixing to the under carriage of transformer to facilitate its movement on rail track. Suitable locking arrangement along with foundation bolts shall be provided for the wheels to prevent accidental movement of transformer. The rail track gauge shall be 1676 mm. To prevent transformer movement during earthquake, suitable clamping devices shall be provided for fixing the transformer to the foundation.

For foundation of cooler bank (Separately mounted) of Transformer, fixing of cooler support shall be through Anchor Fastener with chemical grouting and no pockets for bolting shall be provided.

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.



## 6.5. Conservator

- 6.5.1. Main 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

- 6.5.2. 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 transformer 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 transformer shall be able to carry the specified overload without overflowing of oil.
- 6.5.3. The conservator shall be fitted with lifting lugs in such a position so that it can be removed for cleaning purposes. Suitable provision shall be kept to replace air cell and cleaning of the conservator as applicable.
- 6.5.4. Conservator shall be positioned so as not to obstruct any electrical connection to transformer.
- 6.5.5. The connection of air cell to the top of the conservator is by air proof seal preventing entrance of air into the conservator. The main conservator tank shall be stencilled on its underside with the words **"Caution: Air cell fitted"**. Lettering of at least 150 mm size shall be used in such a way to ensure clear legibility from ground level when the transformer is fully installed. To prevent oil filling into the air cell, the oil filling aperture shall be clearly marked. The transformer rating and diagram plate shall bear a warning statement that the **"Main conservator is fitted with an air cell"**.
- 6.5.6. 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.
- 6.5.7. The transformer 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.
- 6.5.8. 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.
- 6.5.9. 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 so that the oil will not generally become saturated with oxygen. Air cells with well proven long-life characteristics shall be preferred.

- 6.5.10. OLTC shall have conventional type conservator (without aircell) with magnetic oil level gauge with potential free oil level alarm contact and prismatic oil level gauge.

**6.6. Piping works for conservator**

- 6.6.1. Pipe work connections shall be of adequate size preferably short and direct. Only radiused elbows shall be used.

- 6.6.2. The feed pipe to the transformer tank shall enter the transformer cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the transformer 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 80mm. The Gas-venting pipes shall be connected to the final rising pipe between the transformer and Buchholz relay as near as possible in an axial direction and preferably not less than five times pipe diameters from the Buchholz relay.

- 6.6.3. 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

- 6.6.4. A double flange valve of preferably 50 mm and 25 mm size shall be provided to fully drain the oil from the main tank conservator and OLTC conservator tank respectively.

- 6.6.5. Pipe work shall neither obstruct the removal of tap changers for maintenance or the opening of inspection or manhole covers.

**6.7. Condition Controlled Maintenance Free Type Breather**

- 6.7.1. The main Transformer tank conservator shall be fitted with a Maintenance-Free type dehydrating Breather which shall be equipped with a microprocessor control unit and LED status indication.

- 6.7.2. 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.

**6.7.3. 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).

6.7.4. 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.

6.7.5. 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.

6.7.6. 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.

6.7.7. The equipment shall operate at input supply of 230V AC, 50 Hz. Any converter if required shall be supplied with the equipment. Degree of Protection shall be at least IP55 for which type Test report shall be submitted. Necessary protective devices shall be provided in order to protect the equipment against over voltages & high-frequency interference.

6.7.8. The control unit shall be equipped with suitable heater to prevent moisture condensation.





- 6.7.9. The size of Condition controlled maintenance free dehydrating breather shall be decided based on the volume of transformer oil during detailed engineering.
- 6.7.10. 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.
- 6.7.11. Condition Controlled Maintenance Free Type Breather of alternate proven technology shall also be acceptable.

#### 6.8. **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 transformer. The size (Diameter) of shroud shall be such that it should not restrict rapid release of any pressure that may be generated in the tank, which may result in damage to equipment. Oil shroud should be kept away from control cubicle and clear of any operating position to avoid injury to personnel in the event of PRD operation. The device shall maintain its oil tightness under static oil pressure equal to the static operating head of oil plus 20 kPa. It shall be capable of withstanding full internal vacuum at mean sea level. It shall be mounted directly on the tank. Suitable canopy shall be provided to prevent ingress of rain water. One set of potential free contacts (with plug & socket type arrangement) per device shall be provided for tripping. Following routine tests shall be conducted on PRD:

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

#### 6.9. **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 transformer. Operating features and size shall be reviewed during design review. Suitable canopy shall be provided to





prevent ingress of rain water. Pressurised 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 is not acceptable at site.

#### 6.10. **Buchholz Relay**

One number Double float, reed type Buchholz relay complying to IS 3637/ IEC 60255 shall be provided in the connecting pipe between the oil conservator and the Transformer tank with minimum distance of five times pipe diameters between them. Any gas evolved in the Transformer 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 Transformer 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 transformer 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 transformer during the external fault conditions. Pressurised water ingress test for Terminal Box (routine tests) shall be conducted on Buchholz relay.

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

All transformers 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 230V 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 IEC 61850 compliant communications.

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

All Transformers shall be provided with a device for measuring the hot spot temperature of each winding (HV, IV and LV) 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 ±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 20V 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 /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 IEC 61850 compliant communications.

- 6.13. 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.

6.14. **Earthing Terminals**

- 6.14.1. 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.
- 6.14.2. Two earthing terminals suitable for connection to copper grounding conductor shall also be provided on each cooler, 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 through tank and connected through two flexible insulated copper links.
- 6.14.3. Equipotential 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 links.
- 6.14.4. Each transformer unit should have provision for earthing and connected to grounding mat when not in service. For this purpose, all 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.

6.15. **Core**



- 6.15.1. The core shall be constructed from non-ageing, cold rolled high permeability (HI-B) grade or better grain-oriented silicon steel laminations.
- 6.15.2. 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.
- 6.15.3. 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.
- 6.15.4. Core and winding shall be capable of withstanding the shock during transport, installation and service. Adequate provision shall be made to prevent movement of core and winding relative to tank during these conditions.
- 6.15.5. All steel sections used for supporting the core shall be thoroughly sand / shot blasted after cutting, drilling and welding.
- 6.15.6. Each core lamination shall be insulated with a material that will not deteriorate due to pressure and hot oil.
- 6.15.7. The supporting frame work of the core shall be so designed as to avoid presence of pockets which would prevent complete emptying of tank through drain valve or cause trapping of air during oil filling.
- 6.15.8. Adequate lifting lugs will be provided to enable the core and windings to be lifted.
- 6.15.9. 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 transformers. 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.
- 6.15.10. In case core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the lamination, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.
- 6.15.11. The insulation of core to tank, core to yoke clamp (frame) and yoke clamp (frame) to tank shall be able to withstand a voltage of 2.5 kV (DC) for 1 minute. Insulation resistance shall be minimum 500MΩ for all cases mentioned above.



**6.16. Windings**

- 6.16.1. The manufacturer shall ensure that windings of all transformers are made in clean, dust proof (Cleanroom class ISO 9 or better as per ISO 14644-1), humidity controlled environment with positive atmospheric pressure.
- 6.16.2. 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**.
- 6.16.3. Epoxy bonded Continuously Transposed Conductor (CTC) shall be used in main winding.
- 6.16.4. The insulation of transformer 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 transformer oil during service.
- 6.16.5. Coil assembly and insulating spacers shall be so arranged as to ensure free circulation of oil and to reduce the hot spot of the winding.
- 6.16.6. The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes.
- 6.16.7. The conductor shall be transposed at sufficient intervals in order to minimize eddy currents and to equalise the distribution of currents and temperature along the winding.
- 6.16.8. 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 considering the fact that the system will not always be in the new factory condition.
- 6.16.9. 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.
- 6.16.10. The conductor insulation shall be made from high-density (at least 0.75 gm/cc) paper having high mechanical strength. The characteristics for the paper will be reviewed at the time of design review.
- 6.16.11. Wherever required, electrostatic shield, made from material that will withstand the mechanical forces, will be used to shield the high voltage windings from the magnetic circuit.
- 6.16.12. All winding insulation shall be processed to ensure that there will be no detrimental shrinkage after assembly. All windings shall be pre-sized before being clamped.



- 6.16.13. Windings shall be provided with clamping arrangements which will distribute the clamping forces evenly over the ends of the winding.
- 6.16.14. 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.
- 6.16.15. Winding paper moisture shall be less than 0.5%.
- 6.16.16. The primary winding and secondary 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.

6.17. **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.

6.18. **Winding terminations into bushings**

- 6.18.1. Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions to ensure the integrity of the transformer in service.
- 6.18.2. 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.
- 6.18.3. 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 to get oil level inspection gauges to face in a direction for ease of inspection from ground level.
- 6.18.4. 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.
- 6.18.5. 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.

7. **Paint system and procedures**

The typical painting details for transformer 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. The detailed painting procedure shall be finalized during award of the contract.

## **8. 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.

### **8.1. 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  $\geq 15 \mu\text{m}$ .

### **8.2. Oil filling**

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

8.2.2. 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 transformer tank and should be less than 1mbar.

8.2.3. Oil filling under vacuum at site shall be done with transformer oil at a temperature not exceeding 65°C. Vacuum shall not be broken until the





Transformer is oil filled up to the Buchholz relay.

- 8.2.4. The minimum safe level of oil filling (if different from the Buchholz level) to which the Transformer shall be oil filled under vacuum, shall be indicated in the manual.
- 8.2.5. The Ultra High Vacuum type oil treatment plant (on returnable basis) of adequate capacity (**generally 6000** litres per hour and above) suitable for treatment of oil in EHV class Transformer shall be used. The plant shall be capable of treatment of new oil (as per IS 335 / IEC 60296 and reconditioning of used oil (as per IS: 1866/IEC: 60422 for oil in service) at rated capacity on single pass basis as follow:
- 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.

The above oil treatment plant (Filtration unit) shall be arranged by the bidder at his own cost.

#### 8.2.6. **Transportation of Oil**

The insulating oil for the Transformer 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 Transformer 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.

### 9. **Spare Transformer Units Connection Arrangement**

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

### 10. **Bushings**

- 10.1. Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition, substation layout and movement along with the spare Transformer 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.

10.2. 420kV, 245kV, 145kV and 52kV Bushings shall be either of the following type:

- a) RIP (Resin Impregnated paper) condenser type with composite polymer insulator (housing)
- b) or RIS (Resin Impregnated Synthetic) condenser type with composite polymer insulator (housing).

However, OIP (Oil impregnated Paper) with porcelain / composite polymer housing type is also acceptable for 52kV Bushings

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

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

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

10.4. 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.

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

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

10.6. Where current transformers are specified, the bushings shall be removable without disturbing the current transformers.

10.7. Bushings of identical rating of different makes shall be interchangeable to optimise the requirement of spares. **Mounting dimensions of bushing shall be approved from employer.**

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



- 10.9. 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)

- 10.10. Clamps and fittings shall be of hot dip galvanised/stainless steel.
- 10.11. Bushing turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay.
- 10.12. No arcing horns shall be provided on the bushings.
- 10.13. RIP/RIS Bushing shall be specially packed to avoid any damage during transit and suitable for long storage, with non-returnable packing wooden boxes with hinged type cover. Without any gap between wooden planks. Packing Box opening cover with nails/screws type packing arrangement shall not be acceptable.
- 10.14. RIP/RIS 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.

10.15. The terminal marking and their physical position shall be as per IEC: 60076.

10.16. 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.

10.17. 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/RIS) at transformer 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. Neutral Formation and Earthing Arrangement**

### **11.1. For 3-Phase Unit**

The neutral of the transformer shall be brought out through bushing. The neutral terminal of 3-phase transformer 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 conductors connected to Employer's grounding mat.

### **11.2. For 1-Phase Unit**

The neutral of the transformer shall be brought out through bushing. The contractor shall connect the neutrals of 1-phase transformers by overhead connection using an overhead common brass/tinned copper/Aluminum pipe/ACSR conductor grounding bus, supported from the tank and fire walls by using porcelain insulators. 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 by contractor. The neutral formation shall be such that neutral winding of single-phase spare transformer can be disconnected or connected to either of the three phase banks.



### 11.3. **Delta Formation (applicable for 1-Phase Transformer)**

The tertiary/LV winding terminals of the transformer shall be brought out through bushing. The contractor shall connect Tertiary/LV of 1-phase transformers in DELTA configuration by overhead connection to operate in 3-Phase Bank. The Delta shall be formed by approximate size of 3" IPS Al tube, which shall be insulated with heat shrinkage insulating sleeve or cable of suitable voltage class and adequate thickness and shall be supported by structure mounted bus post insulators at suitable intervals. The minimum phase to phase horizontal spacing for delta formation shall be 1.5 meter. All associated materials like bus post insulators, Aluminium tube, clamps & connectors, support structures; hardware etc. required for tertiary delta formation shall be provided by the contractor.

## 12. **Cooling Equipment and its Control**

### 12.1. **Cooling Equipment for Radiator Bank**

12.1.1. The cooler shall be designed using radiator banks or tank mounted radiators. However, for transformers up to **100 MVA (three-phase unit)**, **only tank-mounted radiators shall be accepted**. Design of cooling system shall satisfy the performance requirements.

12.1.2. In case of separately mounted radiator bank arrangement, the main tank shall have provision such that cooler banks can be placed on either side of the main tank without the need of any extra member/pipe maintaining the electrical clearances.

12.1.3. The radiator shall be of sheet steel in accordance with IS 513/**ISO 3574/EN 10130** and minimum thickness mm. Each radiator bank shall be provided with the following accessories:

- (a) Cooling Fans, Oil Pumps, Oil Flow Indicator (as applicable)
- (b) Top and bottom shut off valve
- (c) Drain Valve and sampling valve
- (d) Top and bottom oil filling valves
- (e) Air release plug
- (f) Two grounding terminals for termination of two (2) Nos. earthing copper conductor.
- (g) Thermometer pockets with captive screw caps at cooler inlet and outlet.
- (h) Lifting lugs

12.1.4. Each radiator bank shall be detachable and shall be provided with flanged inlet and outlet branches. Expansion joint shall be provided on top and bottom cooler pipe connection.

12.2. 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 / cooler bank shall be provided to record temperature during temperature rise test. Suitable arrangement shall be



made for bank mounted cooler arrangement.

- 12.2.1. One number standby fan shall be provided with each radiator bank.
- 12.2.2. Cooling fans shall not be directly mounted on radiator. It may cause undue vibration. These shall be located so as to prevent ingress of rain water. Each fan shall be suitably protected by galvanised wire guard. The exhaust air flow from cooling fan shall not be directed towards the main tank in any case.
- 12.2.3. Two (2), 100% centrifugal or axial in line oil pumps, if applicable, (out of which one pump shall be standby) shall be provided with each radiator bank. Measures shall be taken to prevent mal-operation of Buchholz relay when all oil pumps are simultaneously put into service. The pump shall be so designed that upon failure of power supply to the pump motor, the pump impeller will not limit the natural circulation of oil.
- 12.2.4. An oil flow indicator shall be provided for the confirmation of the oil pump operating in a normal state. An indication in the flow indicator and potential free contacts for remote alarm shall be provided.
- 12.2.5. Valves shall be provided across the pump and oil flow indicator to avoid oil drain and long outage during maintenance / replacement of pump and oil flow indicator.
- 12.2.6. Cooling fans and oil pump motors shall be suitable for operation from 400 volts, three phase 50 Hz power supply and shall be of premium efficiency class IE3 conforming to IS: 12615/ IEC 60034. Each cooling fan and oil pump motors shall be provided with starter, thermal overload and short circuit protection. The motor winding insulation shall be conventional class 'B' type. Motors shall have hose proof enclosure equivalent to IP: 55 as per IEC 60034-5.
- 12.2.7. 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.
- 12.2.8. Air release device and oil plug shall be provided on oil pipe connections. Drain valves shall be provided in order that each section of pipe work can be drained independently.

### 12.3. **Cooling Equipment Control for Radiator banks**

- 12.3.1. Automatic operation control of fans/pumps shall be provided (with temperature change) from contacts of winding temperature indicator. The Contractor shall recommend the setting of WTI for automatic changeover of cooler control over entire cooling option. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.
- 12.3.2. Suitable manual control facility for cooler fans and oil pumps shall be provided. Selector switches and push buttons shall also be provided in





the cooler control cabinet to disconnect the automatic control and start/stop the fans and pump manually.

- 12.3.3. The changeover to standby oil pump in case of failure of service oil pump shall be automatic.
- 12.3.4. In addition to the traditional starting of fan and pump by oil / winding temperature, the starting of forced cooling shall be done if the load exceeds a current setting of 0.6 p.u. for 5 seconds.
- 12.3.5. Once started, the cooling shall remain in operation for a minimum duration of 30 minutes. This timer shall be at least adjustable from 15 to 60 minutes. **Furthermore, a one-week timer is required to check the healthiness of the cooling system on a routine basis for one hour at a time.** Starting the pumps on load shall provide the cooling system a lead on the temperature that is about to follow during high loading conditions. Spurious operation should however be avoided by appropriate settings. All settings shall be adjustable.
- 12.3.6. Adequate warning/ safety labels are required to indicate that the fans may start at any time.
- 12.3.7. If any one group(s) is out of service and isolated, this shall not affect the automatic starting of the other radiator banks.
- 12.3.8. Following lamp indications shall be provided in cooler control cabinet:
- a) Cooler Supply failure (main)
  - b) Cooler supply changeover
  - c) Cooler Supply failure (standby)
  - d) Control Supply failure
  - e) Cooling fan failure for each bank
  - f) Cooling pump failure for each pump
  - g) Common thermal overload trip
  - h) Thermal overload trip for each fan/pump
  - i) No oil flow/reverse flow for pumps
  - j) Stand by fan/pump ON

One potential free initiating contact for all the above conditions shall be wired independently to the terminal blocks of cooler control cabinet and for single ph. unit connection shall be extended further to CMB.

- 12.3.9. Redundant Programmable Logic Control (PLC) based control of cooling system, meeting all specified functional requirements, shall also be acceptable.
- 12.3.10. The cooler control cabinet / Individual Marshalling box shall have all necessary devices meant for cooler control and local temperature indicators. All the contacts of various protective devices mounted on the transformer and all the secondary terminals of the bushing CTs shall also be wired upto the terminal board in the cooler control cabinet/Individual Marshalling box. All the CT secondary terminals in the cooler control cabinet shall have provision for shorting to avoid CT open circuit while it





is not in use.

12.3.11. All the necessary terminations for remote connection to Purchaser's panel shall be wired upto the Common Marshalling box (in case of 1-Ph unit) or Marshalling Box (3-Ph unit).

12.3.12. The Contractor shall derive AC power for Cooler Control Circuitry from the AC feeder. In case auxiliary power supply requirement for Cooler Control Mechanism is different than station auxiliary AC supply, then all necessary converters shall be provided by the Contractor. Details of station auxiliary power supply are mentioned in GTR.

**12.4. Unit cooler arrangement for transformer (if applicable)**

12.4.1. The cooler shall be designed using Unit Cooler arrangement with capacity as specified in Annexure-A. Design of cooling system shall satisfy the performance requirements.

12.4.2. Each Unit Cooler shall have its own cooling fans, oil pumps, oil flow indicator, shut off valves at the top and bottom of at least 80 mm size, lifting lugs, top and bottom oil filling valves, air release plug at the top, a drain and sampling valve and thermometer pocket fitted with captive screw cap on the inlet and outlet.

12.4.3. An oil flow indicator shall be provided for the confirmation of the oil pump operating in a normal state. An indication shall be provided in the flow indicator to indicate reverse flow of oil/loss of oil flow.

12.4.4. Valves shall be provided across the pump and oil flow indicator to avoid oil drain and long outage during maintenance / replacement of pump and oil flow indicator.

12.4.5. Cooling fans and oil pump motors shall be suitable for operation from 400 volts, three phase 50 Hz power supply and shall conform to IS: 12615/IEC34. Each cooling fan and oil pump motors shall be provided with starter thermal overload and short circuit protection. The motor winding insulation shall be conventional class 'B' type. Motors shall have hose proof enclosure equivalent to IP: 55 as per IEC60034-5.

12.4.6. The cooler, pipes, support structure and its accessories shall be hot dip galvanised or corrosion resistant paint should be applied to external surface of it.

12.4.7. Expansion joint shall be provided on top and bottom cooler pipe connections as per requirement.

12.4.8. Air release device and oil plug shall be provided on oil pipe connections. Drain valves shall be provided in order that each section of pipe work can be drained independently.

**12.5. Cooling Equipment Control (OFAF or ODAF) for Unit Coolers (if applicable)**



- i) Suitable manual control facility for unit cooler shall be provided.
- ii) The changeover to standby unit cooler bank oil pump in case of failure of any service unit cooler shall be automatic.
- iii) Selector switches and push buttons shall also be provided in the cooler control cabinet to disconnect the automatic control and start/stop the unit cooler manually.
- iv) Cooler fans & oil pumps of all unit coolers (except standby cooler) shall operate continuously. The starting of unit cooler shall be done as soon the Circuit Breaker of HV/IV/LV (as applicable) side is switched on.
- v) Once started the cooling shall remain in operation as long as the transformer is in service. When the transformer is switched off the cooling shall continue to run for a further duration of 30 minutes. This timer shall be at least adjustable from 15 to 60 minutes. Further, a one-week timer is required to check the healthiness of the complete cooling system on a routine basis for one hour at a time. Spurious operation should however be avoided by appropriate settings. All settings shall be adjustable
- vi) Adequate warning/ safety labels are required to indicate that the fans may start at any time.
- vii) If any one group(s) is out of service and isolated, this shall not affect the automatic starting of the other unit cooler.
- viii) Following lamp indications shall be provided in cooler control cabinet:
  - Cooler Supply failure (main)
  - Cooler supply changeover
  - Cooler Supply failure (standby)
  - Control Supply failure
  - Cooler unit failure for each unit cooler
  - No oil flow/reverse oil flow for pumps
  - Thermal overload trip for each fan / pump

One potential free initiating contact for all the above conditions shall be wired independently to the terminal blocks of cooler control cabinet and for single ph. unit connection shall be extended further to CMB.

## **12.6. Auxiliary Power Supply for OLTC, Cooler Control and Power Circuit**

### **12.6.1. For Single Phase unit**

- 12.6.1.1. Two auxiliary power supplies, 400-volt, three phase four (4) wire shall be provided at common marshalling box through bus bar arrangement. All loads shall be fed by one of the two sources through an electrically interlocked automatic transfer scheme housed in the CMB. Power supply to individual phase unit shall be extended from the CMB. Power supply to spare unit shall be extended from nearest CMB only. Suitably rated power



contactors, separate MCBs/MCCBs shall be provided in the Common Marshalling Box for each circuit.

12.6.1.2. For each circuit, suitably rated MCBs/MCCBs as required for further distribution of auxiliary power supply to DM boxes, Online moisture monitoring system and Online DGA system etc.(as applicable), shall be provided by contractor, in individual marshalling boxes /cooler control boxes. Power from CMB (through bus bar at CMB) to IMB (at bus inside) through cable shall be provided by contractor.

12.6.1.3. Auxiliary power supply distribution scheme shall be submitted for approval.

12.6.1.4. Supply and laying of Power, Control and special cables from common marshalling box to individual MB/Cooler Control Cubicle (including spare unit) & further distribution from IMB/CCC to all accessories is in the scope of the contractor. Further any special cable (if required) from CMB to Owner's Control Panels/Digital RTCC panels is also in the scope of the contractor.

#### 12.6.2. **For Three Phase Transformer**

12.6.2.1. Two auxiliary power supplies, 400-volt, three phase four (4) wire shall be provided by the Purchaser at cooler control cabinet / Marshalling Box. All loads shall be fed by one of the two sources through an electrically interlocked automatic transfer scheme housed in the cooler control cabinet / Marshalling.

12.6.2.2. For each circuit, suitably rated power contactors, MCBs/MCCBs as required for entire auxiliary power supply distribution scheme including distribution to DM boxes, Online Gases and moisture monitoring system etc. (as applicable), shall be provided by contractor in cooler control cabinet/ Marshalling.

12.6.2.3. Auxiliary power supply distribution scheme shall be submitted for approval. Supply and laying of Power, Control and special cables from marshalling box to all accessories is in the scope of the contractor. Further any special cable (if required) from MB to Owner's Control Panels/Digital RTCC panels is also in the scope of the contractor.

12.6.3. **Design features of the transfer scheme** shall include the following:

- a) Provision for the selection of one of the feeders as normal source and other as standby.
- b) Upon failure of the normal source, the loads shall be automatically transferred after an adjustable time delay to standby sources.
- c) Indication to be provided at cooler control cabinet/Individual Marshalling Box/Common 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.



12.6.4. For spare unit which is not connected through isolator switching arrangement, 400 volt, three phase four (4) wire AC supply shall be provided for heater, On line DGA etc. as applicable. Necessary cabling in this regard shall be done by the Contractor.

## 12.7. Valves

12.7.1. 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.

12.7.2. Suitable means shall be provided for locking the valves in the open and close positions. Provision is not required for locking individual radiator valves.

12.7.3. Each valve shall be provided with the indicator to show clearly the position (open/close) of the valve.

12.7.4. All valves flanges shall have machined faces. Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently.

12.7.5. All valves in oil line shall be suitable for continuous operation with transformer oil at 115 deg C.

12.7.6. Gland packing/gasket material shall be of "O" ring of nitrile rubber for all the valve's flanges. All the flanges shall be machined.

12.7.7. The oil sampling point for main tank shall have two identical valves put in series. Oil sampling valve shall have provision to fix rubber hose of 10 mm size to facilitate oil sampling.

12.7.8. Valves or other suitable means shall be provided to fix various on line condition monitoring systems to facilitate continuous monitoring.

Type of valves shall be used for transformer 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	OLTC- tank equalizing valve	Gate / Needle
8	OLTC Drain cum filling valve	Gate
9	Valve for vacuum application on Tank	Gate



Sr. No.	Description of Valve	Type
10	Conservator Drain valve	Gate
11	Aircell equalizing valve	Gate/Globe/Ball
12	Valve for Conservator vacuum (top)	Gate
13	Filter valve for Cooler Bank (Header)	Gate
14	Cooler Bank isolation valve	Butterfly
15	Pump Isolation valve	Butterfly
16	Valve for N2 injection (NIFPS) (if applicable)	Gate
17	Valve for NIFPS Drain (if applicable)	Gate

#### 12.7.9. **Flow sensitive conservator Isolation valve**

- a) In order to restrict the supply of oil in case of a fire in transformer, 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.

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

### 13. **Cabling**

- 13.1. 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 copper and shall be routed through covered cable tray or GI conduit and shall be properly dressed.

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.

- 13.2. Cabling of spare unit with isolator switching arrangement shall be in such a way that spare unit of transformer 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. Changeover of RTCC signals shall be carried out in CMB.

#### **14. Tap Changing Equipment**

Each transformer shall be provided with Off load tap / On Load Tap changing equipment as specified elsewhere.

##### **14.1. Off load tap Changer equipment (if applicable)**

The off load / Off Circuit tap changer (OCTC) equipment shall be handle operated with a locking arrangement along with tap position indicator. The external handle shall be situated in an unobstructed position. The contacts are positively self-locating in each tapping position without constraint from the operating mechanism. The rating of the contacts shall be suitable to carry maximum current of the transformer. For three phase transformer the tap change switch shall simultaneous switch the similar taps on the three phases. A warning plate indicating that OCTC shall be operated only when the transformer is de-energised, shall be fitted.

##### **14.2. ON Load Tap Changing (OLTC) Equipment (Vacuum or Oil type)**

###### **14.2.1. Main OLTC Gear Mechanism**

- 14.2.1.1. Each single / three phase transformer shall be provided with voltage control equipment of the tap changing type for varying its effective transformation ratio whilst the transformers are on load.

- 14.2.1.2. 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 transformer 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 transformer. The contacts shall be accessible for inspection without lowering oil level in the main tank and the contacts shall be replaceable.





- 14.2.1.3. 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 transformer.
- 14.2.1.4. 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.
- 14.2.1.5. Tap changer shall be so mounted that bell cover of transformer can be lifted without removing connections between windings and tap changer.

14.2.2. **Local OLTC Control Cabinet (Drive Mechanism Box)**

Each transformer unit of OLTC gear shall have following features:

- 14.2.2.1. 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.
- 14.2.2.2. 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 transformer.
  - A 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.
- 14.2.2.3. 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.
- 14.2.2.4. 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.

14.2.2.5. All relays and operating devices shall operate correctly at any voltage within the limits specified in Chapter - 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.

14.2.2.6. 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.

14.2.2.7. 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.

14.2.2.8. OLTC local control cabinet shall be provided with tap position indication for the transformer. 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.

14.2.2.9. '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.



- 14.2.2.10. Following minimum LED indications shall be provided in DM box:
- INCOMPLETE STEP which shall not operate for momentary loss of auxiliary power.
  - OLTC motor overload protection operated
  - Supply to DM Motor fail
  - OLTC IN PROGRESS
  - Local / Remote Selector switch position of DM
  - OLTC upper/lower limits reached
  - 400V Main AC supply ON
  - 400V Standby AC supply ON
- 14.2.2.11. Following minimum contacts shall be available in DM Box, which shall be wired to CMB for single phase unit. Further these contacts shall be wired to Digital RTCC panel:
- INCOMPLETE STEP which shall not operate for momentary loss of auxiliary power.
  - OLTC motor overload protection operated
  - Supply to DM Motor fail
  - OLTC IN PROGRESS
  - Local / Remote Selector switch position of DM
  - OLTC upper/lower limits reached
- 14.2.2.12. 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.
- 14.2.2.13. A permanently legible lubrication chart if required shall be fitted within the OLTC local control cabinet.
- 14.3. **OLTC Control from Common Marshalling Box (CMB)**
- 14.3.1. It shall be possible to monitor, control/operate, the OLTC of all the three 1-phase transformers of a transformer bank from Common Marshalling Box. The control and monitoring terminations of a spare transformer unit (1-Ph) shall be brought to CMB. The necessary switching arrangement through male-female plug-in TB assembly shall be provided for replacing spare unit with any one of the faulty phase unit for monitoring & control from CMB.
- 14.3.2. 'Independent-combined-remote selector switch, raise/lower switch and emergency stop Push Button shall be provided in the common marshalling box for OLTC control.
- 14.3.3. When the selector switch is in **independent** position, the OLTC control shall be possible from individual Local OLTC Control Cabinet (DM Box) only.
- 14.3.4. In '**combined position**', raise-lower switch (provided in the CMB), shall be used to operate for bank of three single phase transformers from CMB.



- 14.3.5. In '**remote position**' control of OLTC shall be possible from Digital RTCC/SCADA etc.
- 14.3.6. From CMB, the operation of OLTC shall be for 3-phases of transformer units without producing phase displacement. Independent operation of each single-phase transformer from CMB/ Digital RTCC/SCADA will be prevented.
- 14.3.7. Following minimum **LED indications** shall be provided in CMB:
- a. INCOMPLETE STEP
  - b. OLTC motor overload protection
  - c. Supply to DM Motor fail
  - d. OLTC IN PROGRESS
  - e. Local / Remote Selector switch positions of DM
  - f. OLTC upper/lower limits reached
  - g. 400V Main AC supply ON
  - h. 400V Standby AC supply ON

Following **contacts** shall be wired to TBs in CMB for further wiring to C & R Panels.

- i. 400V Main AC supply Fail
- j. 400V Standby AC supply Fail

Following **contacts** shall be wired to TBs in CMB for further wiring to digital RTCC Panel:

- a. INCOMPLETE STEP
- b. OLTC motor overload protection
- c. Supply to DM Motor fail
- d. OLTC IN PROGRESS
- e. Local / Remote Selector switch positions of DM
- f. OLTC upper/lower limits reached
- g. 'Independent-combined-remote' selector switch positions of CMB

Further, OLTC Tap position Digital indications for all three 1-Ph Transformer units either separately or through selector switch shall be provided in CMB. The same shall also be wired to Digital RTCC Panel to display tap positions for all three 1-ph unit separately.

#### 14.4. **Digital RTCC Panel**

- 14.4.1. 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.
- 14.4.2. Each Digital RTCC relay shall be used to control 1 bank of transformers (i.e. 3 Nos. 1- Phase units or 1 No. 3-Phase 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.

For existing substations, the requirements of RTCC relays are specified in



Chapter- PSR and digital relays and associated required cables and accessories for the same shall be included in the scope.

- 14.4.3. 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 transformer / 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.

All Digital RTCC Relays shall be of same make for smooth integration of these relays for parallel operations of all transformers in the substation.

- 14.4.4. The RTCC Panel shall be provided with digital RTCC relay having Raise/Lower push buttons, Manual/ Automatic mode selection features, Master / Follower/ Independent/ Off mode selection features for control of OLTC. Touch screen option in the relay, instead of electrical push button/switch is also acceptable.

- 14.4.5. **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.

- 14.4.6. **In Auto Mode:** In Auto mode, digital RTCC relay shall automatically control OLTC taps based on power system voltage and voltage set points. An interlock shall be provided to cut off electrical control automatically upon recourse being taken to the manual control in emergency.

- 14.4.7. **Master / Follower/ Independent/ Off mode**

Master / Follower parallel operation is required with Group simultaneous feature in Digital RTCC relay. Master-follower scheme implies that controlled decision shall be taken by the Master and control actions (Raise/Lower tap position) shall be executed simultaneously by Master & Follower units. Same logic needs to be implemented in digital RTCC relays.

**Master Position:** If the digital RTCC relay is in master position, it shall be possible to control the OLTC units of other parallel operating transformers in the follower mode by operation from the master unit.

**Follower Position:** If the digital RTCC relay is in Follower position, control of OLTC shall be possible only from panel where master mode is selected.

**Independent Position:** In independent position of selector switch, control of OLTC shall be possible only from the panel where independent



mode is selected.

Suitable interlock arrangement shall be provided to avoid unwanted/inconsistent operation of OLTC of the transformer

14.4.8. **Raise/Lower control:** The remote OLTC scheme offered shall have provision to raise or lower taps for the complete bank of three 1-phase transformers / 3-Phase Transformers. Individual 1-phase OLTC operation shall not be possible from the remote control panel.

14.4.9. 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 transformer in real time. The digital RTCC Relay shall have multiple selectable set point voltages and it shall be possible to select these set points from SCADA, with a facility to have the possibility of additional set points command from SCADA.

Communication between the Digital RTCC relays to execute the commands for parallel operation shall be implemented using required communication protocol. IEC- 61850 GOOSE messaging between Digital RTCC relays for OLTC parallel operation is not permitted. Suitable communication hardware shall be provided to communicate up to distance of 1km between digital RTCC relays. Scope shall also include communication cables between digital RTCC relays. Cables as required for parallel operation of OLTCs of all transformers (including existing transformers wherever required) from Digital RTCC relays shall be considered included in the scope of bidder.

14.4.10. 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.

14.4.11. 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 so that only one tap change from each tap changing pulse shall be effected. If the command remains in the "operate" position, lock-out of the mechanism is to be ensured.

14.4.12. 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 transformer units
- h. Independent-combined-remote selector switch positions of CMB (In case of single-phase transformer)
- i. 400V, AC Main Supply Fail.
- j. 400V, AC Standby Supply Fail

14.4.13. In case of parallel operation or 1-Phase Transformer unit banks, OLTC out of step alarm shall be generated in the digital RTCC relay for discrepancy in the tap positions.

## **15. SCADA Integration and Interconnection**

15.1.1. All required power & control cables including optical cable, patch chord (if any) upto MB (for 3-Ph unit) or Common MB (for 1-Ph unit) shall be in the scope of contractor. Further, any special cable between MB (for 3-Ph unit) or Common MB (for 1-Ph unit) to switchyard panel room/control room shall be under the present scope. All cable from RTCC to OLTC Drive Mechanism Box shall be provide (if applicable).

15.1.2. Fiber optic cable, power cable, control cables, as applicable, between MB (for 3-Ph unit) or Common MB (for 1-Ph unit) 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.

15.1.3. Cooling and OLTC of transformers shall be monitored and controlled from SCADA.

15.1.4. SCADA Integration of online monitoring equipment:

All the online monitoring equipment i.e. Online Dissolved Gas (Multi-gas) and Moisture Analyser, Online Bushing Monitoring System etc. provided for individual transformer 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/220V or as per available Station DC supply). Ethernet switch shall be suitable for operation at ambient temperature of 50 Deg C.

## **16. Constructional features of Cooler Control Cabinet/ Individual Marshalling Box/ Common Marshalling Box/ Junction Box / Outdoor cubicle and Digital RTCC Panel**

16.1. Each transformer unit shall be provided with local OLTC Drive Mechanism Box, cooler control cabinet /individual marshalling box, Digital RTCC panel (as applicable) and common marshalling (for a bank of three 1-phase units) shall be provided.

16.2. Common marshalling box (for single phase unit) shall be floor mounted and of size, not less than 1600mm (front) X 650mm (depth) X 1800mm





(height). Individual Marshalling Box and Cooler control Box shall be tank mounted or ground mounted. The gland plate shall be at least 450 mm above ground level (for ground mounted panel).

- 16.3. The cooler control cabinet / individual marshalling box, common marshalling box, Junction box and all other outdoor cubicles (**except OLTC Drive Mechanism box**) shall be made of stainless steel sheet of minimum grade of SS304 and of minimum thickness of 1.6 mm. Digital RTCC panel shall be made of CRCA sheet of minimum thickness of 2.5mm and shall be painted suitably as per **Annexure -D**.
- 16.4. The degree of protection shall be IP: 55 for outdoor and IP: 43 for indoor in accordance with 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 / 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 in line with latest international standard.
- 16.6. 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.
- 16.7. The size of Common marshalling box shall not be less than 1600mm (front) X 650mm (depth) X 1800mm (height). All the separately mounted cabinets and panels shall be free standing floor mounted type and have domed or sloping roof for outdoor application.

## **17. Current Transformer**

- 17.1. Current transformers shall comply with IEC 61869 (part 1 & 2).
- 17.2. It shall be possible to remove the turret mounted current transformers from the Transformer tank without removing the tank cover. Necessary precautions shall be taken to minimize eddy currents and local heat generated in the turret.
- 17.3. Current 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.
- 17.4. For 1-Phase Transformer, one number single phase current transformer (outdoor separately mounted) for earth fault protection shall be provided for each bank of transformer and shall be located in the neutral conductor connecting common neutral point with earth.
- 17.5. 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 Purchaser's approval before proceeding with the design of bushing current transformers.

**18. Oil Storage Tank (if specified in BPS)**

- 18.1. Oil storage tank shall be of capacity as specified in BPS along with complete accessories. The oil storage tank shall be designed and fabricated as per relevant Indian Standards e.g. IS: 803/API 650/EN 14015 or other internationally acceptable standards. 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 adequate thickness. Diameter of the tank shall be 2.0 meter approximately. The tank shall be designed for storage of oil at a temperature of 100 deg C.
- 18.2. The maximum height of any part of the complete assembly of the storage tank shall not exceed 4.0 metres above road top.
- 18.3. 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.
- 18.4. The tank shall also be fitted with manhole, outside & inside access ladder, silica gel breather assembly, inlet & outlet valve, oil sampling valve with suitable adapter, 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 from the tank.
- 18.5. The following accessories shall also form part of supply along with each Oil storage tank:
  - a) Four numbers of 50NB suitable rubber hoses for transformer 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.
  - b) 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.



- c) One number of digital vacuum gauge with sensor capable of reading up to 0.001 torr, operating on 230V 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.

- 18.6. The painting of oil storage tank and its control panel shall be as per technical specification.
- 18.7. 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.

## **19. Oil Sampling Bottle (if specified in BPS)**

Oil sampling bottles (if specified in BPS) shall be suitable for collecting oil samples from transformers 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.

## **20. Oil Syringe (if specified in 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.



**21. 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.

**22. Test Kit (if specified in BPS)**

BDV Kit as per Annexure-H of specification

Portable DGA Kit as per Annexure-I of specification

Transformer Oil Filtration Plan as per Annexure-P of specification

**23. Fittings & accessories**

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

- a. Conservator for main tank with aircell, oil filling hole and cap, isolating valves, drain valve, magnetic oil level gauge (with canopy) with high and low oil level alarm contacts and prismatic oil level gauge and Condition Controlled Maintenance Free Type Breather etc.
- b. Pressure relief devices including canopy with special shroud to direct oil
- c. Sudden pressure relief relay (for 400kV Transformer only) including canopy
- d. Buchholz relay double float, reed type with canopy and isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm / trip contacts (gas collecting device)
- e. Air release plug
- f. Conservator air cell rupture detection relay
- g. Inspection openings and covers
- h. Bushing of each type with metal parts and gaskets to suit the termination arrangement



- i. Winding & Oil temperature indicators
- j. Cover lifting eyes, transformer lifting lugs, jacking pads, towing holes and core and winding lifting lugs
- k. Protected type mercury or alcohol in glass thermometer or magnetic or micro- switch type dial type temperature indicator as applicable
- l. Rating and diagram plates (in Hindi & English) on transformers and auxiliary apparatus
- m. Roller Assembly (as per clause 6.4)
- n. On load tap changing gear, OLTC DM Box, Off Circuit Tap Changer (OCTC) individual marshalling box / Cooler control cabinet, Common Marshalling Box, and Digital RTCC Panel as applicable
- o. Cooling equipment
- p. Bushing current transformers, Neutral CT (if applicable)
- q. Oil flow indicators (if applicable)
- r. Terminal marking plates
- s. Valves schedule plate
- t. All the valves as per clause 6.1.9 d), e) and 12.7 above
- u. Ladder (suitably placed to avoid fouling with bushing or piping) to climb up to the transformer tank cover with suitable locking arrangement to prevent climbing during charged condition. Additional ladder for conservator in case it is not tank mounted.
- v. Suitable Platform for safe access of Flow sensitive non-return valve and buchholz relay shall be provided, in case these are not accessible from transformer top.
- w. Haulage lugs
- x. Neutral bus connection arrangement (3-Phase Transformer)
- y. Brass/tinned copper grounding bar supported from the tank by using porcelain insulator and flexible conductor for earthing of neutral and Line terminals as per clause 6.15.4
- z. Online Dissolved Gas (Multi-8 gas) and Moisture Measuring Equipment (if specified in Chapter-PSR) as per **Annexure-J**
- aa. Online Dissolved Gas (Multi-4 gas) and Moisture Measuring Equipment (if specified in Chapter-PSR) as per **Annexure-K**
- bb. On line dissolved Hydrogen and Moisture Measuring Equipment (if



specified in Chapter PSR) as per Annexure-L

- cc. Nitrogen Injection Type Fire Prevention & Extinguishing System (if specified in BPS) as per Annexure – M
- dd. On line bushing monitoring system (if specified in Chapter PSR) as per Annexure – N
- ee. All Cables (Power, control and shielded / twisted pair for 4-20mA cable from Transformer MB, Cooler control cubicle, etc. (as applicable) to CMB shall be under the present scope. Any special cable if required to be included upto RTCC panel/ employer's C&R panel.
- ff. Managed Ethernet switch, LIU patch cords etc. (if applicable) shall be provided in CMB/MB (as per clause 15). All IEC 61850 compliant signals from various monitoring equipment/accessories shall be wired upto the Ethernet switch.
- gg. Flow sensitive conservator Isolation valve
- hh. Flanged bi-directional wheels

## 24. Inspection and Testing

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

### 24.1. 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 & relevant international standard**”. Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the contractor.

### 24.2. Type Tests on Bushing & accessories:

Type test reports of following Bushing & accessories, shall be





furnished by the contractor along with drawings.

- 1) Bushing (Type Test as per IEC:60137 for all voltage class, additionally Snap back & Seismic test report shall be submitted for 400 kV class bushing)
- 2) OLTC (as per IEC:60214 including IP-55)
- 3) Marshalling & common marshalling box and other outdoor cubicle (IP-55 test)
- 4) RTCC IP-43

#### 24.3. **Pre-Shipment Checks at Manufacturer's Works**

24.3.1. Check for inter-changeability of components of similar transformers for mounting dimensions.

24.3.2. Check for proper packing and preservation of accessories like radiators, bushings, dehydrating breather, rollers, buchholz relay, fans, control cubicle, connecting pipes, conservator etc.

21.3.1. Before dispatch of Transformer 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.

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

21.3.3. 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.

#### 24.4. **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.

#### 24.5. **Receipt and Storage Checks**

24.5.1. Check and record condition of each package, visible parts of the transformer etc. for any damage.



24.5.2. Check and record the gas pressure in the transformer tank as well as in the gas cylinder.

24.5.3. Check and record reading of impact recorder at receipt and verify the allowable limits as per manufacturer's recommendations.

24.6. **Installation Checks**

24.6.1. Visual check for wedging of core and coils before filling up with oil and also check conditions of core and winding in general.

24.6.2. Inspection and performance testing of accessories like tap changers, cooling fans, oil pumps etc.

24.6.3. Check the direction of rotation of fans and pumps and Check the bearing lubrication.

24.6.4. Check whole assembly for tightness, general appearance etc.

24.6.5. Oil leakage test

24.6.6. Capacitance and tan delta measurement of bushing before fixing/connecting to the winding, contractor shall furnish these values for site reference.

24.6.7. Leakage check on bushing before erection

24.6.8. Measure and record the dew point of gas in the main tank before assembly.

24.7. **Commissioning Checks**

24.7.1. Check the breather healthiness.

24.7.2. Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.

24.7.3. Check the bushing for conformity of connection to the lines etc.,

24.7.4. Check for correct operation of all protection devices and alarms/trip :

- i. Buchholz relay
- ii. Excessive winding temperature
- iii. Excessive oil temperature
- iv. Low oil flow
- v. Low oil level indication
- vi. Fan and pump failure protection

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

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



- i) Control wiring
  - ii) Cooling system motor and control
  - iii) Main windings
  - iv) Tap changer motor and control
- 24.7.7. Check for cleanliness of the transformer and the surroundings
- 24.7.8. 2 kV AC for 1 minute test between bushing CT terminal and earth.
- 24.7.9. Phase out and vector group test
- 24.7.10. Ratio test on all taps
- 24.7.11. Magnetising current test
- 24.7.12. Capacitance and Tan delta measurement of winding and bushing
- 24.7.13. Frequency response analysis (FRA). FRA equipment shall be arranged by purchaser.
- 24.7.14. DGA of oil just before commissioning and after 24 hours energisation at site.
- 24.7.15. Gradually put the transformer on load, check and measure increase in temperature in relation to the load and check the operation with respect to temperature rise and noise level etc.
- 24.7.16. Continuously observe the transformer operation at no load for at least 24hours.
- 24.7.17. Contractor shall prepare a comprehensive commissioning report including all commissioning test results as per Pre-Commissioning Procedures forward to Purchaser for future record.



**Annexure – A****1.0 Technical Particulars / Parameters of Transformers (220/132/33 kV 3-Phase Auto Transformer)**

<b>Claus e No.</b>	<b>Description</b>	<b>Unit</b>	<b>Technical Parameters</b>
3.1	Rated Capacity		
	HV	MVA	66.67
	IV	MVA	66.67
	LV (Tertiary)	MVA	5MVA (Thermal loading) (However, No loading only delta formation in this scope)
3.2	Voltage ratio (Line to Line)		220/132/33
3.3	Vector Group (3-Phase)		YNad11
3.4	Single/Three Phase Design		1 (SINGLE)
3.5	Applicable Standard		IEC 60076
3.6	Cooling		ONAN / ONAF
3.7	Rating at different cooling	%	80 / 100
3.8	Cooler Bank Arrangement		2X50%
3.9	Frequency	Hz	50
3.10	Tap Changer (OLTC)		+10% to -10% in 1.25% steps on common end of series winding for 220kV side voltage variation
3.11	Type of Transformer		Constant Ohmic impedance type (Refer note 1)
3.12	Impedance at 75 Deg C		
	HV – IV		
	Max. Voltage tap	%	10.3
	Principal tap	%	12.5
	Min. Voltage tap	%	15.4
	HV – LV		
	Principal tap (minimum)	%	45.0
	IV – LV		
	Principal tap (minimum)	%	30.0
3.13	Tolerance on Impedance (HV-IV)	%	As per IEC
3.14	Service		Outdoor
3.15	Duty		Continuous
3.16	Overload Capacity		IEC-60076-7
3.17	Temperature rise over 50deg C ambient Temp		
i)	Top oil measured by thermometer	°C	45
ii)	Average winding measured by resistance method	°C	50
3.18	Winding hot spot rise over yearly weighted temperature of 32 °C	°C	61
3.19	Tank Hotspot Temperature	°C	110
3.20	Maximum design ambient temperature	°C	50



Claus e No.	Description	Unit	Technical Parameters
3.21	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV <sub>p</sub>	950
	IV	kV <sub>p</sub>	650
	LV	kV <sub>p</sub>	250
	Neutral	kV <sub>p</sub>	95
ii)	Chopped Lightning Impulse withstand Voltage		
	HV	kV <sub>p</sub>	1045
	IV	kV <sub>p</sub>	715
	LV	kV <sub>p</sub>	275
iii)	Switching Impulse withstand Voltage		
	HV	kV <sub>p</sub>	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV <sub>rms</sub>	395
	IV	kV <sub>rms</sub>	275
	LV	kV <sub>rms</sub>	95
	Neutral	kV <sub>rms</sub>	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤ 0.5
3.22	Bushing		
i)	Rated voltage		
	HV	kV	245
	IV	kV	145
	LV	kV	52
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	1250
	IV	A	2000
	LV	A	3150
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV <sub>p</sub>	950
	IV	kV <sub>p</sub>	650
	LV	kV <sub>p</sub>	250
	Neutral	kV <sub>p</sub>	170
iv)	Switching Impulse withstand Voltage		
	HV	kV <sub>p</sub>	750
v)	One Minute Power Frequency withstand Voltage		
	HV	kV <sub>rms</sub>	505
	IV	kV <sub>rms</sub>	305
	LV	kV <sub>rms</sub>	105



Claus e No.	Description	Unit	Technical Parameters			
	Neutral	kV <sub>rms</sub>	77			
vi)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)			
	HV	mm	7595			
	IV	mm	4495			
	LV	mm	1612			
	Neutral	mm	1116			
vii)	Max Partial discharge level at U <sub>m</sub>					
	HV	pC	10			
	IV	pC	10			
	LV	pC	10			
3.23	Max Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100			
3.24	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	80			
3.25	<b>Maximum Permissible Losses of Transformers</b>					66.67 MVA
i)	Max. No Load Loss at rated voltage and frequency	kW				Guarante ed by Manufac turer
ii)	Max. Load Loss between HV & IV at rated current and frequency and at 75 <sup>0</sup> C	kW				Guarante ed by Manufac turer
iii)	Max. I <sup>2</sup> R Loss at rated current at 75 <sup>0</sup> C	kW				Guarante ed by Manufac turer
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW				Guarante ed by Manufac turer

**Notes:**

1. For parallel operation with existing transformer, the impedance, OLTC connection & range and the winding configuration (if necessary) is to be matched.
2. No external or internal Transformers / Reactors are to be used to achieve the specified HV/IV, HV/LV and IV/LV impedances.
3. Tan delta of Winding shall be measured at ambient temperature. No temperature correction factor shall be applied.
4. External minimum clearances in air for Phase to Phase and Phase to Earth shall be provided as per IEC60076-3.





### Annexure -B Test Plan

No.	Test	$132 \geq U_m \leq 170kV$	$U_m > 170kV$
1.	Measurement of winding resistance at all taps	Routine	Routine
2.	Voltage ratio measurement	Routine	Routine
3.	Polarity test & Vector Group Test	Routine	Routine
4.	Magnetizing current and Magnetic balance test (for three phase Transformer only)	Routine	Routine
5.	Measurement of insulation resistance & Polarization Index Measurement of insulation resistance between Core, Frame & Tank	Routine	Routine
6.	Measurement of insulation power factor and capacitance between winding and earth and Bushings	Routine	Routine
7.	No-load loss and current measurement	Routine	Routine
8.	Impedance and load loss measurement	Routine	Routine
9.	Full wave lightning impulse test for the line terminals (LI)	Routine	-
10.	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
11.	Applied voltage test (AV)	Routine	Routine
12.	Induced voltage withstand test (IVW)	Routine	-
13.	Induced voltage test with PD measurement (IVPD)	Routine	Routine
14.	On-load tap changer test (Ten complete cycle before LV test)	Routine	Routine
15.	Gas-in-oil analysis	Routine	Routine
16.	Core assembly dielectric and earthing continuity test	Routine	Routine
17.	Oil leakage test on transformer tank	Routine	Routine
18.	Appearance, construction and dimension check	Routine	Routine
19.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed )	Routine	Routine
20.	Measurement of no load current & Short circuit Impedance with 400 V, 50 Hz AC.	Routine	Routine
21.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports )	Routine	Routine
22.	High voltage with stand test on auxiliary equipment and wiring after assembly	Routine	Routine
23.	CT Ratio and polarity test	Routine	Routine
24.	Tank vacuum test	Routine	Routine
25.	Tank pressure test	Routine	Routine
26.	Switching impulse test for the line terminal (SI)	Type	Routine
27.	Line terminal AC withstand voltage test (LTAC)	Routine	Type
28.	Measurement of transferred surge on LV or Tertiary as applicable due to HV lightning impulse and IV lighting impulse (as applicable)	Type	Type
29.	Lightning impulse test for the neutral terminals (LIN)	Type	Type
30.	Temperature rise test	Type	Type
31.	Measurement of Zero seq. reactance(for three phase Transformer only)	Type	Type
32.	Measurement of harmonic level in no load current	Type	Type
33.	Measurement of acoustic noise level	Type	Type
34.	Measurement of power taken by fans and oil pumps (Not applicable for ONAN)	Type	Type
35.	Dynamic Short circuit withstand test (If specified in BPS)	Special	Special



### Annexure -B Test Plan

No.	Test	U <sub>m</sub> ≤ 72.5 kV
1.	Measurement of winding resistance at all taps	Routine
2.	Voltage ratio measurement	Routine
3.	Polarity test & Vector Group Test	Routine
4.	Magnetizing current and Magnetic balance test (for three phase Transformer only)	Routine
5.	Gas-in-oil analysis	Routine
6.	Core assembly dielectric and earthing continuity test	Routine
7.	Measurement of insulation resistance & Polarization Index	Routine
8.	Measurement of insulation power factor and capacitance between winding and earth and Bushings	Routine
9.	No-load loss and current measurement	Routine
10.	Impedance and load loss measurement	Routine
11.	Full wave lightning impulse test for the line terminals (LI)	Routine
12.	Chopped wave lightning impulse test for the line terminals (LIC)	Type
13.	Applied voltage test (AV)	Routine
14.	Induced voltage withstand test (IVW)	Routine
15.	Induced voltage test with PD measurement (IVPD)	Type
16.	On-load tap changer test (Ten complete cycle before LV test)	Routine
17.	Oil leakage test on transformer tank	Routine
18.	Appearance, construction and dimension check	Routine
19.	Short duration heat run test (N o t Applicable for unit on which temperature rise test is performed)	Routine
20.	Measurement of no load current & Short circuit Impedance with 400 V, 50 Hz AC.	Routine
21.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine
22.	High voltage with stand test on auxiliary equipment and wiring after assembly	Routine
23.	CT Ratio and polarity test	Routine
24.	Tank vacuum test	Routine
25.	Tank pressure test	Routine
26.	Lightning impulse test for the neutral terminals (LIN)	Type
27.	Temperature rise test	Type
28.	Measurement of Zero seq. reactance (for three phase Transformer only)	Type
29.	Measurement of harmonic level in no load current	Type
30.	Measurement of acoustic noise level	Type
31.	Dynamic Short circuit withstand test (If specified in BPS)	Special



### Annexure –C Design Review Document

Sr. No.	Description
1.	Core and Magnetic Design
2.	Over-fluxing characteristics upto $1.7U_m$
3.	Inrush-current characteristics while charging from HV & IV respectively.
4.	Winding and tapping design
5.	Short-circuit withstand capability including thermal stress for min. 2 Sec.
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.	Tap changers
15.	Protective devices
16.	Fans, pumps and radiators
17.	Sensors and protective devices– its location, fitment, securing and level of redundancy
18.	Oil and oil preservation system
19.	Corrosion protection
20.	Electrical and physical Interfaces with substation
21.	Earthing (Internal & External)
22.	Processing and assembly
23.	Testing capabilities
24.	Inspection and test plan
25.	Transport and storage
26.	Sensitivity of design to specified parameters
27.	Acoustic Noise
28.	Spares, inter-changeability and standardization
29.	Maintainability
30.	PRD and SPR (number & locations)
31.	Conservator capacity calculation
32.	Winding Clamping arrangement details with provisions for taking it “in or out of tank”
33.	Conductor insulation paper details
34.	The design of all current connections
35.	Location & size of the Valves



**Annexure – D**  
**Painting Procedure**

<b>PAINTING</b>	<b>Surface preparation</b>	<b>Prime r coat</b>	<b>Intermediate undercoat</b>	<b>Finish coat</b>	<b>Total dry film thick-ness (DFT)</b>	<b>Colour shade</b>
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	--	--	--	--



<b>PAINTING</b>	<b>Surface preparation</b>	<b>Primer coat</b>	<b>Intermediate undercoat</b>	<b>Finish coat</b>	<b>Total dry film thickness (DFT)</b>	<b>Colour shade</b>
Digital RTCC Panel	Seven tank process as per IS:3618 & IS:6005/ <b>ISO 9717, ISO 16274 &amp; ASTM B 733</b>	Zinc chromate primer (two coats)	--	EPOXY paint with PU top coat or POWDER coated	Minimum 80µm / for powder coated minimum 100µm	RAL 7035 shade for exterior and Glossy white for interior
Control cabinet / 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 a) for bulk supply b) for delivery in drums	IEC 60814	(Max.) 30 mg/kg 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: 4 to12 % Paraffins: <50% & 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.) (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)





Sl. No.	Property	Test Method	Limits
8.	Presence of oxidation inhibitor	IS 13631 or IEC 60666	0.08% (Min.) to 0.4% (Max.) Oil should contain no other additives. 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: < 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) 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)



Sl. No.	Property	Test Method	Limits
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**

**4 Technical Parameters of Current Transformers for 200MVA, 220/132kV 3-Ph Transformers)**

Description	Current Transformer Parameters (Transformer)		
	HV Side	IV Side	Neutral Side
<b>(a) Ratio</b>			
CORE 1 for 200 MVA	1000/1	1000/1	1000/1
CORE 1 for 160 & 100 MVA	800/1	800/1	800/1
CORE 2 for 200 MVA	600/1	1000/1	-
CORE 2 for 160 & 100 MVA	500/1	800/1	-
<b>(b) Minimum knee point voltage or burden and accuracy class</b>			
CORE 1 for 200 MVA	1000V, PX	1000V, PX	1000V, PX
CORE 1 for 160 MVA	800V, PX	800V, PX	800V, PX
CORE 2	0.2S Class 15VA ISF < 5	0.2S Class 15VA ISF < 5	-
<b>(c) Maximum CT Secondary Resistance</b>			
CORE 1	1.5 Ohm	1.5 Ohm	1.5 Ohm
CORE 2	-	-	-
<b>(d) Application</b>			
CORE 1	Restricted Earth Fault	Restricted Earth Fault	Restricted Earth Fault
CORE 2	Metering	Metering	-
<b>(e) Maximum magnetization current (at knee point voltage)</b>			
CORE 1	100 mA	100 mA	100 mA
CORE 2	-	-	-

NOTE:

- i) Parameters of WTI CT for each winding shall be provided by the contractor.
- ii) For estimation of spares, one set of CTs shall mean one CT of each type used in transformer.
- iii) 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.



## **Annexure–G Spare Transformer Unit Storage & Connection Arrangement**

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

Connection of spare unit of Transformer with other units shall be made by isolator switching arrangement. Neutral formation for spare unit of Transformer shall be done by manual connection. The spare Transformer unit shall be completely erected and commissioned similar to the other Transformer units. The contractor shall carry out all pre-commissioning tests on the spare Transformer 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. **Transformer without isolator switching arrangement:** Employer intends to keep the spare Transformer unit without isolator switching arrangement due to space limitation. In case of failure of any of the running unit, this spare Transformer shall be physically shifted to replace faulty Transformer.

The spare Transformer shall be placed on the elevated foundation block to facilitate quick movement. The Transformer unit may be required to be stored for long duration. The spare Transformer unit shall be completely erected and commissioned similar to the other Transformer 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 Transformer 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 Transformers needs to be commissioned in switchyard bay (as advised by Engineer in-charge), the contractor shall erect, test and commission the spare Transformer unit similar to other units in service. However, packaging material as above for long-term storage shall be included in the scope of bidder.



**ANNEXURE - H****Technical Specification of Oil BDV Test Set (If specified in 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 Transformer 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-I****Technical Specification of Portable Dissolved Gas Analysis of Oil (If specified in BPS)**

<b>S.No.</b>	<b>Particulars</b>	<b>Specification</b>
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 atleast 15000 records</p>





S.No.	Particulars	Specification
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 & Dimensions	<p>01. Temperature 0-50 Deg. C</p> <p>02. 85% non-condensing</p> <p>03. Portable</p>
08	Warranty	The entire test set up shall be covered on warranty for a period of 5 years from the last date of complete commissioning and taking over the test set up. During this period, if the kit needs to be shifted to suppliers works for repairs, supplier will have to bear the cost of, spares, software, transportation etc. of kit for repair at test lab/works.
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 - J****Online Dissolved Gas (Multi- 8 gas) and Moisture Analyser (If specified in Chapter PSR)**

- 1.1. Online Dissolved Gas (Multi-gas) and Moisture Analyser along with all required accessories including inbuilt display shall be provided with each Transformer 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 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 equipment shall be suitable for proper operation in EHV substation (400kV) environment where switching takes place in the EHV/HV System. The suitable indications for power On, Alarm, Caution, normal operation etc. shall be provided on the front panel of the equipment. The equipment shall have IP55 Stainless



Steelenclosure, suitable for 55 °C ambient temperature and EMI and EMC compatibility.

- 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	± 10%
Repeatability	±3% to 10% depending upon gases
Oil temperature range	- 20° C to + 120° C
External Temp. Range	- 20° C to + 55° C (External temp range of 55° C is important and should not be compromise due to ambient & operating conditions.)
Humidity range	10 to 95 %
Operating Voltage	230 Vac; 50 Hz (±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.
- 1.13. 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 - K****Online Dissolved Gas (Multi- 4 gas) and Moisture Analyser (If specified in Chapter PSR)**

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

1.15. 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> Or CO	5 – 5,000 ppm  10 – 10,000 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
H <sub>2</sub> O	2 – 100 % RS should have facility for measurement of moisture in oil in ppm

1.16. 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.

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

1.18. 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.

1.19. Online DGA 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 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.



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

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

Accuracy	± 10%
Repeatability	±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 (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 (±20% variation)
Communications	USB&IEC 61850 compliant

- 1.23. 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

- 1.24. 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.

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



supervision of OEM representative or OEM certified representative.

- 1.26. 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 - L****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 Transformer 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 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 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.

11.0 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 - M

### **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 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) and sensing of arc inside transformer by Arc Sensors 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
- 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 and IEC 61850 Compatible.
- 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) Required number of Arc Sensor to be located inside the transformers in strategic locations to be finalized during detailed engineering.
- v) All controls, alarms, panels, cables, cable trays (if required), junction boxes etc.
- vi) Flow sensitive conservator Isolation valve to isolate the conservator oil from the main tank is being provided by the transformer 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	Prime 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 – 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%, 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****Transformer Oil Filtration Plant (If specified in BPS)****Performance Requirement**

The Ultra High Vacuum type oil treatment plant of capacity of 10KLPH / 6KLPH (Kilo litre per hour) shall be mobile and shall be suitable for treatment of new oil and reconditioning of used oil in EHV class transformer, shunt reactor and other oil filled equipment in order to achieve properties of treated oil within specified limits at the rated capacity.

The plant shall be capable of treatment of new oil (as per IEC 296/IS:335) and reconditioning of used oil (as per IS:1865/IEC:422 for oil in-service) 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 kV to 70 kV (min).
- (iv) Vacuum level of degassing chamber at rated flow and at final stage: - not more than 0.15 torr (0.2 m bar) max.

(Degassing chambers of different degree of vacuum should have sufficient surface areas to achieve the final parameters. A detailed justification as to how end parameters shall be met with detailed calculations and test reports in support of the same shall be submitted along with the offer.

- (v) Filtering capacity: Max. particle size less than 0.5 micron in the filtered oil.
- (vi) Processing temperature: - 40°C to 60°C (Maximum allowed temp. in oil to prevent oxidation (when oil is at atmospheric pressure): - 60°C)

Bidder is to furnish along with the bid detailed calculation to establish the sizing and capability of the vacuum pumping system with respect to moisture and gas removal as above.

Bidder is to submit along with the bid test reports, test methodology to prove the capability of the plant offered.

The plant shall also have two independent vacuum pumping systems one for evacuating the transformer for vacuum filling of oil in transformer and the other for degassing chamber. The blank off vacuum of each pumping system shall be  $10^{-3}$  torr or less.

The plant shall be provided with control and indication panel with full automation.

The plant shall be fitted with hoses for connection of oil lines and vacuum lines to transformers and reactors. Hoses shall have leakage rate of  $10^{-2}$  torr-ltr/sec. (max.)

The Ultra High Vacuum Type oil purification plant shall be complete with oil pumps for drawing oil for transformers and reactors, oil heater (max. heating rate =  $2.0W/cm^2$ ) of adequate rating, suitable filter or centrifuge as required to ensure oil quality, degasifier complete with vacuum pumps, oil extraction pump etc. of adequate capacity such that throughout from the purification plant is of guaranteed purity.

The plant shall also be suitable for cleaning and degassing of the oil stored in the storage tanks.



All equipments required as above shall be mounted on a tow-able road worthy trailer unit with 4 nos. pneumatic tyres. The equipment shall be suitable for outdoor use.

### **Design & Construction**

The features and construction details of each 10KLPH/6KLPH mobile outdoor type oil filtration & purification plant shall be in accordance with the requirements stated hereunder.

#### **Oil Pump (Inlet Side)**

Two (2) nos. electrically driven oil pumps with one (1) working and one (1) standby shall be provided. Selection switch is to be provided for selection of either of pumps. The pumps shall be single stage positive displacement gear type. Suitable mechanical seals shall be provided to ensure vacuum tightness. A built-in pressure relief valve to re-circulate the oil to suction side in case of accidental pressure rise shall be provided. Suction lift of the pump shall be at least 5 meters of transformer oil at atmospheric pressure & temperature. A separate bypass valve is provided across the gear pump so that the flow rate through the filter can be adjusted as required. The pump should be controlled by frequency drive. This should help to set the flow rate of filter plant from 4000 – 6000 LPH for 6KLPH machine and from 8000-10000 LPH for 10KLPH machine.

The pumps shall be provided with an interlock with delay such that if there is no oil flow of 30 sec. through the heater, the pump shall trip automatically and also if the pump is not operating the heater will not be energized.

#### **Magnetic Strainer**

The plant shall be provided with suitable magnetic strainer with wire mesh to filter all particles of sizes above 0.5 mm and all magnetic particles. The strainer shall be installed at the suction of the oil pump described above.

#### **Heater**

- a. An oil heater for heating up inlet oil shall be provided at the discharge side of the oil pump.
- b. The oil heater vessel shall be of mild steel welded construction & insulated with glass/mineral wool.
- c. The vessel shall be constructed for ultra high vacuum & pressure application.
- d. Electric heater shall be provided inside the heater vessel to heat up oil from lowest ambient temperature to temperature required for filtration/degasification operation in single pass. The heater shall also be rated for heating the inlet oil from lowest ambient temperature at 70°C in single pass during filling up of transformers. Two separate temperature settings with thermostatic controllers shall be provided for this purpose.
- e. The heating shall be indirect type and specific heat load shall not exceed 2.0 watt/cm<sup>2</sup> in order to avoid local overheating.
- f. The total heating capacity shall be divided into three independent thermostatically controlled heating stages evenly balancing the three phases of power supply. The control switches and knobs shall be housed on a control panel.



- g. An additional preset temper proof safety thermostat set at the highest temperature shall be provided on the heater to put off the heater and give audio and visual alarm to take care of accidental overheating.
- h. The heater body shall be so designed as to allow replacement of heating elements without draining of oil. Suitable pressure relief valve, vent and drain valves & two (2) dial type temperature gauges at inlet & outlet of heater shall be provided.

### **Filter**

- a. Cartridge filter as may be required to ensure maximum particle size to less than 0.5 micron in the filtered oil shall be provided.
- b. The filter body shall be fabricated of mild steel & designed for leak tightness at full vacuum & high pressures. The oil will flow from dirty oil chamber to clean oil chamber through filter elements.
- c. Cartridge type element used shall be suitable for transformer oil in service and submicronic filtration, the media shall be non-hygroscopic and of high dirt holding capacity.
- d. The filter elements shall be easily removable for replacement when required. Compound gauge to indicate pressure across the filter, vent and drain with valves & other necessary accessories shall be mounted on the filter for each operation.

### **External Solenoid Operated valves**

Two valves should be provided at the inlet and outlet of the plant. The moment inlet and outlet pumps are switched on these valves open thus making way for oil to pass. In case of power failure, oil from the transformer will not enter the plant and vacuum system.

### **Degassing Chamber**

- a. The degassing chamber shall be of welded construction and shall be suitable for operation under full vacuum. The fill of rasching rings & trays for distribution shall be designed for efficient distribution of oil over large areas. Incoming transformer oil should be spread over these rings in the form of film and over a longer surface area, thus achieving better degassing and dehumidification.
- b. The degassing chamber shall be multistage (minimum 02 stages) type suitable for ensuring the desired oil properties. Arrangement for condensing back lighter fraction (aromatics) of the insulating oil into the system shall be provided.
- c. The degassing channels shall have adequate height to allow long enough free fall for complete degassing. Design shall be such as to minimize foam formation.
- d. The degassing chambers shall be provided with suitable level monitor for oil or foam level in the chamber and shall trip the inlet gear pump when the level rises above the designed maximum level in order to prevent foam/oil to enter the vacuum pumping system. The oil inlet pump starts again automatically once the oil level in the degassing chamber falls below the preset oil level.
- e. Necessary illuminated sight glass shall be provided through which oil flow



through the degasser can be viewed clearly.

- f. The degasser shall be provided with vacuum gauges, vacuum breaking valves, main and auxiliary vacuum connections and other necessary accessories.

### **Vacuum Pumping System**

- a. The pump shall be provided with a suitable vacuum pumping system for creating adequate high vacuum in the degassing chambers. The pumping system shall consist of suitable combination of Roots Blowers and Rotary vane vacuum pumps with inter-stage condensing units.
- b. The roots blowers shall be of reputed make. Suitable built in labyrinth packing system, slinger rings, oil return chambers shall be provided between bearings and working chambers to prevent penetration of lubricating oil to the working chamber. The pumps motor shall be dynamically balanced. The pumps shall be suitable for starting evacuation from atmospheric pressure and shall be applied with necessary overflow valve.
- c. The rotary vane vacuum pumps shall be installed after the roots blower. An automatic by pass valve across the roots blower shall permit operation of rotary vane pump alone to operate when so required. The rotary vane pumps are provided with gas ballast valve to prevent contamination of vacuum pump oil with moisture. The vacuum pump shall also be provided with suitable non-return valve device such that in the event of power failure the vacuum in the degassing chamber shall be maintained and the vacuum pump oil is not sucked back into the degassing chamber. A high vacuum safety valve (piston type) to prevent back streaming of oil and air intrusion shall be provided. The pump motors shall be having return stop device.
- d. Necessary water cooled condensing units to condense the light fraction (aromatics) and return the same to the transformer oil shall be provided to reduce the loss of aromatics. Condensing units shall also be suitable for operation with broken ice for remote location operation where cooling water connection is not available.

### **Vacuum Pumping system for Transformer Evacuation**

An independent vacuum pumping system shall be provided for evacuating the transformer for oil filling. The vacuum level required for transformer evacuation for oil transfer is about 0.76 torr (1 m bar) for transformer oil heated to 70-80°C. The pumping system shall be identical to that of the degassing vacuum system. **The capacity shall be adequate for evacuation of:**

- a) 60KL Tank in one hour from 1 atm to 1mbar.( For 6KLPH Machine)
- b) 90KL Tank in one hour from 1 atm to 1mbar. (For 10KLPH machine)

The vacuum systems for degasser and transformer evacuation shall be inter connected in such a way that it shall be possible to use either or both the systems for any of the purpose. A reinforced hose of 10 mts. length should be provided. The hoses must be for vacuum leakage rate of  $10^2$  torr-litre/sec.

### **Oil Extraction Pump**

Suitable pumping system shall be provided for extracting oil from degasser under



vacuum and supplying to transformer/reactor etc., at discharge pressure of 1.5 kg/cm<sup>2</sup> at the outlet hose nozzle of the plant, the pump shall be either glandless centrifugal type with canned motors or a combination of gear pump and centrifugal pump with mechanical seals suitable for extracting oil from high vacuum degassing chamber. The oil extraction pump shall be located at a suitable level below the degasser chamber so as to ensure adequate suction head for the pump. The pump shall be supplied with double check valve assembly and solenoid operated non return valve. In order to stop reverse flow of oil in case of power failure, the pumping system shall preferably be self priming type alternatively priming device with safety interlock to protect pump against dry running shall be provided. Sampling valves shall be provided at the discharge of extraction pump for testing of oil properties. A recirculation line with valves shall be provided to re-circulate a part of the purified oil to the inlet point if necessary during operation. The pump should be controlled by **frequency drive**. This should help to set the flow rate of filter plant from 4000 – 6000 LPH for 6KLPH machine and from 8000-10000 LPH for 10KLPH machine.

### **Hoses for Transformer Oil, Vacuum, Air and Water**

- a. Separate reinforced rubber hoses shall be provided for each operation for oil suction, oil discharge, transformer vacuum connection and cooling water supply and return. The hoses shall be at least 15 meter long each and shall be complete with hose quick connect couplers for connection to installations under operation.
- b. Hose pipes for oil service shall be suitable for transformer oil application upto temperature of 100° C, full vacuum and pressure upto 2.5 kg/cm<sup>2</sup>. All oil hoses shall be built up around an earthed core or have built in earthed conductor to avoid static electricity accumulation. Inlet and outlet nozzles of purification plant and corresponding hoses shall be of 50 NB/40 NB size respectively in order to avoid error in connecting.
- c. Vacuum hoses shall be of braided nitrile rubber suitable for full vacuum without collapsing and kinking. The vacuum hoses shall be transparent construction such that accidental oil flow can be easily detected.

**Oil sampling valve:** Suitable valve shall be provided for taking sample during filtration.

### **Material of construction and painting**

- a. Oil heater, filter vessel, degasser shall be of mild steel construction. The internal and external surfaces including oil heater, filter vessel, degasifier and structural steel work to be painted shall be shot or sand blasted to remove all rust and scale of foreign adhering matter or grease. All steel surface in contact with insulating oil shall be painted with two coats of heat resistant oil insoluble, insulating varnish.
- b. All internal paints steel surfaces shall be given a primary coat of zinc chromate, second coat of oil and weather resistant varnish of a color distinct from primary and final two coats of glossy oil and weather resisting paint.
- c. All paints shall be carefully selected to withstand heat and extremes of weather. The paint shall not scale off or crinkle or be removed by abrasion





due to normal handling.

- d. Bolts & Nuts: All bolts and nuts exposed to weather shall be hot dip galvanized/cadmium plated and passivated /zinc plated and passivated.
- e. Material of construction for vacuum pumps air compressor, air drying plant, air receiver shall be steel of suitable grade.
- f. All piping and equipment carrying transformer oil shall be insulated with glass wool/mineral wool insulation.

### **Instrumentation and Control**

Following minimum instruments shall be provided on the oil purification plant:

- a. Compound gauge at oil pump discharge
- b. Compound gauge at filter inlet.
- c. Compound Gauge at filter outlet
- d. Pressure Gauge at discharge pump outlet
- e. Pressure Gauge at degasifier
- f. Vacuum Gauge at transformer evacuation line
- g. Vacuum Gauge in between roots, vacuum pump and rotary vane vacuum pump.
- h. Panel mounted vacuum indicators at degasser
- i. Panel mounted vacuum indicators at transformer evacuating line.
- j. Separate fine vacuum gauge for measurement of vacuum for transformer evacuation system and oil line degassing chamber evacuation system should be provided. This vacuum gauge should be electronic type having range from 0.01 torr to 20 torr and should be of any of these reputed manufacturers' (Wika/ Hasting/ Edwards) make.
- k. Oil Filtration Machine should be fitted with on-line moisture in oil-PPM indicator.
- l. Sight glass at degassifier
- m. Temperature indicator cum controller at heater inlet
- n. Temperature indicator cum controller at heater outlet
- o. Voltmeter
- p. Oil flow meter (Positive displacement type)
- q. Ammeter

### **Control Panel:**

A centralized electrical panel with auxiliary step down transformer, contractors, back up protection fuses, indicating lamps etc. to be provided with following minimum audio and visual alarms:

- a. High temperature at heater outlet
- b. High differential pressure across filters
- c. Oil pump trip
- d. Vacuum pump trip



- e. Loss of vacuum in degassing chamber
- f. Loss of vacuum in transformer evacuation line
- g. No oil flow through heater
- h. High oil level in degasser.

All controls and annunciation equipment should be suitable for 230 V AC.

Suitable interlock as described against each equipment shall be provided for safe and trouble-free operation.

All instruments, control hardware and alarms shall be mounted on a suitable control panel. A mimic diagram with indication lamps showing on-off status of various equipments shall be provided on the control panel.

The plant shall be fully equipped with adequate instrumentation having provision of manual operation, if required. All necessary control and indicating panel shall be provided.

It shall be possible to use the oil transfer pump for the purpose of loading oil to transformers or reactors from tankers and vice versa by by-passing to purification plant, if required.

There shall be independent vacuum pump for creating and holding the transformer/reactor winding under vacuum for vacuum drying and filling of winding when required. The vacuum pump shall have capacity to develop and maintain adequate vacuum in the oil space of the 60KL tank within 1 hour time.

### **Electrical System:**

The plant shall receive 400V, 3 phase, 50 Hz, 4 wire power supply through flexible cable in the distribution panel located on the plant. The incomer of the distribution panel shall be switch fuse unit.

One length of 50 meters of core 1100V grade flexible cable with crimped lugs at one end shall be provided for connection of the unit to the mains. The length of the cable will be covered in a suitable cable drum.

Provision for earthing the plant at the operating locations with earthing terminals for safety shall be provided.

The plant shall be suitably illuminated and ventilated for comfort of operator.

**Capacity Demonstration:** The supplier has to submit the detailed calculations in support of meeting the desired vacuuming capacity in prescribed time along with their technical offer. The capacity calculations submitted by the supplier shall be evaluated as per below mentioned method:

Pumping Down Time (PDT) =  $V/S \ln (P1/P2)$

PDT = 1.2 x (PDT1 + PDT2); Considering 1.2 as service factor

DT1: V= Volume of Tank to be evacuated (90KL or 60KL),

S= Capacity of Vacuum pump in LPM, P1= 760mm of Hg, P2=50 mm of Hg

PDT2: V= Volume of Tank to be evacuated (90KL or 60KL),

S= Capacity of Roots pump in LPM, P1= 50 mm of Hg, P2=0.76 mm of Hg

If the supplier offers the capacity of vacuum pump and roots pump different than the capacity derived from above mentioned method, it has to demonstrate the machine at his Works for required capacity by achieving desired vacuum within prescribed time and this will be the part of technical evaluation i.e. pre-award demonstration of



vacuuming capacity has to be arranged by supplier within 45 days of intimation by NEA without any financial implication to NEA..

The supplier, who offers the vacuuming capacity in line with the above method, shall have to demonstrate the machine (Post-Award) at his Works for required capacity by achieving desired vacuum within prescribed time.

The tank required for the demonstration at his Works is to be arranged by the supplier. The supplier who has already successfully demonstrated the desired vacuuming capacity in the region needs not to repeat again.

**Gaurantee:** Min 01 year from the date of successful & complete commissioning at NEA sub-station. All the materials, including accessories, cables, components etc. are to be covered under warranty/guaranty period. If any component of the plant needs to be shifted to supplier's works for repairs within warranty/guaranty period, suppliers will have to bear the cost of spares, transportation of component/plant for repair at works.

**Commissioning, handing over the Instrument:** Successful bidder will have to commission the plant to the satisfaction of NEA. The equipment failed during the demo shall be rejected and no repairs are allowed.

**Training:** Supplier shall have to ensure that the plant is made user friendly. Apart from the detailed demonstration at site, the supplier shall also have to arrange necessary training to NEA engineers.

