

KARNATAKA POWER TRANSMISSION CORPORATION LIMITED

SECTION – AUTO TRANSFORMER

TECHNICAL SPECIFICATION
SECTION: AUTO TRANSFORMER

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TECHNICAL SPECIFICATION

SECTION: AUTO TRANSFORMER

1.0 General

- 1.1 This specification covers design, engineering, manufacture, testing at manufacturer's works, delivery at site including all materials, accessories, spares, unloading, handling, proper storage at site, erection, testing and commissioning of the equipment specified.
- 1.2 The autotransformers shall in general have constant ohmic impedance between HV and IV on all taps. However, in case of parallel operation with the existing transformer,
- i) The impedance, vector group, OLTC connection & range etc. of the transformer is to be matched with that of the existing transformer. The rating plate details of the existing transformer shall be furnished by the Owner.
 - ii) Necessary provision is to be kept in the transformer control scheme for parallel operation with the existing Master/Follower/ Independent/Off type OLTC control scheme.
 - iii) Matching of physical dimension, orientation etc. to facilitate interchangeability with the existing spare single phase transformer, if necessary.
- 1.3 External or internal reactors shall not be used to achieve the HV/LV and IV/LV impedance specified.
- 1.4 Reference Drawings
The list of drawings indicated below form a part of this specification.
- i. Standard dimensions for RIP condenser bushings (Lower portion)
 - ii. Typical arrangement of auto transformer with regulating winding at the end of series winding
 - iii. Conceptual drawing for showing power & control cable for operation of 3-ph Auto Transformer.
- 1.5 The design and workmanship shall be in accordance with the best engineering practices to ensure satisfactory performance throughout the service life.
- 1.6 Any material and equipment not specifically stated in this specification but which are necessary for satisfactory operation of the equipment shall be deemed to be included unless specifically excluded and shall be supplied without any extra cost.
- 1.7 Components having identical rating shall be interchangeable.

1.8 Transportation

- 1.8.1 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.

- 1.8.2 The contractor shall carry out the route survey along with the transporter and finalize 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 bidder.
- 1.8.3 The main tank of the transformer shall be transported on Hydraulic trailers equipped with GPS system for tracking the location of transformer at all times during transportation from manufacturer works to designated site. The contractor shall intimate to Employer about the details of transporter engaged for transportation of the transformer. The requisite details for tracking the transformer during transit shall be provided to Employer. Requirement of Hydraulic trailer is envisaged for 400kV transformer.
- 1.8.4 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.
- 1.8.5 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 filling during erection. The total duration of storage at site with dry gas shall preferably be limited to three months after which the Transformer shall be processed and filled with oil. The dry air cylinder (s) provided to maintain positive pressure can be taken back by the contractor after oil filling. A gas pressure testing valve with necessary pressure gauged and adaptor valve shall be provided.
The above arrangement is also applicable for turret and other components with insulation assembly transported separately with transformer.
- 1.8.6 Transformer shall also be fitted with sufficient number of Electronic impact recorders (on returnable basis) during transportation to measure the magnitude and duration of the impact in all three directions. The acceptance criteria and limits of impact, which can be withstood by the equipment during transportation and handling in all three directions, shall not exceed "3g" for 50mSec (20Hz) as per KPTCL pre-commissioning document or as per contractor standard, whichever is higher.
- 1.9 The insulating oil for the transformer shall be delivered at site not before 90 days from the date of commissioning, which shall be informed by the owner.

2.0 **Performance**

- 2.1 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 furnished in clause- Technical particulars/parameters.
- 2.2 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 as ONAF (or ONAF-1 as specified) up to specified load and then as OFAF (or ONAF2 or ODAF or ODWF, as specified). 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 deg C. Transformer fitted with two coolers each capable of dissipating 50 percent of the loss at continuous maximum rating, 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 deg C at continuous max rating. The contractor shall submit supporting calculations for the above and the same shall be reviewed during design review.
- 2.3 The transformer shall be free from any electrostatic charging tendency (ECT) under all operating conditions when all oil circulation system are in operation. The manufacturer shall ensure that there is no electrostatic charging tendency in the design. In general, oil flow speed shall not exceed 1.0m/Sec within winding in the oil flow system of the transformers.
- 2.4 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 the tapping.
- 2.5 The transformers shall be capable of being over loaded in accordance with IS 2026-7/ IEC-60076-7. There shall be no limitation imposed by bushings, tap changers etc., or any other associated equipment.
- 2.6 The hotspot temperature in any location of the tank shall not exceed 110 deg. Celsius at rated MVA. This shall be measured during temperature rise test at manufacturer's works.
- 2.7 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. The transformer shall be designed to withstand the thermal stress for short circuit duration of 2 seconds and the same shall be verified during design review. The short circuit level for 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	- 50kA for 1 Sec (sym, rms, 3 phase fault)
132kV System	- 40kA for 1 Sec (sym, rms, 3 phase fault)
66kV System	- 31.5kA for 1 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., $Z_s = 0$)

2.8 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 IV, HV 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.

2.9 Transformer shall be capable of withstanding thermal and mechanical stress caused by symmetrical or asymmetrical faults on any winding.

The thermal ability to withstand short circuit for duration of 2 secs. shall be demonstrated by theoretical evaluation of the ability to withstand a short circuit event by manufacturer's experiences supported by IEC guidelines as per IEC 60076-5, 2006 (latest version)/ IS 2026-5 (latest version). The calculation of dynamic ability to withstand short circuit shall be submitted before drawing approval along with thermal stability calculations.

The windings shall be capable of withstanding axial and radial forces during fault conditions. The detailed calculation towards the above should be furnished before drawing approval.

The short circuit temperature rise should not exceed the limits, fixed as per IS: 2026/IEC: 60076. The calculation towards the above for 400kV, 220kV and 33kV windings shall be furnished before drawing approval.

2.10 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 per cent continuous over voltage condition it does not exceed 1.9 Tesla at all tap positions.

2.11 Radio Interference and Noise Level

2.11.1 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.

- 2.11.2 The noise level of transformer, when energized at normal voltage and frequency with fans and pumps running shall not exceed, when measured under standard conditions, the values specified in Technical Parameters.
- 2.12 Transformers shall withstand, without injurious heating, combined voltage and frequency fluctuations which produce the following over fluxing conditions:
- i) 110% for continuous
 - ii) 125% for 1 - minute
 - iii) 140% for 5 - seconds
 - iv) Bidder shall indicate 150% and 170% over voltage withstand time.
- 2.13 The air core reactance of HV winding of transformer shall not be less than 20%.
- 2.14 **Tertiary Windings**
- 2.14.1 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 these stresses that may be caused by such switching.
- The tertiary winding shall be designed to withstand mechanical & thermal stresses due to dead short circuit on its terminals. Loading/Rating of The tertiary winding is specified in Technical Particulars. Tertiary if not connected to reactor, capacitor or LT transformer, etc., its terminals shall be insulated to avoid any accidental short circuiting.
- 2.15 The transformer shall be designed to withstand a DC current of 10A per phase without injurious heating, noise and vibration.
- 2.16 **Dynamic short Circuit Test requirement.**

The transformer, the design of which is similar to the offered transformer, should have been successfully tested for short circuit withstand capability as per IS 2026 Part-5/IEC 60076 Part-5 in line with the requirement of CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations. The validity of DSC test for transformer shall remain till the design is changed.

The criteria for similar transformer shall be as specified in IS 2026 Part-5/IEC 60076 Part-5. The relevant Test Report/certificate shall be furnished. Further, design review of offered transformer shall be carried out based on the design of reference transformer, which has already been subjected to Short circuit tests in lieu of repetition of Short circuit tests. In case, manufacturer has not conducted short circuit test earlier or there is change in design, the DSC test shall be carried out on one of the offered transformer at his cost.

2.17

Additional Warrantee

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

- 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 values of condition-1 indicated in clause no. 6.5 of IEEE-C57, 104-2008, which are as detailed below:

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

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

2.18

Design review

The transformers shall be designed, manufactured and tested in accordance with the best international engineering practices under strict quality control to meet the requirement stipulated in the technical specification. Adequate safety margin with respect to thermal, mechanical, dielectric and electrical stress etc. shall be maintained during design, selection of raw material, manufacturing process etc so that the transformer provide long life with least maintenance.

Raw material and sub-vendors used by transformer manufacturer shall be declared before commencement of manufacturing. **The validity of Type tests (except dynamic short circuit test) of Transformer shall be 10 years** as on the last date of submission of bid, provided that offered transformer design is identical to the type tested transformer and same active materials (CRGO, conductor and Insulation) of same grade & from the same sub-vendors are used. In case of any change of either active materials or sub-vendors, the type tests shall be carried out by the contractor at no extra cost to Employer. With regard to validity of Dynamic short circuit test once conducted shall be applicable.

Design reviews shall be conducted by purchaser or an appointed Consultant during the procurement process for transformer, however the entire responsibility of design shall be with the manufacturer.

Note: If design review is conducted by appointing an external consultant by KPTCL, the cost of consultancy charges shall be borne by the bidder.

Purchaser may also visit to the manufacturers works to inspect design, manufacturing and test facilities at any time.

The design review will commence after placement of award with successful bidder 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 scope of this specification.

The design review shall be conducted generally following the “CIGRE TB 529: Guidelines for conducting Design Review for Power Transformers”.

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

The manufacturer will be required to demonstrate the use of adequate safety margin for thermal, mechanical, dielectric and vibration etc. in design to take into account the uncertainties of his design and manufacturing processes.

The scope of such a design review shall at least include but not limited to the following:

Sl. No.	Description
1	Core and Magnetic Design
2	Over-fluxing characteristics upto $1.7 U_m$
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 localized 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 Location of Optical temperature sensors
- 35 The design of a ll current connections
- 36 Location & size of the Valves

3.0 **Construction Details**

The features and construction details of each power transformer shall be in accordance with the requirement stated hereunder. The components and fitting associated with transformers are subject to purchaser’s approval and design review.

3.1 Tank and Tank Accessories

3.1.1 Tank

3.1.1.1 Tank shall be of welded 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 drawing, test reports & list of names of the principal users with experience gained shall be supplied on request.

3.1.1.2 All seams and those joints not required to be opened at site shall be factory welded, and wherever possible they shall be double welded. Welding shall conform to BS 5135/IS9595. After fabrication of tank and before painting, dye penetration test shall be carried out on welded parts of jacking bosses, lifting lugs and all load bearing members. The requirement of post weld heat treatment of tank/stress relieving shall be based on recommendation of BS-5500 table 4.4.3.1/IS 10801.

3.1.1.3 Tank stiffeners shall be provided for general rigidity and welded to the tank continuously along its ends and sides (Intermittent welds will not be accepted). These shall be designed to prevent retention of water. Sharp edges on stiffeners should be avoided for better paint adhesion.

3.1.1.4 The tank shall be proven design either bell type with bolted/welded joint or conventional type (preferably) with welded/bolted top cover. The bell type tank shall be provided with the 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 of the joint.

- 3.1.1.5 Each tank shall be provided with:
- (a) Lifting lugs - Four symmetrically placed lifting lugs shall be provided so that it will be possible to lift the complete 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. The lifting lugs shall be so arranged and located as to be accessible for use when the transformer is loaded on the transport vehicle.
 - (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 for at least half of the total mass of the transformer filled with oil allowing in addition for maximum possible misalignment of the jacking force to the centre of the working surface.
 - (c) Suitable haulage holes shall be provided.
 - (d) Provision of 4 numbers of gated valves for UHF sensors for PD measurements at various location. Location of valves shall be finalized during detailed engineering.
 - (e) Suitable provision of pockets for OTI, WTI & RTDs including two spare pockets.
- 3.1.1.6 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.
- 3.1.1.7 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 injury when using plates or rails.
- 3.1.1.8 The tank shall be designed to withstand:
- a. Mechanical shocks during transportation.
 - b. Vacuum filling of oil.
 - c. Continuous internal pressure of 35kN/m² over normal hydrostatic pressure of oil.
 - d. Short circuit forces.
- 3.1.1.9 Wherever possible, the transformer tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipes.
- 3.1.1.10 Adequate space shall be provided at the bottom of the tank for collection of sediments.
- 3.1.1.11 Tank shields, if required, shall be such that no magnetic field shall exist outside the tank. They shall be of magnetically permeable material. If required impermeable shields shall be provided at the coil ends. Tank shield shall not resonate when excited at the natural frequency of the equipment.
- 3.1.1.12 Suitable guides shall be provided in the tank for positioning the core and

coil assembly.

- 3.1.1.13 Tank hot spot:
Under extreme conditions, the maximum temperature on any metal part shall not exceed 110°C.
- 3.1.1.14 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.
- 3.1.1.15 Tank should be provided with adequately sized inspection covers, either in circular shape or in rectangular shape, preferably at diagonally opposite sides of the tank to access the active part and one at each end of the tank cover for easy access of the lower end of the bushings, earthing connections and tap changers etc. for inspection. Inspection covers shall be bolted type and shall not weigh more than 25Ks. Handles shall be provided on the inspection cover to facilitate its lifting.
- 3.1.1.16 After fabrication of tank and before painting, **Non-destructive test (dye penetration test) is mandatory on the load bearing members** such as base plate joints, jacking pads and lifting devices etc.
- 3.1.1.17 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 below. 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 temperatures upto 120°C. The detailed painting procedure shall also be submitted along with the bid which shall be finalized before award of the contract.

	Surface preparation	Primer coat	Intermediate undercoat	Finish coat	Total dry film Thickness (DFT)	Colour shade
Main tank, pipes, conservator tank, oil storage tank, DM Box, etc. (external surfaces)	Shot Blast cleaning Sa 2 1/2*	Epoxy base Zinc primer (30-40 µm)	Epoxy high build Micaceous iron oxide (HB MIO) 75µm)	Aliphatic polyurethane (PU) Minimum 50µm)	Minimum 155µm	RAL 7035 /KPTCL approved drawing
Main tank, Pipes (Above 80NB) conservator tank, oil storage tank etc. (Internal surfaces)	Shot Blast cleaning Sa 2 1/2*	Hot oil Proof Low viscosity varnish or hot oil resistant, non-corrosive paint	–	–	Minimum 30µm	Glossy White for paint/KPTCL approved drawing

Radiator (External surfaces)	Chemical/ Short Blast cleaning Sa 2 1/2*	Epoxy base Zinc primer (30-40 µm)	Epoxy base Zinc primer 30 - 40 µm)	PU paint (Minimu m 50 µm)	Minimu m 100 µm	Matching shade of tank/differe nt shade aestheticall y matching to tank/KPTC L approved drawing
	Manufacturer may also offer Radiator with hot dip galvanized in place of painting with minimum thickness of 40µm (min)					
Radiator and pipes up to 80NB (Internal surfaces)	Chemical cleaning if required.	Hot oil proof, low viscosity varnish or Hot oil resistant, non-corrosive paint	-	-	-	-
Control cabinet/marshalling box – No painting is required.						
RTCC panel	Seven tank process as per IS:3618 & IS:6005	Zinc chromate primer (two coats)	-	Epoxy paint with PU top coat or powder coated	Minimu m 80µm/f or powder coated minimu m 100 µm	RAL 7032, Siemens Grey shade for exterior and glossy white for interior/KP TCL approved drawings

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

3.1.2 Tank Cover

3.1.2.1 The tank cover shall be designed to prevent retention of rain 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.

3.1.2.2 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.

3.1.2.3 The tank covers shall be provided with pockets for oil and winding temperature indicators. The location of pockets shall be in the position where oil reaches maximum temperature. Further, it shall be possible to remove bulbs of OTI/WTI/RTD without lowering the oil in the tank. The thermometer shall be fitted with a captive screw to prevent the ingress of water.

3.1.2.4 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.

- 3.1.2.5 All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. If gasket is compressible, metallic stops/other suitable means shall be provided to prevent over-compression.

- 3.1.2.6 Currents flowing in tank cover and bushing turrets

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

- 3.1.2.7 The transformer shall be provided with a 100 mm nominal diameter pipe flange, butterfly valve bolted blanking plate and gasket fitted at the highest point of the transformer tank for maintaining vacuum in the tank.

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

- 3.1.2.9 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.

- 3.1.2.10 **Gasket for tank & cover**

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

3.1.3 **Axles and Wheels**

- 3.1.3.1 The transformer shall be mounted either on rollers or on concrete plinth foundation directly, as per manufacturer's standard practice.
- 3.1.3.2
- a) The roller mounted transformers 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.
 - b) Flanged bi-directional wheels and axels shall be so designed that under both the directions of movement they shall not deflect sufficiently to interfere with the movement of the transformer. Wheels shall be provided with suitable bearings, which shall be rust and corrosion resistant. Fillings for lubrication shall also be provided.
 - c) The wheels are required to swivel and shall be arranged so that they can be turned through an angle of 90° when the tank jacked up to clear off rails. Means shall be provided for locking the swivel movement in positions parallel to and at right angles to the longitudinal axis of the tank.
- 3.1.3.3 The rail track gauge shall be 1676 mm. 3-Phase Auto-Transformer of 400kV class shall have four (4) rails.

3.1.3.4 VOID

3.1.4 **Foundation and Anti Earthquake Clamping Device**

- 3.1.4.1 To prevent transformer movement during earthquake, suitable clamping devices shall be provided for fixing the transformer to the foundation. The contractor shall supply necessary bolts for embedding in the concrete foundation. The arrangement shall be such that the transformer can be fixed to or unfastened from these bolts as desired. The fixing of the transformers to the foundation shall be designed to withstand seismic events to the extent that a static coefficient of 0.3g applied in the direction of least resistance to that loading will not cause the transformer or clamping devices as well as bolts to be over stressed. Details of device used and its adequacy shall be brought out in additional information schedule.
- 3.1.4.2 For foundation of separately mounted cooler bank of transformer, fixing of cooler support shall be through Anchor Fastener with chemical grouting and no pockets for bolting shall be provided.
- 3.1.4.3 For support of cooler pipes, Buchholz pipe (if required) and fire-fighting pipe pylon supports, pre-fabricated metallic support from pit shall be provided which shall be further encased with concrete to prevent rusting.

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

3.1.5 **Conservator & Oil Preservation System**

- 3.1.5.1 Main conservator shall have air cell type constant oil pressure system to prevent oxidation and contamination of oil due to contact with moisture. Conservator shall be fitted with magnetic oil level gauge with potential free high & low oil level alarm contacts & prismatic oil level guage.

The main conservator shall preferably be on the left side of the tank while viewing from HV side.

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

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

3.1.5.4 Conservator tank and pipe work

- 3.1.5.4.1 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 100degC. The capacity of the conservator tank shall be such that the transformer shall be able to carry the specified overload without overflowing of oil.

- 3.1.5.4.2 The conservator shall be fitted with integral 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 wherever applicable.

- 3.1.5.4.3 Conservator shall be positioned so as not to obstruct any electrical connection to transformer. Pipe work shall neither obstruct the removal of tap changers for maintenance or the opening of inspection or manhole covers.

- 3.1.5.4.4 Pipe work connections shall be of adequate size for their duty and as short and direct as possible. Only radiused elbows shall be used.

- 3.1.5.4.5 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. 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.

- 3.1.5.4.6 This pipe shall rise towards the oil conservator, through the Buchholz relay, at an angle of not less than 5 degree.
- 3.1.5.4.7 A double flange valve of preferably 50mm and 25mm size shall be provided to fully drain the oil from the main tank conservator and OLTC conservator tank respectively.
- 3.1.5.4.8 The feed pipe diameter for the main conservator shall be not less than 80mm.
- 3.1.5.4.9 No metal corrugated bellow (Flexible metal system) should be used in the feed pipe connecting main tank to conservator.
- 3.1.5.4.10 Pipe work shall neither obstruct the removal of tap changers for maintenance or the opening of inspection or manhole covers.

3.1.5.5 Oil Preservation Equipment

The requirements of air cell type oil sealing system are given below.

- 3.1.5.5.1 Contact of the oil with atmosphere is prohibited by using a flexible air cell of nitrile rubber reinforced with nylon cloth.
- 3.1.5.5.2 The temperature of oil is likely to rise upto 110deg C during operation. As such air cell used shall be suitable for operating continuously at this temperature.
- 3.1.5.5.3 Air cell of conservator shall be able to withstand the vacuum during installation/maintenance periods. Otherwise provision shall be kept to isolate the conservator from the main tank when the latter is under vacuum by providing a vacuum sealing valve or other suitable means in the pipe connecting main tank with the conservator. The 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, the recommended replacement intervals and the supplier.
- 3.1.5.5.4 To prevent oil filling into the air cell, the oil filling aperture shall be clearly marked.
- 3.1.5.5.5 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 150mm 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**”.
- 3.1.5.5.6 The contractor shall furnish the leakage rates of the rubber bag/air cell for oxygen and moisture. It is preferred that the leakage rate for oxygen from the air cell into the oil will be low enough that the oil will not generally become saturated with oxygen before 10 years. Air cells with well proven

long life characteristics shall be preferred.

- 3.1.5.5.7 OLTC shall have conventional type conservator with magnetic oil level gauge with potential free oil level alarm contact and prismatic oil level gauge.

3.1.5.6 **Dehydrating Filter Breather**

- i. Conservator of OLTC shall be fitted with a dehydrating silicagel filter breather. Connection shall be made to a point in the oil conservator not less than 50mm above the maximum working oil level by means of a pipe with a minimum diameter of 25mm. Breathers having a mass less than 10kg may be supported by the connecting pipe. Whereas units of 10kg and above shall be supported independent of the connecting pipe. Connecting pipes shall be securely clamped to the transformer or other structure supplied by the contractor, in such a manner so as to eliminate undesirable vibration and noise. In the case where a breather of less than 10kg is supported by the pipe, there shall be a cleat directly above the breather flange. The design shall be such that:
 - a) Passage of air is through dust filter and silicagel.
 - b) Silicagel is isolated from atmosphere by an oil seal.
 - c) Moisture absorption indicated by a change in colour of the tinted crystals can be easily observed from a distance.
 - d) Breather is mounted not more than 1200 mm above rail top level.
 - e) To minimise the ingress of moisture following shall be provided.
Two breathers (each 2.5 litres minimum volume) shall be connected in series for OLTC tank conservator.
- ii. Conservator of Main tank shall be provided with maintenance free type breather. For details of the same refer Cl. No. 11.

3.1.6 **Pressure Relief Device (PRD)**

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

PRD shall be provided with special shroud to direct the hot oil in case of fault condition. It shall be provided with an outlet pipe which shall be taken right up to the soak pit of the 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.

3.1.7 **Sudden pressure Relay/Rapid Pressure Rise Relay**

One number of sudden pressure relay/Rapid pressure rise relay with alarm/trip contacts (Terminal connector plug & socket type arrangement suitable for 2.5mm control cable) shall be provided on tank of transformer. Operating features, size and quantity shall be reviewed during design review. Pressurised water ingress test for terminal box (routine test) shall be conducted on sudden pressure relay/Rapid Pressure Rise Relay. Suitable canopy shall be provided to avoid ingress of rain water.

3.1.8 **Buchholz Relay**

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

The Buchholz relay shall not operate during starting/ stopping of the transformer oil circulation under any oil temperature conditions. The use of pipe or relay aperture baffles shall not be used to decrease the sensitivity of the relay. The relay shall not mal-operate for through fault conditions or be influenced by the magnetic fields around the transformer during the external fault conditions. Pressurized water ingress test for terminal box (Routine test) shall be conducted on Buchholz relay.

3.1.9 **Temperature Indicators**

3.1.9.1 **Oil Temperature Indicator (OTI)**

All transformers shall be provided with a 150 mm dial type thermometer for top oil temperature indication with angular sweep of 270°. It shall have adjustable, potential free alarm and trip contacts, (plug & socket type arrangement suitable for 2.5 Sq.mm control cable) besides that required for control of cooling equipment if any. Maximum reading pointer and resetting device shall be provided in the OTI. A temperature sensing element suitably

located in a pocket on top oil shall be provided. This shall be connected to the OTI by means of capillary tubing. Temperature indicator dials shall have linear gradations to clearly read atleast every 2degC. The range of temperature should be 0-150°C with accuracy of ± 1.5 degree C or better of full scale deflection.

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

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

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

a) Temperature transducer with Pt100 sensor

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

b) Remote oil temperature indicator

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

3.1.9.2 Winding Temperature Indicator (WTI)

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

The Thermometer shall have adjustable, potential free alarm, trip contacts besides that required for control of cooling equipment, if any. Instrument should be provided with maximum reading pointer and resetting device,

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

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

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

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

a) Temperature transducer with Pt100 sensor for each winding

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

b) Remote winding temperature indicator (RWTI)

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

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

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

3.1.9.3 **Fibre Optic Temperature Monitoring System:**

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

1. System shall be of proven and rugged technology. The temperature sensing tip along with the fibre optic cable shall be of an already type tested design. Details of the relevant tests conducted shall be submitted along with the offer. The probes shall be directly installed in each phase/winding of power transformer to measure the winding hot spot and at the top (inside) of the transformer to measure top oil temperature. There shall be minimum sixteen (16) probes inside the transformer. Twelve (12) probes shall be installed, 2 Nos of each phase/winding at the hottest spots of each of the phase winding. Of the remaining probes, two (2) probes shall be at the top (inside) of the transformer for measuring top oil temperature and two (2) probes at the hottest spot of the core.
2. The locations of the probes shall be proposed by the Manufacturer by identifying the hot spots with necessary supporting calculations/documents and shall be finalized by agreement with the Purchaser.
3. Probes shall be able to be completely immersed in hot transformer oil; they shall withstand exposure to hot Kerosene vapor during the transformer insulation drying process (VPD). The probes shall meet the requirement to eliminate the possibility of partial discharge in high electrical stress areas in the transformer.
4. Temperature range of the system should be -30°C to 200°C & accuracy of $\pm 2^{\circ}\text{C}$ with no recalibration required. The probes shall not get damaged/affected during filtration of the transformer.
5. Probes shall be all Silica, Double Teflon jacketed fibre with perforations/slits in the outer jacket to allow complete oil filling.

The fibre with Teflon jacket shall be strong enough to withstand the severe conditions prevailing inside an EHV transformer.
6. A Microprocessor based monitoring & recording unit shall be a part of the system. In order to facilitate measurement of temperature from the optical sensors, microprocessor based monitoring unit having at least 16 channels shall be provided. System should include analog outputs for each measurement channel. Temperature resolution of the analog outputs shall be $\pm 0.1^{\circ}\text{C}$ and the systems shall offer a user programmable temperature alarm outputs with 16 relays, alarm lamps (LED) and controller system status indicators. All inputs and outputs of the system shall meet the requirements of surge test of IEEE C37.90.1-2002 in which a 4000 V surge is applied to all the inputs and outputs without permanent damage to the instrument. The microprocessor based unit shall be of an already type tested design & details of type tests conducted shall be submitted with the offer. The device shall be communicable type & the protocol shall be IEC 61850 compliant. Provision for Time Synchronization with GPS shall be made.

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

7. The system shall be capable of retaining temperature data of 90 days at one (1) reading/ minute and should retain maximum temperature of each channel until reset.
8. The manufacturer should submit data showing that the probes are located in the hottest point of the winding, while submitting drawings for approval.
9. a The fiber optic cable within the tank shall be rigidly supported to prevent injury from vibration and clamped securely so that they will not be displaced or deformed during short circuit.

b. The fiber optic cables are to be brought out of the main tank through the tank wall penetrator feed through plate. The Feed through plate shall be welded on the Tank such that no oil leakage/moisture ingress will occur. The external fiber optic extension cable shall then be run to main control cabinet, routed inside the conduits with large bend radiuses.
10. The controller shall be housed in the cooler control cubicle or in a separate box of IP56 class mounted on the transformer tank. The position shall be clearly indicated in the GA drawings.
11. Temperature rise test measurements shall be made with the FO Thermometers. The equipment shall be operational during temperature rise tests and demonstrated during these tests. During probe verification, the hottest spot for each phase shall be identified, and temperature data for all probes recorded and reported in the test report.
12. For remote indications on RTCC panel output of 4 to 20 mA shall be made available.

3.1.10 **Earthing Terminals**

- 3.1.10.1 Two (2) earthing pads (each complete with two (2) nos. holes, M 16 bolts, plain and spring washers) suitable for connection to 75 x 12 mm galvanised steel grounding flat shall be provided each at position close to earth of the two (2) diagonally opposite bottom corners of the tank.

- 3.1.10.2 Two earthing terminals suitable for connection to 75 x 12 mm galvanised steel flat shall also be provided on each cooler, individual/common marshalling box and any other equipment mounted separately. For the tank-mounted equipment like online drying/Online DGA/Optical Sensor monitoring unit etc. double earthing shall be provided through the tank for which provision shall be made through tank and connected through two flexible insulated copper link.
- 3.1.10.3 Equipotential flexible copper link of suitable size at least 4 Nos, for Tank mounted turrent with tank and tank with cover and or Bell shall be provided. For other components like – pipes, conservator support etc. connected to tank shall also be provided with equipotential flexible copper link.
- 3.1.10.4 Each transformer unit should have provision for earthing and connection to grounding mat when not in service.
- 3.2 **Core**
- 3.2.1 **The core shall be constructed from high grade non-ageing, Cold Rolled Grain Oriented (CRGO) silicon steel laminations. Indian transformer manufacturers shall use core material as per above specification with BIS certification.**
- 3.2.2 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. The step-lap construction arrangement is preferred for better performance in respect of noise, no-load current and no-load loss.
- 3.2.3 The hot spot temperature and surface temperature in the core shall be calculated for over voltage conditions specified in the document and it shall not exceed 125 deg C and 120 deg C respectively.
- 3.2.4 Insulation of core to clamp/frame shall be tested at 2.5kV DC for 1 minute without breakdown after the transformer is filled with liquid and insulation resistance should be at least 500 Mega ohm for new transformer.
- 3.2.5 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.
- 3.2.6 All steel sections used for supporting the core shall be thoroughly sand/shot blasted after cutting, drilling and welding.
- 3.2.7 Each core lamination shall be insulated with a material that will not deteriorate due to pressure and hot oil.
- 3.2.8 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.

- 3.2.9 Adequate lifting lugs will be provided to enable lifting of active part (core & winding).
- 3.2.10 Core assembly shall be manufactured in such a way that lamination shall remain flat and finally assembled core shall be free from distortion.
- 3.2.11 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.

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.
- 3.2.12 When bell type tank construction is offered, suitable projecting guides shall be provided on core-assembly to facilitate removal of tank.
- 3.2.13 Bidder should have in house core cutting facility for proper monitoring and control on quality and also to avoid any possibility of mixing of prime material with defective / second grade material

3.3 **Windings**

- 3.3.1 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.
- 3.3.2 The conductors shall be of electrolytic grade copper free from scales and burrs. Oxygen content shall be as per IS 12444. Epoxy bonded continuously Transposed conductor (CTC) shall be used in main winding for rated current of 400A or more.
- 3.3.3 The conductor insulation shall be made from high-density (at least 0.75 gm/cc) paper having high mechanical strength. The characteristics for the paper will be reviewed at the time of design review.
- 3.3.4 The insulation of transformer windings and connections shall be free from insulating compounds which are liable to soften, ooze out, shrink or collapse and be non-catalytic and chemically inactive in transformer oil during service.
- 3.3.5 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.

- 3.3.6 The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes.
- 3.3.7 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.
- 3.3.8 The maximum current density in any winding shall not exceed 3 Amps / sq. mm at all taps.
- 3.3.9 Fiber optic Sensors shall be embedded in each phase of the winding. The sensors shall be located where the Temperature is the highest.
- 3.3.10 The winding shall be designed to withstand the dielectric tests specified. The type of winding used shall be of time tested. An analysis shall be made of the transient voltage distribution in the windings, and the clearances used to withstand the various voltages. Margins shall be used in recognition of manufacturing tolerances and considering the fact that the system will not always be in the new factory condition.
- 3.3.11 The barrier insulation including spacers shall be made from high-density pre-compressed press board (1.15 gm/cc minimum for load bearing and 0.95 gm/cc minimum for non-load bearing) to minimize dimensional changes. Kraft insulating paper used on conductor should have density of >0.75g/cc. The characteristics of the insulation paper will be reviewed at the time of design review.
- 3.3.12 All spacers shall have rounded edges. Radially stepped spacers between winding disks will not be accepted.
- 3.3.13 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.
- 3.3.14 All insulating materials and structures shall be protected from contamination and the effects of humidity during and after fabrication and after receipt, by storing them in a separate, climate-controlled area. All blocks shall be installed such that the grain is oriented in the horizontal direction, perpendicular to the winding compressive forces. Aspect ratio of selected conductor shall be chosen suitably based on manufacturer's experience to result in stable winding under normal and abnormal service condition after assembly.
- 3.3.15 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.
- 3.3.16 **Winding paper moisture shall be less than 0.5%.**

- 3.3.17 Windings shall be provided with clamping arrangements which will distribute the clamping forces evenly over the ends of the winding.
- 3.3.18 **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.
- 3.4 **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.
- 3.4.1 **Winding terminations into bushings**
- 3.4.2 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.
- 3.4.3 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.
- 3.4.4 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.
- 3.4.5 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 bushings.
- 3.4.6 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.
- 3.5 **Unused uninhibited Insulating Oil**
- 3.5.1 a) Uninhibited Mineral insulating oil shall be used & shall comply with IEC-60296- 2012 (Latest version).

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

The oil shall be got tested at R&D section, KPTCL before filling and after filling into the Transformer (before energizing) as per relevant standards.
- b) Sufficient quantity of oil necessary for first filling of all tanks, coolers

and radiator at the proper level along with 10% extra oil for topping up shall be supplied in non-returnable containers suitable for outdoor storage.

c) At manufacturer's works the quality of oil used for first filling, testing and impregnation of active parts shall meet at least parameters as mentioned below. The oil test results shall form part of equipment test report.

- BDV (kV rms) 70 kV (min.)
- Moisture content 10 ppm (max.)
- Tan-delta at 90degC 0.01 (max.)
- Resistivity at 90degC 6×10^{12} ohm-cm (min.)
- Interfacial Tension 35 mN/m (min.)

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

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

3.5.2 Particles in the oil

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

3.5.3 Moisture content in the solid insulation

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

3.5.4 Oil filling

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

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

3.5.7 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.

3.5.8 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.

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

- a) Removal of moisture from 100 ppm to 3 ppm (max.)
- b) Removal of dissolved gas content from 10% by Vol. to 0.1% by vol.
- c) Improvement of dielectric strength break down voltage from 20 to 70 KV
- d) Vacuum level of degassing chamber not more than 0.15 torr/0.2 mbar at rated flow and at final stage. Machine shall have minimum of two degassing chambers and these should have sufficient surface areas to achieve the final parameters.
- e) Filter shall be capable of removing particle size more than 0.5 micron in the filtered oil.
- f) Processing temperature shall be automatically controlled and have an adjustable range from 40° C to 80° C.

3.5.10 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.

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

3.5.11 Preparation of long term storage of spare units (if applicable).

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

Purchaser intends to replace any of the Transformer (1-Phase) unit by the completely assembled oil filled spare Transformer (1-Phase units) fitted

with bushings, cooler etc by isolator switching arrangement and without physically shifting the Transformer.

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

3.6 **Terminal Arrangements**

3.6.1 **Bushings**

3.6.1.1 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 IS/IEC 60137. All details of the bushing shall be submitted for approval & design review.

3.6.1.2 Bushing for various voltage rating shall be as follows

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

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

3.6.1.3 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)

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

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

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

3.6.1.7 Porcelain used in bushing manufacture shall be homogenous, free from lamination, cavities and other flaws or imperfections that might affect the

mechanical or dielectric quality and shall be thoroughly vitrified, tough and impervious to moisture.

- 3.6.1.8 Polymer/composite insulator shall be seamless sheath of a silicon rubber compound. The housing & weather sheds should have silicon content of minimum 30% by weight. It should protect the bushing against environment influences, external pollution and humidity. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core. The technique being followed with detailed procedure and sampling shall be finalized during finalization of MQP.

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

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

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

- 3.6.1.9 Clamps and fittings shall be of hot dip galvanized/stainless steel.
- 3.6.1.10 Bushings turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay.
- 3.6.1.11 No arcing horns shall be provided on the bushings.
- 3.6.1.12 Corona shield, wherever required, shall be provided at bushing terminal (air end) to minimize corona.
- 3.6.1.13 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.

- 3.6.1.14 Oil end portion of RIP/RIS Bushings shall be fitted with metal housing with positive dry air pressure and a suitable pressure monitoring device shall be fitted on the metal housing during storage to avoid direct contact with moisture with epoxy. The pressure of dry air needs to be maintained in case of leakage. Alternatively, oil filled metal housing with suitable arrangement for taking care oil expansion due to temperature variations shall also be acceptable. Manufacturer shall submit drawing/documents of packing for approval during detail engineering. Detail method for storage of bushing including accessories shall be brought out in the instruction manual.
- 3.6.1.15 The terminal marking and their physical position shall be as per IS 2026/IEC: 60076.
- 3.6.1.16 Tan delta measurement at variable frequency (in the range of 20Hz to 350Hz) shall be carried out on each condenser type bushing (OIP & RIP/RIS) at Transformer manufacturing works as routine test before despatch and the result shall be compared at site during commissioning to verify the healthiness of the bushing.
- 3.6.1.17 Tan delta value of OIP/RIP/RIS condenser bushing shall be 0.005 (Max) in the temperature range of 10°C to 40°C. If Tan δ is measured at a temperature beyond above mentioned limit, necessary correction factor as per IEEE shall be applicable.

3.7 **Terminal connectors**

- a) Bushing terminals shall be provided with terminal connectors of approved type and size for connection of external parts. Terminal connectors must have been successfully designed and type tested strictly as per Section – General Technical Requirement.
- b) Contractor shall submit the drawings of HV, IV & LV terminal connectors which he intends to supply and obtain owners approval before arranging procurement/manufacturing

3.8 **Neutral Earthing Arrangement**

3.8.1 **For 3- phase unit:**

The neutral terminal of auto 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) 75 x 12 mm galvanised steel flats connected to Employer's grounding mat.

3.8.2 **For 1-Phase Unit:**

The contractor shall connect the neutrals of three (3) 1-Phase transformers

by overhead connection to operate in three phase banks. The neutral terminals of winding of the three (3) single phase transformers shall be connected to an overhead common brass/ tinned copper/Aluminium pipe/ACSR conductor grounding bus, supported from the tank and fire walls by using porcelain insulators. 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 unless approved otherwise. 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.

3.9 Tertiary Delta Formation (applicable for 1-Phase Transformer)

The contractor shall connect 33kV of single phase transformers in DELTA configuration by overhead connection to operate in 3-Ph Bank. The Delta shall be formed by approximate size of 3" IPS Al. tube, which shall be insulated with heat shrinkage insulating sleeve (shall be of reputed make, to be approved by KPTCL) of at least 52kV class of 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.

3.10 Spare Unit connection arrangement (applicable for 1-Phase Transformer)

Connection arrangement of spare unit of transformer with other units shall be made by isolator switching. Tertiary delta and neutral formation for spare unit of transformer shall be done by manual connection. The contractor shall make connection arrangement as well as control scheme of OLTC and Cooler in such a way that spare unit of transformer can be connected in phase of faulty unit without physically shifting it from its location. For this purpose, HV, IV, Tertiary and Neutral connections of spare unit are to be extended upto the other unit by forming auxiliary buses with tertiary connection insulated with heat shrinkage insulating sleeve (shall be reputed make approved by KPTCL) of atleast 52kV class of adequate thickness and shall be supported by structure mounted bus post insulators at suitable intervals to enable spare unit connection through flexible/rigid conductor and suitable connector in place of existing unit to be replaced. A typical sketch of connection arrangement is shown in the drawing enclosed at Annexure-D. However, the detail configuration and actual sizes of various items shall be finalized during detailed engineering and shall be subject to Employer's approval. All associated materials like Bus post insulators, Aluminium tube, conductors, clamps & connectors, insulated strings, hardware, cables, support structures, required for the above mentioned arrangement shall be provided by the contractor.

3.11 Cooling Equipment and its Control

3.11.1 **Cooling Equipment**

- 3.11.1.1 The cooler shall be designed using 2 x 50% radiator banks. Design of cooling system shall satisfy the performance requirements. The cooler bank should be one side of the transformer ie., on left side of the transformer while facing the 400kV bushings.
- 3.11.1.2 The radiator shall be of sheet steel complying with IS 513 and minimum thickness 1.2mm. 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 of at least 80mm size.
 - c) Drain Valve and sampling valve.
 - d) Top and bottom oil filling valves.
 - e) Air release plug at top.
 - f) Two grounding terminals suitable for termination of two (2) Nos. 75x12mm galvanized steel flats.
 - g) Thermometer pockets fitted with captive screw caps at cooler inlet and outlet.
 - h) Lifting lugs.
- 3.11.1.3 Each radiator bank shall be detachable and shall be provided with flanged inlet and outlet branches. Expansion joint (for separately) ground mounted cooler banks) shall be provided on top and bottom cooler pipe connection.
- 3.11.1.4 Required number of standby fans of approximately 20% capacity shall also be provided with each radiator bank.
- 3.11.1.5 Cooling fans shall not be directly mounted on radiator The supporting frames for the cooling fans shall be fixed preferably on separate support or to the main tank in such a manner that the fan vibration does not affect the performance of the radiators and its valves. Fans shall be located so as to prevent ingress of rain water. Each fan shall be suitably protected by galvanized wire guard. The exhaust air flow from cooling fan shall not be directed towards the main tank in any case.
- 3.11.1.6 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.
- 3.11.1.7 The changeover to standby oil pump in case of failure of service oil pump shall be automatic.
- 3.11.1.8 An oil flow indicator shall be provided for the confirmation of the oil flow direction. An indication in the flow indicator and potential free contacts for remote alarm shall be provided.
- 3.11.1.9 Valves shall be provided on either side of the pump and oil flow indicator to

avoid oil drain and long outage during maintenance/replacement of pump and oil flow indicator.

- 3.11.1.10 Cooling fans and oil pump motors shall be suitable for operation from 415 volts, three phase 50 Hz power supply and shall be of premium efficiency class IE3 conforming to IS: 12615. 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 IS:4691/IEC 60034-5.
- 3.11.1.11 The cooler pipes, support structure including radiators and its accessories shall preferably be hot dip galvanised or corrosion resistant paint should be applied to it.
- 3.11.1.12 Expansion joint shall be provided, one each on top and bottom cooler pipe connections.
- 3.11.1.13 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.

3.11.2 **Unit cooler arrangement for transformer (if applicable)**

- 3.11.2.1 The cooler shall be designed using 5 x 25% unit Cooler arrangement. Design of cooling system shall satisfy the performance requirements.
- 3.11.2.2 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.
- 3.11.2.3 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.
- 3.11.2.4 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.
- 3.11.2.5 Cooling fans and oil pump motors shall be suitable for operation from 415 volts, three phase 50 Hz power supply and shall conform to IS: 325/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 IS:4691/IEC:34-5
- 3.11.2.6 The cooler, pipes, support structure and its accessories shall be hot dip galvanized or corrosion resistant paint should be applied to external surface of it. Expansion joint shall be provided on top and bottom cooler pipe connections as per requirement.

- 3.11.2.7 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.
- 3.11.2.8 **Cooling Equipment Control (OFAF or ODAF) Cooling [for Unit Cooler arrangement (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. 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.
 - vi) Adequate warning/ safety labels are required to indicate that the fans may start at any time.
 - vii) All settings shall be adjustable.
 - viii) If any one group(s) is out of service and isolated, this shall not affect the automatic starting of the other unit cooler.
 - ix) Indicating Devices.

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) Cooler unit failure for each unit cooler
- f) No oil flow/reverse oil flow for pumps.
- g) 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.

3.11.3 **Cooling Equipment Control (ONAN/ONAF/OFAF/ODAF COOLING)**

- 3.11.3.1 Automatic operation control of fans/pumps shall be provided (with temperature change) from contacts of winding temperature indicator. The Manufacturer shall recommend the setting of WTI for automatic change over of cooler control over entire operating range depending on types of cooling system like ONAN/ONAF/OFAF (or ODAF) or ONAN/ONAF1/ONAF2. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.
- 3.11.3.2 Suitable manual control facility for cooler fans and oil pumps shall be provided.
- 3.11.3.3 The changeover to standby oil pump in case of failure of service oil pump shall be automatic.
- 3.11.3.4 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.

3.11.4 **Indicating Devices**

Following lamp indications shall be provided in cooler control cabinet:

- a) Control Supply failure (Main).
- b) Cooling fan failure for each bank.
- c) Cooling pump failure for each pump.
- d) No oil flow/reverse oil flow for pumps.
- e) Common thermal overload trip.
- f) Cooler supply changeover
- g) Cooler supply failure (Standby)
- h) Cooler supply failure.
- i) Thermal overload trip.
- j) No oil flow/reverse flow for pumps.
- k) Standby 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 phase unit connection shall be extended further to Common Marshaling Box (CMB).

- 3.11.5 The cooler control cabinet/Individual Marshalling box(IMB) 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.

- 3.11.6 All the necessary terminations for remote connection to Purchaser's panel shall be wired upto the common marshaling box (in case of 1-Ph unit) or Marshaling Box (3-Ph unit).
- 3.11.7 The cooler control cabinet shall have two (2) sections. One section shall have the control equipment exclusively meant for cooler control. The other section shall house the temperature indicators, aux. CTs and the terminal boards meant for termination of various alarm and trip contacts as well as various bushing CT secondary. Alternatively the two sections may be provided as two separate panels depending on the standard practice of the Bidder.
- 3.11.8 AC power for cooler control circuitry shall be derived 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 stationed auxiliary power supply are mentioned in GTR specification.
- 3.11.9 The temperature indicators shall be so mounted that the dials are about 1200mm from ground level. Glassed door of suitable size shall be provided for convenience of reading.

3.12 **Auxiliary Power Supply of OLTC, Cooler Control and Power Circuit**

A. For Single Phase unit

- a) Two auxiliary power supplies, 415 volt, three phase four (4) wire shall be provided at common marshalling box for OLTC & cooler control and power circuit. 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.
- b) For each circuit, suitably rated MCBs/MCCBs as required for further distribution of auxiliary power supply to DM boxes, Online Gases and moisture monitoring system, Online drying system and Fibre optic temperature monitoring unit etc. (as applicable), shall be provided in individual marshalling boxes /cooler control boxes.
- c) Auxiliary power supply distribution scheme shall be submitted for approval. Supply and laying of Power, Control and special cables from common marshalling box to individual MB/Cooler Control Cubicle (including spare unit) & further distribution from IMB/CCC to all accessories is in the scope of the manufacturer/contractor. Further any special cable (if required) from CMB to Owner's Control Panels/ RTCC panels is also in the scope of the manufacturer/contractor.

- d) Connection arrangement for spare unit 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 also be brought in common marshalling box of all the banks. Necessary arrangement in schematic of Common marshalling box is required to facilitate change-over of all the signals of faulty units to spare unit of Transformer, to ensure flow of control, protection and indication signals between Purchaser's Control panels / RTCC Panel / SCADA and individual units under operation (i.e. any designated unit for bank or spare unit, if it replaces any designated unit). To facilitate change-over of spare unit signals with faulty unit in CMB, male-female plug-in connector or better arrangement shall be provided to reduce the outage time.

B. For Three Phase Transformer

- a) Two auxiliary power supplies, 415 volt, three phase four (4) wire shall be provided by the Purchaser at cooler control cabinet/Marshalling Box for OLTC & cooler control and power circuit. 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 Box.
- b) 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, Online Drying System and Fibre optic temperature monitoring unit etc. (as applicable), shall be provided in cooler control cabinet/Marshalling box.
- c) 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 manufacturer/contractor. Further any special cable (if required) from MB to Owner's Control Panels/RTCC panels is also in the scope of the manufacturer/contractor.
- d) All relays and operating devices shall operate correctly at any voltage within the limits specified below:

Normal Voltage	Variation in Voltage	Frequency (in Hz)	Phase/Wire	Neutral connection
415V	±10%	50 ±5%	3 Phase 4Wire	Solidly earthed
240 V	±10%	50±5%	1 Phase 2 Wire	Solidly earthed
220 V	190 V to 240 V	DC	Isolated 2 wire system	--
110V	95 V to 120 V	DC	Isolated 2	--

			wire system	
48V	--	DC	2 wire system (+) earthed	--

Combined variation of voltage and frequency shall be limited to $\pm 10\%$.

3.12.5 **Design features of the transfer scheme** shall include the following:

- Provision for the selection of one of the feeder as normal source and other as standby.
- Upon failure of the normal source, the loads shall be automatically transferred after an adjustable time delay to standby sources.
- Indication to be provided at cooler control cabinet/IMB/CMB for failure of normal source and for transfer to standby source and also for failure to transfer.
- Automatic re-transfer to normal source without any intentional time delay following re-energization of the normal source.
- Both the transfer and the re-transfers shall be dead transfers and AC feeders shall not be paralleled at any time.

3.12.6 **A. Power Supply for OLTC Circuits**

- AC feeder shall be brought to the local OLTC control cabinet by the manufacturer/Contractor after suitable selection at cooler control cabinet for which description is given in 3.12.5 above, for control power circuit of OLTC.
- The manufacturer/Contractor shall derive AC power for OLTC control circuitry from the AC feeder as mentioned above by using appropriately rated dry type transformers.

B. Power Supply for Cooler Circuits

- Control and power supplies are to be given for Cooler circuits after the selection as mentioned in 3.12.5 above.
- The Contractor shall derive AC power for Cooler Control Circuitry by using appropriately rated dry type transformer in case of using supply voltage different from the Employer's auxiliary supply. If the control circuit is operated by DC supply then suitable main and standby convertors shall be provided by the Contractor, to be operated from AC power source.
- Necessary isolating switches and MCBs/MCCBs shall be provided at suitable points as per Employer's approved scheme.

3.13 **Valves**

- 3.13.1 Type of valves shall be used for transformer as per following table. The location and size of valves for other application shall be finalized during design review. Utility may specify any other valve required for some other applications.

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
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)	Gate
17	Valve for NIFPS Drain	Gate
18	Valve for UHF Sensors (applicable for 400kV and above voltage class Transformer only)	Gate

- 3.13.2 All valves upto and including 50 mm shall be of gun metal or of cast steel. 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.
- 3.13.3 Suitable means shall be provided for locking the valves in the open and close positions. Provision is not required for locking individual radiator valves.
- 3.13.4 Each valve shall be provided with the indicator to show clearly the position (open/close) of the valve.
- 3.13.5 All valves flanges shall have machined faces.
- 3.13.6 All valves in oil line shall be suitable for continuous operation with transformer oil at 115°C.
- 3.13.7 The oil sampling point for main tank shall have two identical valves to be put in series .Oil sampling valve shall have provision to fix rubber hose of 10 mm size to facilitate oil sampling.
- 3.13.8 A valve or other suitable means shall be provided to fix the on line

dissolved gas monitoring system to facilitate continuous dissolved gas analysis. The location & size of the same shall be finalised during detailed design review.

3.13.9 Suitable small bore (8 mm copper) piping with an appropriate valve shall be provided to take sample of oil from the OLTC chamber by the user while at ground.

3.13.10 After testing, inside surface of all cast iron valves coming in contact with oil shall be applied with one coat of oil resisting paint/varnish with two coats of red oxide zinc chromate primer followed by two coats of fully glossy finishing paint conforming to IS:2932. Outside surface except gasket setting surface of butterfly valves shall be painted with two coats of red oxide zinc chromate conforming to IS:2074 followed by two coats of fully glossy finishing paint.

All valves shall be painted with a shade (preferably red or yellow) distinct & different from that of main tank surface and as per the painting system and procedure specified.

3.13.11 All hardware used shall be Hot dip galvanised/stainless steel.

3.14 **Wiring & Cabling:**

All interconnecting control and power cables between various parts of Transformers like turret CT, MBs, Fans, pumps, Buchholz, PRD etc shall be routed through covered cable tray or GI conduit and shall be properly dressed. All cables shall be armoured type. Un-armoured cables (if provided) in any circuitry, shall be through GI conduit and no part shall be exposed. Cable terminations shall be through stud type TB and ring type lugs. Type tested cables from approved sources shall be provided. Both ends of all the wires (Control & Power) shall be provided with proper ferrule numbers for tracing and maintenance. Further, any special cables (if required) shall also be considered included in the scope. All cable accessories such as glands, lugs, cable tags/numbers, etc. as required shall be considered included in the scope of supply.

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

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

3.14.2 Compression type cable connector shall be provided for termination of power and control cables.

3.14.3 All controls, alarms, indicating and relaying devices provided with the

transformer shall be wired up to the terminal blocks inside the local control cabinets (both cooler and OLTC control cabinets).

- 3.14.4 All devices and terminal blocks with the cooler control cabinet shall be clearly identified by symbols corresponding to those used on applicable schematic or wiring diagrams.
- 3.14.5 Not more than 2 wires shall be connected to one terminal. Each terminal shall be suitable for connecting two 2.5 sq. mm stranded copper conductor control cable from each side.
- 3.14.6 All internal wiring shall be securely supported, neatly arranged, readily accessible and connected to equipment terminals and terminal blocks.
- 3.14.7 Engraved code identification plastic Alpha numeric ferrules marked to correspond with schematic diagrams shall be fitted at both ends of wires. Alpha Numeric ferrules shall fit tightly on wires and shall not fall off when the wire is disconnected from terminal block.
- 3.14.8 Cabling of spare unit of transformer with isolator switching arrangement shall be in such a way that spare unit can be brought into service in case of failure/ outage of a healthy unit without physically shifting. All control, protection, indication signals of spare unit shall be brought to the Common Marshalling Box (CMB) 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. Plug & socket arrangement shall be provided for quicker transition of faulty unit to spare unit to avoid interconnection errors.

3.15 **Tap Changing Equipment**

3.15.1 Tap Change Switch General Requirement

The On Load tap changer shall be of High-speed, Transition Resistor type and shall comply with IS 8468/IEC 60214.

OLTC shall be motor operated for local as well as remote operation. An external handle shall be provided for local manual operation. This handle shall be suitable for operation by a man standing at ground level.

The On Load tap changer shall be sourced from reputed manufacturer and it should be type tested as per relevant IEC 60214 including switching and transient resistance test of the relevant switch and test methods in full conformance to the procedure indicated in IEC 60214

3.15.2 On Load Tap Changing Gear (OLTC)

The requirements of On Load tap changing equipment are given here below:

3.15.2.1 Main OLTC Gear Mechanism

- 3.15.2.1.1 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. The OLTC shall conform to IS 8468/IEC 60214.
- 3.15.2.1.2 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.
- 3.15.2.1.3 The current diverting contacts shall be housed in a separate oil chamber not communicating with the oil in main tank of the transformer and the chamber shall be designed to withstand the vacuum. The contacts shall be accessible for inspection without lowering oil level in the main tank and the contacts shall be replaceable.
- 3.15.2.1.4 The voltage class, maximum tapping current, step voltage of OLTC shall have adequate design margin for safe & reliable service life of both OLTC and transformer. OLTC shall have long contact life, quick & easy to disassemble diverter switch inserts, simple to adjust & control and easy to replace diverter's contacts etc.
- 3.15.2.1.5 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.
- 3.15.2.1.6 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. Provision of a suitable device like tie-in-resistor has to be made, wherever required, to limit the recovery voltage to a safe value. The use of tie-in-resistor (if used) shall be clearly marked in rating and diagram plate of the transformer. The whole of the driving mechanism shall be of robust design and capable of giving satisfactory service without undue maintenance.
- 3.15.2.1.7 Tap changer shall be so mounted that bell cover of transformer can be lifted without removing connections between windings and tap changer.

3.15.2.2 Local OLTC Control Cabinet (Drive Mechanism Box) and OLTC control from Drive mechanism box.

Each transformer unit with OLTC gear shall have following features:

3.15.2.2.1 OLTC shall be suitable for manual (handle operated) and electrical (motor operated) operation.

For local manual operation from Local OLTC Control cabinet (Drive Mechanism Box), an external handle shall be provided.

3.15.2.2.2 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 digit 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.

3.15.2.2.3 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.

3.15.2.2.4 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 (or locking arrangement suitable for long term operation) for hinged door of cabinet
- vi. Cable terminal glands for power and control cables to the OLTC gear
- vii. All contactors, relay coils and other parts shall be protected

against corrosion, deterioration due to condensation, fungi etc.
viii. The cabinet shall be tested at least IP 55 protection class.

- 3.15.2.2.5 All relays and operating devices shall operate correctly at any voltage within the limits specified in GTR.
- 3.15.2.2.6 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.
- 3.15.2.2.7 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 shall be provided.
- 3.15.2.2.8 OLTC local control cabinet shall be provided with tap position indication for the transformer. The contractor shall also provide a set of instruments for tap position indication in the control room (in Digital RTCC or control panel).
- 3.15.2.2.9 'Local-remote' selector switch shall be provided in the local OLTC control cabinet. In Local mode, all electrical commands from remote [from CMB, RTCC, SAS, Numerical RTCC unit (ITCS) 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/ RTCC/SAS/Numerical RTCC unit (ITCS) etc. shall be executed. The remote-local selector switch shall be having at-least two spare contacts per position.
- 3.15.2.2.10 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 RTCC panel/ Numerical RTCC Unit (ITCS):
- 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.
 - 415V Main AC supply ON.
 - OLTC out of step.
- 3.15.2.2.11 The following minimum contacts shall be available in DM Box. For three phase unit & these contacts shall be further wired to digital RTCC panel/relevant BCU (as applicable):

- (a) INCOMPLETE STEP which shall not operate for momentary loss of auxiliary power.
- (b) OLTC motor overload protection.
- (c) Supply to DM Motor fail.
- (d) OLTC IN PROGRESS.
- (e) Local/Remote Selector switch position.
- (f) OLTC upper/lower limits reached.
- (g) 415V Main AC supply ON.

3.15.2.2.12 OLTC Tap position indication shall be provided in DM Box. 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 RTCC/SAS/Numerical RTCC unit (ITCS) system.

3.15.2.2.13 Thermal device or other means shall be provided to protect the motor & control circuit.

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. Both ends of all the wires (control & power) connected to Drive Mechanism Box must be provided with proper ferrule nos. for tracing and maintenance.

3.15.2.2.14 A permanently legible lubrication chart and control circuit shall be fitted within the OLTC local control cabinet.

3.15.2.3 **OLTC Control from Common Marshalling Box (CMB) (for 1 Phase transformers)**

3.15.2.3.1 It shall be possible to monitor, control/operate, the OLTC of all the three 1-ph of a transformer bank from Common Marshalling Box. The control and monitoring terminations of a spare transformer unit shall be brought to CMB. The necessary switching arrangement through male-female plug-in TB assembly shall be provided for replacing spare unit with any one of the faulty phase unit for monitoring & control from CMB.

3.15.2.3.2 'Independent-combined-remote selector switch, raise/lower switch and Emergency stop push button shall be provided in the common marshalling box for OLTC control.

3.15.2.3.3 When the selector switch is in **independent** position, the OLTC control shall be possible from individual Local OLTC Control Cabinet (DM Box) only.

3.15.2.3.4 In '**combined position**', raise-lower switch (provided in the CMB), shall be used to operate for bank of three single phase transformers from CMB.

3.15.2.3.5 In '**remote position**' control of OLTC shall be possible from RTCC/SAS/Numerical RTCC unit (ITCS), etc.

3.15.2.3.6 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/ RTCC/ SAS/Numerical RTCC unit (ITCS) shall be prevented.

3.15.2.3.7 A. Following minimum **LED indications** shall be provided in CMB:

- a. INCOMPLETE STEP
- b. OLTC motor overload protection operated.
- 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. 415V Main AC supply ON
- h. OLTC out of step

B. Following **contacts** shall be wired to TBs in CMB from DM Box for further wiring to RTCC Panel, Numerical RTCC Unit (ITCS)/SAS:

- a. INCOMPLETE STEP
- b. OLTC motor overload protection operated
- 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
- h. Cooler 415V Main AC supply Fail
- i. OLTC out of step

Further, OLTC Tap position Digital indications for all three 1-Ph Transformer units separately shall be provided in CMB. The same shall also be wired to RTCC Panel/ Numerical RTCC Unit (ITCS) to display tap positions for all three 1-ph unit separately.

3.15.2.4 **Remote Electrical Group Control**

The remote OLTC scheme offered shall have provision to raise or lower taps for the complete bank of three single phase transformers/3-phase transformer. Individual single phase OLTC operation shall not be possible from the remote control panel. It shall be possible to operate 4 Nos. of transformers in group control of OLTC.

The OLTC control scheme shall have provision of remote electrical group control when the three phase bank is in parallel operation with three phase transformers/three phase banks of single phase transformers.

- a) A four position selector switch having Master, Follower, Independent and Off position shall be provided in the remote OLTC control panel for three (3) phase bank of single phase transformers/3-Phase transformer. This shall be wired to enable the operator to select operation of OLTC in either Master, Follower or Independent mode.

- b) Out of step relays with timer contacts shall also be provided to give alarm and indication in case taps of all the transformers under control are not in same position.
- c) Master Position
If the selector switch is in master position, it shall be possible to control the OLTC units of other transformer banks/three phase transformer in the follower made by operation of the master unit.
- d) Follower Position
If the selector switch is in Follower position control of OLTC shall be possible only from panel where master mode is selected.
- e) 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.

3.15.2.5 The control circuits shall comply with following conditions:

- 3.15.2.5.1 An interlock to cut off electrical control automatically upon recourse being taken to the manual control in emergency.
- 3.15.2.5.2 Reinforcement of the initiating impulse for a tap change, ensuring a positive completion once initiated to the next (higher or lower) tap.
- 3.15.2.5.3 "Step-by-Step" operation ensuring only one tap change from each tap changing impulse and a lock-out of the mechanism if the control switch (or push button) remains in the "operate" position.
- 3.15.2.5.4 An interlock to cut-out electrical control when it tends to operate the gear beyond either of the extreme tap positions.
- 3.15.2.5.5 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.
- 3.15.2.5.6 Tap change in progress indication shall be provided by means of an indicating lamp at the Employer's control panel. Necessary contacts for this and for remote tap position indicator at Employer's control panel shall be provided by the Bidder.
- 3.15.2.5.7 Protective apparatus, considered essential by the Bidder according to specialities of the gear shall be provided.

3.15.2.6 **OLTC Routine Tests:**

OLTC manufacturer shall conduct the following routine tests fully in

compliance with IEC 60214 on every unit as given below before dispatch to assure the quality of the product.

Sl. No.	IEC Reference	Test description	Acceptance level
1	60214 Cl No. 5.3.1	Mechanical Endurance Test	Minimum 1000 operations
2	60214 Cl No. 5.3.2	Sequence Test	Switching operation with timing less than 50m sec.
3	60214 Cl No. 5.3.4	Pressure Test	10 PSI (0.7kg per Sq.cm.) for 8 hrs. at room temp.
4	60214 Cl No. 5.3.4	Vacuum (Helium) Test	Vacuum level of 6×10^{-5}
5	60214 Cl No. 5.3.3	Auxiliary circuit insulation tests	Should withstand 2KV relative to earth for 1 min
6	Special Test	Gas Tightness Test	Helium based or any other mutually agreed method
7	Special Test	Contact resistance Test	< 2 miliohms
8	Special Test	Physical & Dimensional Checks	As per approved drawing

All the relevant test reports shall be submitted along with the test report of Transformer for KPTCL approval.

The Tap Changer shall be suitably protected through Oil Surge Relay and it shall be of reed magnetic switch type. This surge relay shall be tested for an Oil flow velocity of 1.20 ± 0.20 m/s.

3.15.2.7 VOID

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

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

3.16.2 Common marshaling box (for single phase unit) shall be ground 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.

- 3.16.3 The cooler control cabinet/individual marshaling box, common marshaling box, junction box and all other outdoor cubicles (except OLTC Drive Mechanism box) shall be made of stainless steel sheet of minimum thickness of 1.6mm. and minimum grade of SS 304. RTCC panel shall be made of CRCA sheet of minimum thickness of 2.0mm and shall be painted suitably as per CL.No. 3.1.1.14
- 3.16.4 The degree of protection shall be IP: 55 for outdoor and IP: 43 for indoor in accordance with IEC-60947.
- 3.16.5 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 other (approved) material of better quality, whereas for all indoor control cabinets/ RTCC panel, the sealing gaskets shall be of neoprene rubber or any other (approved) material of better quality. The gaskets shall be tested in accordance with approved quality plan IS: 3400.
- 3.16.6 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 Marshalling Box. All the CT secondary terminals in the Marshalling Box shall have provision for shorting to avoid CT open circuit while it is not in use. All the necessary terminations for remote connection to Purchaser's panel shall be wired up to the Common Marshalling box.
- 3.16.7 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.
- 3.16.8 **Local OLTC Control Cabinet**
The Local OLTC control cabinet shall house all necessary devices meant for OLTC control and indication.
- 3.16.9 A. **Remote Tap Changer Control Panel.**
The Contractor shall supply a Remote Tap Changer Control (RTCC) panel suitable for remote operation of On load tap changing gear.

The RTCC panel shall house actuating switch for electrical raise/lower control, tap position indicator, signal lamps for "Tap change in progress" and "Tap changer out of step", and all other auxiliary devices for remote electrical control of the OLTC. For tap position indicator, the dual output type OLTC transducer shall be provided in the RTCC panel. One of the outputs of this transducer shall be used for local indication of tap position in RTCC panel and other output (4-20 mA) shall be used for Station

Automation System.

The RTCC panel shall be located in Employer's control room/Air conditioned Bay controller Kiosk. The size & colour of the RTCC panel shall match with Employer's control panel. The matching details shall be furnished at the time of award.

RTCC panel for Single phase unit shall have provision for connecting/operating the spare single phase unit.

Annunciator (facia type) scheme complete with accessories/Potential free contacts for the following shall be provided in the RTCC panel and Numerical RTCC unit (ITCS) independently.

- i) Tap changer incomplete/Motor stuck up.
- ii) Tap changer out of step
- iii) Tap changer motor overload trip.
- iv) Failure of AC supply to the OLTC local control Kiosk.
- v) OLTC control supply fail
- vi) Running Fan failure of each group
- vii) Stand by fan failure of each group.
- viii) Running Pump failure of each group.
- ix) Stand by pump failure of each group.
- x) 415V cooler control supply fail.
- xi) No flow / reverse flow of oil in oil pump of each group.
- xii) 415V Cooler Main Supply fail.
- xiii) 415V Cooler Stand by Supply fail.

Potential free contacts for the following shall be provided in the RTCC panel (for indication) and Numerical RTCC unit (ITCS) independently:

- i) Fan 'ON' for each group / each fan.
- ii) Pump 'ON' for each group/ each pump.
- iii) Standby fan 'ON' for each group.
- iv) Cooling system in Local manual mode
- v) Cooling system in Local Auto mode.
- vi) Cooling system in Remote manual mode.
- vii) Cooling system in Remote Auto mode.
- viii) 415 Volts cooler Supply 'ON',
- ix) 415 Volts cooler supply auto change over from Main to Stand- by.
- x) 415 Volts cooler supply-A 'ON'
- xi) 415 Volts cooler supply-B 'ON'
- xii) Cooler control supply 'ON'
- xiii) 415 Volts OLTC supply 'ON'.
- xiv) OLTC control supply 'ON'.
- xv) Tap changer upper limit reached.
- xvi) Tap changer lower limit reached
- xvii) Tap changer in local mode
- xviii) Tap changer in Remote RTCC/ITCS/SAS mode
- xix) Tap change in progress
- xx) Tap changer in Independent/Master/follower mode.

xxi) 'Independent - combined - remote' selector switch position of CMB

B. Microprocessor based Numerical RTCC Unit for Tap changer Control & Transformer Monitoring

Microprocessor based technology has been envisaged for the control of forced cooling equipment, condition monitoring and OLTC control of transformers.

Tenderers shall provide full description of the control system offered and details of deviations from specified requirement shall be brought out in the offer along with necessary justifications.

The intent of this section is to describe the desired functional and environmental requirements in respect of microprocessor based Intelligent Transformer Control System (ITCS) without limiting the additional features that the tenderer may be able to include in the offer. The TCS should provide facilities such as SCADA/ SAS links, transformer cooler control and data logging, control of the OLTC, remote OLTC tap position indication in digital form at local and the remote temperature indications for windings and top oil, temperature alarms and trip, marshalling of other control and alarm functions, emergency overload control, recording of accumulated "use of life" local display of status of control and alarm functions and selection of local and remote control etc.

The TCS equipment (other than HMI and microprocessor unit) shall be located within the auxiliary marshalling cubicle and the Man Machine Interfacing (MMI) unit in the transformer RTC control panel in the control room.

If the TCS is supplied as a draw-out type module, it should take care of shorting all CT inputs automatically while drawing out.

a) FUNCTIONS:

i) Monitoring:

The TCS shall be capable of monitoring the analog data and status signals of the following:

Transformer LV load, voltage, tap changer status including tap positions, tap changing in progress, status of control switches (both cooler control & OLTC), OLTC motor current, OLTC motor trip, temperature difference between OLTC compartment and main tank. Temperature and condition of the transformer cooler status including top oil temperature, ambient temperature, winding hot spot temperature, run status of cooler fans and / or pumps, fan or pump trip, Interface with the fibre optic thermometer where fibre optics probe have been specified. This data shall be available for display, data logging and remote communication. For each analog value the TCS shall display the present and minimum and maximum value reached since the last time

that the minima and maxima where reset to the current values.

ii) Cooling Control:

The TCS shall be capable of controlling all cooling systems of the transformer including pumps, fans. The control function shall operate in such a way as to keep the transformer temperature within the limit set by the Purchaser.

The TCS shall be capable of :

Predictive mode to turn on the cooling system based on predicted top oil and winding hot spot temperatures in addition to normal control based on actual temperatures. This should work in the event of a sudden sustained increase in load current, before the temperatures had risen to normal control settings, so as to keep the transformer cooler longer. Predicted temperature shall be based on a thermal model of each specific transformer (based on actual heat run tests), ambient temperature and load.

Periodic automatic testing :

It shall be possible to automatically exercise testing of the cooler system at preset intervals to ensure that they are still functional, with an alarm if the test fails.

iii) OLTC Control:

The control shall include selection of the following operating modes and features as applicable, by push buttons or keys at the controller or from SCADA/ SAS.

Manual OLTC control by pushbuttons or keys at the controller or from SCADA/ SAS.

AVR (automatic voltage regulation)

Independent mode

Master or follower parallel mode

Circulating current parallel mode

VAR sharing parallel mode

Reverse reactance parallel mode

AVR time delay shall be settable with definite time, fast – tap – down and inverse-time modes.

AVR shall have the option of Line Drop Compensation (“LDC”).

AVR shall be blocked, if the voltage drops below the under voltage set points, to prevent false operation in the event of supply line faults, VT fuse failure etc.

OLTC operations shall be blocked if the current through the OLTC exceeds a preset value.

Each TCS unit shall have integration feature for parallel operation of atleast four Nos., 3-Phase transformers or 12 Nos. 1-Phase of transformers working in parallel. The system shall be self-sufficient and shall not require any

additional devices like parallel balancing module, etc.

iv) Performance Calculations and Prediction:

The TCS shall be capable of calculating –

Watts and VARs

Accumulated number of tap changers from each tap position (discrete counter for each position) and total number of tap changers.

Winding hot spot temperatures for each winding and maximum achieved.

Winding hot spot insulation ageing rate (per unit)

Accumulated insulation ageing (use of life) based on the winding hot spot (years) as per the loading guide for oil immersed power transformer. The use of life calculations shall also convey to the operator the amount of time available at the present over load rating and the amount of overload available for two hours duration from the time in question.

Accumulated operating hours for each fan and pump group.

Accumulated number of starts for each fan and pump group.

v) Alarms:

Alarms shall be extended to the SCADA/ SAS system for :

Voltage out of range for too long (AVR mode only)

Voltage exceeds over-voltage alarm setting or is less than under-voltage alarm setting.

OLTC auxiliary power failure

OLTC fail (tap changed in progress too long or OLTC motor trip)

Temperature abnormalities such as high oil temperature and high winding temperature.

Top oil or winding hot spot temperature exceeds alarm settings.

Top oil or winding hot spot temperature exceeds trip or stage to alarm settings

Cooler auxiliary power failure

Cooler fail (contactor failed to close when switched on, or motor trip, or oil flow failed)

All OLTC and temperature trip signals shall be provided by means of voltage free contacts where the contacts have a rating of not less than 0.4A at 125 VDC resistive. All other trip signals such as Buchholz, pressure relief and OLTC surge shall be provided directly from the voltage free contacts of the respective device, not via the TCS. The alarms can however be wired via the TCS.

vi) Data Logging and Event Recording:

Monitored data shall be time and date stamped and logged in a format, which can be easily imported to data analysis software such as MS Excel/ Access. The local data storage capability which can store all data at one minute intervals shall be stated by the tenderer.

A separate event record is required to record the date and time (to

nearest second) when the status of any alarm changes. The number of events that can be stored shall be stated by the tenderer.

vii) Communication:

The TCS shall accept all Analogue / Digital quantities relevant to the control of the transformer or as required by the purchaser. These quantities shall be able to be interfaced to the purchaser's SCADA/SAS equipment. The ITCS shall be capable of down loading data files via telephone line and GSM System. The protocol for communication shall be as per IEC 61850.

viii) Other capabilities:

Tenderers may also offer TCS which performs both Dissolved Gas Analysis and moisture in oil condition monitoring.

b) MAN MACHINE INTERFACE:

Access to control variables within the TCS shall be available to the personnel as required by the purchaser. The form of these interface should preferably be via a permanent front panel that contains a display and keypad. The menu facilities shall be as simple and intuitive as possible. Facilities to access the TCS via local RS-232 port and software running on a laptop PC under the latest version of Windows shall also be provided. A sample of the PC software shall be supplied to the purchaser for evaluation before proceeding with that method. Software supplied to the purchaser is not returnable and becomes the property of the purchaser.

The unit supplied shall be field programmable so that in the event of change in transformer/location it could be customized to site condition without sending back to works. The programming shall be menu driven & can be easily configurable.

c) ELECTRICAL ISOLATION AND TRANSIENT PERFORMANCE:

All equipment shall be type tested, tested during manufacture and after completion in accordance with latest IEC 60255 and IEC 60068.

d) POWER SUPPLIES:

The TCS should be powered directly from the Sub-station battery bank.

e) INPUTS / OUTPUTS

f) DIGITAL INPUT AND OUTPUT MODULES

The "on" state of all digital inputs and outputs shall be indicated by Light Emitting Diodes (LED) on the front of the modules. These LEDs shall be visible from the front panel on which the TCS equipment is mounted. All inputs shall be electrically isolated from the external circuit and capable of being driven from 42 V dc to 240 V dc.

All output shall be electrically isolated from external circuit and rated for switching 42 V dc to 240 V dc and 0.5 Amp.

Sufficient number of DI and DO modules shall be provided to suit the scheme requirement during drawing approval and during commissioning as per field condition. Additional 20% spare DI's and DO's shall be provided for future use.

4-20mA analog inputs shall be provided for the following: Oil temperature, Core temperature, HV- R phase, Y phase & B phase winding temperature, IV- R phase, Y phase & B phase winding temperature, OLTC oil temperature, OLTC motor current, Ambient temperature, all Dissolved gases (9Nos.) in PPM, Water content in PPM. Additional 20% spare 4-20mA analog inputs shall be provided for future use.

g) COMMUNICATION PORTS:

Communication ports shall be provided for the following –

Connection to a local computer for down loading data files, uploading settings, software upgrade etc.

Communication with SCADA RTU/ SAS.

Connection to a dial-in modem for down loading data files uploading settings, software upgrade etc.

Communication with sensors and other auxiliary equipment.

Serial communication with remote via a fibre optic links

Connection to LAN to WAN or Intranet.

h) SELF-MONITORING:

The TCS shall have a self-check of power on and shall continually monitor all functions and the validity of all input values to make sure the control system is in a healthy condition. In the event that the unit is unable to control the transformer, the device is to revert to a fail-safe condition. Any monitoring system problem shall initiate an alarm.

i) MEMORY RETENTION:

The TCS shall be capable of retaining its information in the event of a power failure.

j) REAL TIME CLOCK:

There shall be real time clock for time stamping the data log and event records. A long life battery shall be provided to keep the clock operating in the event of the power failure. An alarm shall be generated if the battery fails. It shall also be possible to synchronize the TCS clock with GPS system provided at the substations.

k) SECURITY:

Levels of security to limit access to authorized users shall be provided for

Viewing data and down loading data files (no access control)

Changing control mode and manual control operations (password control)

Changing settings and configuration (password control)

Software upgrade (password control)

l) MOUNTING:

The TCS input/output modules /units shall be mounted within the auxiliary marshalling cubicle or in a separate cubicle with a similar construction located on the transformer. The cubicle shall be rated to IP56. The cubicle shall be capable of protecting the equipment contained within and keep it in operational condition at all times given the conditions described in the environmental section. The Man Machine Interface (MMI) unit will be mounted on the transformer Tap changer control panel in the control room. Cabling between the MMI unit and input / output modules / unit shall be supplied by the supplier of transformer/ITCS. The details of the cable shall be furnished. It shall be possible to have a second MMI mounted in the transformer control cubicle if required.

4.0 **Fittings & Accessories**

4.1 The following fittings and accessories shall be provided with each transformer covered in this specification:

- a. Conservator for main tank with air cell, oil filling hole and cap, air cell, isolating valves, drain valve, magnetic oil level gauge with low level alarm contacts, prismatic oil level gauge and Condition controlled maintenance free type breather.
- b. Conservator for OLTC with drain valve, oil surge Relay, filling hole with cap, magnetic oil level gauge, prismatic oil level gauge and dehydrating silicagel breather with flexible connection pipes to be used during replacement of any silica gel breather.
- c. Oil preservation equipment.
- d. Pressure relief devices with alarm/trip contacts and with special shroud to direct the hot oil.
- e. Sudden pressure relief relay with alarm contacts.
- f. Buchholz relay double float/reed type with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm and trip contacts.
- g. Air release plug.
- h. Inspection openings and covers.
- i. Bushing of each type with metal parts and gaskets to suit the termination arrangement.
- j. Winding and oil temperature indicators (local and remote).
- k. Cover lifting eyes, transformer lifting lugs, jacking pads, haulage lugs, towing holes and core and winding lifting lugs.
- l. Protected type alcohol in glass thermometer or magnetic or micro-

switch type, dial type temperature indicator as applicable (mercury should not be used).

- m. Top & bottom oil sampling valve, Drain valves, Filter valves at top and bottom with threaded male adaptors, Shut off valves on the pipes connection between radiator bank and transformer tank, Shut off valves on both sides of the Buchholz relay, Sampling gas collectors for Buchholz relay at accessible at height, Valves for radiators, Valve for vacuum application, Valve for online DGA, Valves for drying out system, Flow sensitive conservator isolation valve, Gate Valve (4 Nos. of min. 50NB) for UHF sensors for PD measurements, Valves for NIFPES system and other valves as specified in the specification.
- n. Rating and diagram plates on transformers and auxiliary apparatus.
- o. Roller assembly (Flanged bi-directional wheels)
- p. Cooler control cabinet/Individual marshaling box, common marshaling box, fibre optic temperature monitoring unit as applicable.
- q. On load tap changing gear, OLTC DM Box and RTCC panel along with microprocessor based Numerical RTCC unit for Tap changer control & Transformer monitoring.
- r. Cooling equipments including fans & pumps (as applicable).
- s. Bushing current transformers.
- t. Oil flow indicator.
- u. Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently.
- v. Terminal marking plates.
- w. Valves schedule plates, oil filling instruction plate of conservator, schematic diagram plate for operation of OLTC.
- x. 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.
- y. 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.
- z. Oil flow indicator.
- aa. On-line dissolved gas (multi-gas) and moisture analyzer
- bb. On-line insulating oil drying system (Cartridge type)

- cc. Fibre optic temperature monitoring system.
- dd. Oil storage tank of 20 cubic meter capacity along with complete accessories
- ee. Hydraulic Jacks of suitable capacity (1 set per station).
- ff. Oil Sampling bottles made of stainless steel having a capacity of one litre.
- gg. Oil Syringe.
- hh. Conservator air cell rupture detection relay.
- ii. One complete set of all metal blanking plates & covers.
- jj. Suitable terminal connectors on bushings.
- kk. Suitable neutral bus connection arrangement.
- ll. All necessary provision required for NIFPS.

4.2 Suitable galvanized iron or stainless steel tray for cabling on main tank for better aesthetics

- 4.3 a) The fittings listed above are only indicative and any other fittings which generally are required for satisfactory operation of the transformer are deemed to be included.
- b) The accessories required with the transformer shall be SCADA/ SAS compatible. For OTI, WTI, TPI, etc. dual output of 4-20mA shall be provided.
- c) All the microprocessor based IEDs such as Online DGA, FOTMS, ITCS, Online Drying system, etc. shall be interfaced with the SAS of the sub-station in co-ordination with the SAS supplier. Necessary files such as ICD, CID and PICS, MICS and PIXIT documents shall be provided in soft copy for integration with third party HMI.
- d) The required communication cables for the above is in the scope of the bidder/ supplier.
- e) The auxiliary supply to all the IEDs shall be 220V, DC.
- f) Warranty for the “Products and Solutions” for the IEDs as per International Standards shall be furnished. Also, guarantee for the availability of spares and solutions for all the IEDs for at least 10 years from the date of supply of products to be furnished.
- g) KPTCL Engineers shall be trained for operation of ITCS, Fibre optic temperature monitoring system & online DGA.

4.4 **TOOLS & TACKLES**

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

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

- 4.5 All IEC 61850 compliant signals from various monitoring equipments /accessories shall be wired upto the SAS Ethernet switch provided in the C&R panel and shall be interfaced with the SAS system.

5.0 **Bushing Current Transformer**

- 5.1 Current transformers shall comply with IS:16227/IEC-61869-1 & 2.

- 5.2 It shall be possible to remove the turret mounted current transformers from the tank without removing the tank cover. Necessary precautions shall be taken to minimize eddy currents and local heat generated in the turret.

- 5.3 Current transformer secondary leads shall be brought out to a weatherproof terminal box near each bushing. These terminals shall be wired out to cooler control cabinet/ marshalling box using separate cables for each core.

- 5.4 Bushing Current transformer parameters indicated in this specification are tentative and liable to change within reasonable limits. The Contractor shall obtain Employer's approval before proceeding with the design of bushing current transformers.

- 5.5 **Current Transformer Technical Parameters (On each phase) for 3-phase 500MVA and 1-phase, 167 MVA, 400/220/33 kV Auto Transformers.**

Description	Current Transformer Parameters (Transformer)			
	HV Side	IV side	Neutral side	Tertiary
(a) Ratio				
Core - 1	1600/1	1600/1	1600/1	2000/1A
Core - 2	1000/1A	1600/1		2000/1A
(b) Minimum Knee point voltage or burden and accuracy class				
Core - 1	1600V, PX	1600V, PX	1600V, PX	PX
Core - 2	0.2 Class 20VA ISF ≤ 5	0.2 Class 20VA ISF ≤ 5		PX
(c) Maximum CT Secondary Resistance				
Core - 1	4.0 Ohm	4.0 Ohm	4.0 Ohm	

c Core - 2	–	–	–	
(d) Application				
r Core - 1	Restricted Earth Fault	Restricted Earth Fault	Restricted Earth Fault	Protection
e Core - 2	Metering	Metering	–	Protection
(e) Maximum magnetization current (at knee voltage)				
T Core - 1	25mA	25mA	25mA	
r Core - 2	–	–	–	

n
sformer Technical Parameters (On each phase) for 3-phase 500MVA and 1-phase, 167 MVA, 400/220/33 kV Auto Transformers.

NOTE:

- i) Accuracy class PS as per IS: 61869/ IS 16227
- ii) Class (for the relevant protection and duties) as per IEC 60185.
- iii) Parameters of WTI CT for each winding shall be provided by the contractor.
- iv) For estimation of spares, one set of CTs shall mean one CT of each type used in transformer.
- v) The CT used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
- vi) One number of CT of ratio 2000/1A of accuracy class 5P20, Burden 10VA for circulating current protection shall be provided in one phase of Tertiary winding (within Delta formation).

6.0 Online Dissolved Gas (Multi-gas) and Moisture Analyser

- 6.1. Online Dissolved Gas (Multi-gas) and Moisture Analyser along with all required accessories shall be provided with each transformer for measurement & analysis of dissolved gases and moisture in the oil. Interpretations shall be as per IEC 60599 (2007-05 or latest version).

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

Gases & Moisture	Typical Detection Range
H ₂	5 – 5,000 ppm
CH ₄	5 – 5,000 ppm
C ₂ H ₆	5 – 5,000 ppm
C ₂ H ₄	3 – 5,000 ppm
C ₂ H ₂	1 – 3,000 ppm
CO	10 – 10,000 ppm
CO ₂	20 – 30,000 ppm
O ₂	500 – 25,000 ppm
H ₂ O	2 – 100 % RS should have facility for measurement of moisture in oil in ppm

- 6.3. 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.
- 6.4. Equipment shall have facility to give SMS alert to at least three users whenever any fault gas violates the predefined limit.
- 6.5. Equipment should work on 220V DC supply. All the necessary power and control cables, communication cables, cable accessories as required shall be provided by the supplier.
- 6.6. 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 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.
- 6.7. The equipment shall display all the individual gas and moisture concentration on its display unit and shall have facility to download all the stored data from the unit for further analysis. The sampling rate shall be selectable as 2 or 4 or 6 or 12 hours etc. The equipment shall have inbuilt memory to store these results for complete one year even if sampling is done at the lowest interval. The carrier and calibration gas (if applicable) shall have minimum capacity to work for at least three years without

replacement. All the consumable (if any) upto warrantee period shall be included in the scope of supply.

- 6.8 The equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the Equipment.
- 6.9 The Equipment must have an automatic Calibration facility at fixed intervals. For calibration if anything required including cylinder must be mounted with the Equipment.
- 6.10. The technical feature of the equipment shall be as under:

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

- 6.11. Software for fault indication and fault diagnostics shall include following:
Fault indication:
i) IEEE, IEC or user configurable levels of dissolved gases
ii) Rate of change trending

Fault Diagnosis:
i) Key gases
ii) Ratios (Rogers, IEC. etc.)
iii) Duval's Triangle
- 6.12. The equipment shall be supplied with all necessary accessories required for carrying out DGA of oil sample complete in all respect as per the technical specification. The following shall be also form a part of supply.
i) Software running on PC under the latest version of windows shall be provided in duplicate
ii) Operation Manual (2 set for every unit),
iii) Software Manual and
iv) Compact disc giving operation procedures of Maintenance Manual & Trouble shooting instructions.
- 6.13 The installation and commissioning at site shall be done under the supervision of representative or OEM certified representative.
- 6.14 The equipment shall be covered on warranty for a period of 5 year from the last date of complete commissioning and taking over the test set up.

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.

7.0 On-line insulating oil drying system (Cartridge type)

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

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

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

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

8.0 **Oil Storage Tank**

8.1 General

This specification covers supply of oil storage tank of 20 cubic meter capacity along with complete accessories.

8.2 Standard

The oil storage tank shall be designed and fabricated as per relevant Indian Standards e.g. IS:10987 or BS 2594.

8.3 Specifications

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. Size of the storage tank shall be as follows:

Diameter : 2.0 meter
Minimum Capacity : 20 cubic metre

The tank shall be designed for storage of oil at a temperature of 100°C.

8.4 The Bidder may further note that maximum height of any part of the complete assembly of the storage tank shall not exceed 4.0 metres above road top.

8.5 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.

8.6 The tank shall also be fitted with manhole, outside & inside access ladder, silicagel breather assembly, inlet & outlet valve, oil sampling valve with suitable adopter, oil drainage valve, air vent etc. Pulling hook on both ends of the tank shall be provided so that the tank can be pulled from either end while completely filled with oil. Bidder shall indicate the engine capacity in horse power to pull one tank completely fitted with oil. 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 oil (Electro mechanically operated) with centrifugal pump shall be provided at bottom inlet, so that pump shall be utilized both ways during oil fill up and draining. Suitable arrangement shall also be provided to prevent overflow in the tank.

8.7 The following shall form part of supply along with Oil storage tank

(i) Four numbers of 50NB suitable rubber hoses for transformer oil application upto temperature of 100°C, full vacuum and pressure up to 2.5 Kg/ cm² with couplers and unions each not less than 10 metre long shall be provided.

(ii) Two numbers of 100NB vacuum hoses, suitable for full vacuum

without collapsing and kinking, with couplers and unions each not less than 10 metre long shall also be provided.

- (iii) One number of digital vacuum gauge with sensor capable of reading up to 0.001 torr, operating on 240V 50Hz AC supply shall be supplied. Couplers and unions for sensor should block oil flow in the sensor. Sensor shall be provided with atleast 8 meter cable so as to suitably place the Vacuum gauge at ground level.

8.8 The painting of oil storage tank and its control panel shall be as per clause no 3.1.1.13.

8.9 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 cubical with IP-55 enclosure.

9.0 OIL SAMPLING BOTTLE

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

9.2 Oil Sampling bottles shall be made of stainless steel having a capacity of one litre.

9.3 Oil Sampling bottles shall be capable of being sealed gas-tight and shall be fitted with cocks on both ends.

9.4 The design of bottle & seal shall be such that loss of hydrogen shall not exceed 5% per week.

9.5 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 alongwith suitable connectors to fit the tube on to the oil sampling valve of the equipment and the oil collecting bottles respectively.

10.0 Oil Syringe

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

The tentative dimensions are given below

Dimensions

Volume	50 ml \pm 1.5 %
Piston outside diameter	27.45 \pm 0.20 mm
Barrel Diameter (OD)	32.35 \pm 0.55 mm
Barrel Diameter (OD)	44.00 \pm 0.75 mm
Barrel Diameter (OD)	34.05 \pm 0.65 mm

Length (L)	178.00 mm \pm 0.50 mm
Increment	2.0 ml

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

The cylinder-Plunger fit is leak proof and shall meet the requirement of IEC-60567. Plunger shall be individually ground and fitted to barrel for smooth movement with no back flow. Barrel rim should be flat on both sides to prevent rolling and should be wide enough for convenient fingertip grip. The syringe shall be custom fit and uniquely numbered for matching. The syringe shall be clearly marked with graduations of 2.0 ml and 10.0 ml and shall be permanently fused for life time legibility.

11.0 Condition Controlled Maintenance Free Type Breather

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

11.2 Dehydrating breather's operating principle:

When the oil conservator breaths-in (e.g. at reduced load), the air flows through a filter made of high-grade steel wire mesh. The equipment fitted with filter & the dust cap, filters the dust, sand and other dirt particles from the air. The filtered air flows through the desiccant chamber filled with colourless, moisture adsorbing pellets and are dehydrated. The dehydrated air rises further via the pipe in the oil conservator. The desiccant is dehydrated by the built-in heating unit which is controlled by sensors, thus obviating the need for periodic desiccant replacement. The dehydrating breather is mounted on the pipe to the oil conservator at a height of 1200mm approximately from transformer rail top level.

11.3 Technical Features:

11.3.1 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.

11.3.2 Following LEDs for local display on control unit, and suitable contacts & analog signal shall be provided for wiring to remote location:

- a) Led for Power of control unit – ON
- b) LED for Filter heater – ON
- c) LED for Anti-condensation heater (of control unit) – ON
- d) LED & relay contact for “Device Error”

- e) LED & relay contact for Regeneration active (De-humidification in process)
 - f) Analogue output signal (4-20mA) for the Temperature of air (in filter unit/pipe).
- 11.3.3 The Breather shall be equipped with test button which should allow to carry out a self-test and to check the functions like relay circuits, heating or the signal transmission in the control room, etc. at any time.
- 11.3.4 Control unit shall be equipped with communication port for downloading the operational data logged by the unit. All necessary software required for downloading and analyzing the logger data shall also be provided by the supplier. Supply of Laptop/PC for above software is not envisaged.
- 11.3.5 The moisture and temperature measurement system (Sensor) installed should be modular making it easy to replace the same if at all the same is necessary during the service of breather.
- 11.3.6 The equipment shall operate at input supply of 230V AC, 50Hz. Any converter if required shall be supplied with the equipment.
- 11.3.7 Degree of Protection shall be at least IP55 for which type Test report shall be submitted. Necessary protective devices shall be provided in order to protect the equipment against over voltages & high-frequency interference.
- 11.3.8 The control unit shall be equipped with suitable heater to prevent moisture condensation.
- 11.3.9 The size of condition controlled maintenance free dehydrating breather shall be decided based on the volume of transformer oil during detailed engineering.
- 11.4 The equipment shall be covered on warranty for a period of 5 years from the last date of complete commissioning and taking over. During this period, if the equipment needs to be shifted to suppliers works for repairs, supplier will have to bear the cost of spares, software, transportation etc. of this equipment for repair at test lab/works. Further supplier shall make alternate arrangement for smooth operation of the transformer.
- 11.5 Condition Controlled Maintenance Free Type Breather of alternate proven technology shall also be acceptable.
- 11.6 Further, provision shall also be made to fix conventional dehydrating breather. The piping and flange arrangement shall be made such that it is possible to fix both the maintenance free type breather and conventional dehydrating filter breather. Such an arrangement is envisaged for smooth operation of the transformer incase of exigencies i.e., withdrawal /removable of maintenance free type breather for repair/service.

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

12.0 Nitrogen Injection type fire prevention & extinguishing system:

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

The details of the same are explained in Section – Fire protection system of bid document.

All necessary provisions required for Nitrogen injection fire protection system shall be made in the transformer.

13.0 Guaranteed Losses:

- i) The bidder while quoting should clearly indicate the guaranteed value of the losses which **shall be firm and without any tolerance limit** in respect of under mentioned losses at normal tap, as required in GTP.
 - (a) No load loss at rated voltage and rated frequency.
 - (b) Load losses at rated output, rated voltage and rated frequency.
 - (c) I²R Loss at rated output, rated voltage and rated frequency.
 - (d) Auxiliary losses at rated output.
- ii) Void
- iii) Void
- iv) The Maximum permissible losses (No load loss, I²R loss, auxiliary loss and load loss) at rated voltage/current (at 75 deg C) have been specified in Technical particulars/parameters. Following penalties shall be levied on the manufacturer/contractor/bidder (as the case may be) if losses measured during routine test are found to be within +2% tolerance of the Guaranteed losses declared by the manufacturer/contractor/bidder (as the case may be), beyond which the transformer shall be liable for rejection. No benefit shall be given for supply of transformer, with losses (measured during routine tests) less than the Guaranteed losses declared by the manufacturer/contractor/bidder (as the case may be).

Sl. No.	Differential of specified losses vs Measured losses	RATE (in INR per KW)
1	No Load Loss	Rs. 10,00,000/KW
2	I ² R Losses/Load Losses (Differential of whichever loss is higher shall be considered for penalty)	Rs. 8,00,000/KW
3	Auxiliary Losses	Rs. 8,00,000/KW
Note: For a fraction of a kW, the penalty shall be applied on pro rata basis.		

14.0 **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.

14.1 **Bought Out Items**

14.1.1 The makes of all major bought out items shall be subject to Employer's approval.

14.1.2 The Contractor shall also prepare a comprehensive inspection and testing programme for all bought out/sub-contracted items and shall submit the same to the Employer for approval. Such programme shall include the following components:

- a) Buchholz Relay.
- b) Axles and wheels.
- c) Winding temperature indicators.
- d) Oil temperature indicators.
- e) Bushings.
- f) Bushing current transformers.
- g) Cooler control cabinet & other outdoor cubicle.
- h) Oil pumps.
- i) Fans/Air Blowers
- j) OLTC.
- k) Terminal connectors.
- l) On-line DGA Online drying system, Fibre optic temperature monitoring system & microprocessor based numerical RTCC.

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

14.2 **Factory Tests**

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

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

The contractor shall submit a Inspection and test plan (ITP) for approval. A typical test plan is indicated below. Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the contractor.

TEST PLAN AND PROCEDURES **Tests for Transformers**

No.	Test	$U_m > 170kV$
1	Measurement of winding resistance at all taps	Routine
2	Measurement of Voltage ratio at all taps	Routine
3	Check of phase displacement and vector group	Routine
4	Measurement of No-load loss and current measurement at 90%, 100% and 110% of rated voltage and rated frequency.	Routine
5	Magnetic balance test (for three phase Transformer only) and measurement of magnetizing current	Routine
6	Short circuit Impedence and load loss measurement at principal tap and extreme taps	Routine
7	Measurement of insulation resistance & Polarization Index	Routine
8	Measurement of insulation power factor and capacitance between winding to earth and between windings.	Routine
9	Measurement of insulation power factor and capacitance of bushings	Routine
10	Tan delta of bushing at variable frequency (Frequency Domain Spectroscopy)	Routine
11	Chopped wave lightning impulse test for the line terminals (LIC)	Routine
12	Lightning impulse test for the neutral terminals (LIN)	Type *
13	Switching impulse test for the line terminals (SI) (Not applicable for $U_m \leq 72.5kV$)	Routine
14	Applied voltage test (AV)	Routine
15	Line terminal AC withstand voltage test (LTAC) (Not applicable for $U_m \leq 72.5kV$)	Type *
16	Induced voltage withstand test (IVW)	-
17	Induced voltage test with PD measurement (IVPD)	Routine
18	Measurement of transferred surge on Tertiary due to HV lightning impulse and IV lightning impulse	Type *
19	Measurement of transferred surge on Tertiary due to HV switching impulse and IV switching impulse	Type *

20	Test on On-Load tap changer (Tap changer fully assembled on the transformer)	Routine
21	Measurement of dissolved gasses in dielectric liquid	Routine
22	Check of core and frame insulation	Routine
23	Leak testing with pressure for liquid immersed transformers (tightness test)	Routine
24	Appearance, construction and dimension check	Routine
25	Measurement of no load current & Short circuit Impedance with 415V, 50Hz AC.	Routine
26	Frequency Response analysis (FRA) (soft copy of test report to be submitted to site along with test reports)	Routine
27	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine
28	Tank vacuum test	Routine
29	Tank pressure test	Routine
30	Check of the ratio and polarity of built-in current transformers	Routine
31	Temperature rise test	Type **
32	Measurement of Zero seq. reactance (for three phase Transformer only)	Type *
33	Measurement of harmonic level in no load current	Type *
34	Determination of acoustic sound level	Type *
35	Measurement of power taken by fans and oil pumps (Not applicable for ONAN)	Type *
36	Dynamic Short circuit withstand test.	Type *

* Type test shall be carried out at first unit manufactured against the LOA at each manufacturing plant if applicable [Refer technical specification clause 2.18 (Design review)].

** Temperature rise test shall be conducted on all units.

14.2.1 **Routine Tests**

All standard routine tests in accordance with IEC: 60076/IS: 2026 along with dielectric tests shall be carried out on each transformer. Operation and dielectric testing of OLTC shall also be carried out as per IS: 2026/IEC:60076.

Following additional routine tests shall also be carried out on each transformer:

14.2.2.1 **Magnetic Circuit Test**

After assembly each core shall be tested for 1 minute at 2000 Volts between all bolts, side plates and structural steel work.

14.2.2.2 **VOID.**

14.2.2.3 **VOID**

14.2.2.4 **VOID.**

- 14.2.2.5 VOID
- 14.2.2.6 VOID.
- 14.2.2.7 Tank Tests

(i) Oil Leakage Test

All tanks and oil filled compartments shall be tested for oil tightness by being completely filled with air or oil of a viscosity not greater than that of insulating oil conforming to IEC:60296 at the ambient temperature and applying a pressure equal to the normal pressure plus 35 KN/Sq.m (5 psi) measured at the base of the tank. The pressure shall be maintained for a period of not less than 12 hours for oil and one hour for air during which time no leak shall occur.

(ii) Vacuum Test

All transformer tank of each size shall be subjected to the specified vacuum. The tank designed for full vacuum shall be tested at an internal pressure of 3.33 KN/Sq.m absolute (25 torr) for one hour. The permanent deflection of flat plate after the vacuum has been released shall not exceed the values specified below:

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

(iii) Pressure Test

All transformer tank of each size, its radiator, conservator vessel and other fittings together or separately shall be subjected to an air pressure corresponding to twice the normal head of oil or to the normal pressure plus 35 KN/m² whichever is lower measured at the base of the tank and maintained for one hour. The permanent deflection of flat plates after the excess pressure has been released shall not exceed the figure specified above for vacuum test.

- 14.2.2.8 Measurement of capacitance and tan delta to determine capacitance between winding and earth. Tan delta value shall not be more than 0.5% corrected at 20deg C. Temperature correction factor table shall be given by the Contractor and shall form the part of test results.

14.2.2.9 VOID.

14.2.2.10 Routine tests on bushings shall be conducted as per IEC: 60137

14.2.2.11 Lightning Impulse withstand test in all phases as per IEC 60076/IS: 2026

14.2.3 **Type Tests**

Type tested Transformer shall be offered. The type test reports shall not be older than **Ten(10)** years as on the **last date of submission of bid**.

a) For Transformers manufactured in India:

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

b) For Transformer manufactured Abroad:

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

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

14.2.3.1 **Temp. Rise Test (as per IS:2026 / IEC 60076)**

Gas chromatographic analysis on oil shall also be conducted before and after this test and the values shall be recorded in the test report. The sampling shall be in accordance with IEC 60567. For the evaluation of the gas analysis in temperature rise test the procedure shall be as per IS:9434 (based on IEC:60567) and results will be interpreted as per IEC-61181). The DGA results shall generally conform to IEC/IEEE/CIGRE guidelines.

The temperature rise test shall be conducted at a tap for the worst combination of loading on the three windings of the transformer. The Contractor before carrying out such test shall submit detailed calculations showing alternatives possible, on various taps and for the three types of ratings of the transformer and shall recommend the combination that results in highest temperature rise for the test.

14.2.3.2 VOID

14.2.4 **Type Tests on fittings:**

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

1. Bushing (Type Test as per IEC: 60137, including snap back/seismic test)
2. Buchholz relay (Type Test as per IS: 3637 and IP-55 Test on terminal box as per IS: 13947/IEC: 60529)
3. OLTC (As per IEC: 60214 and IP-55 test on driving mechanism box)
4. Cooler Control cabinet and other outdoor cubicle (IP-55 test as per IS: 13947/IEC: 60529)
5. RTCC (IP-43 test – as per IS : 13947/IEC: 60529)
6. Pressure Relief device Test
The pressure Relief Device of each size shall be subjected to increase in oil pressure. It shall operate before reaching the test pressure specified in transformer tank pressure test. The operating pressure shall be recorded. The device shall seal off after excess pressure has been released. The terminal box / boxes of PRD should conform to degree of protection as per IP-55 of IS: 13947.
7. Sudden pressure relay test
8. Magnetic Oil Level gauge & Terminal Box for IP-55 degree of protection as per IS: 13947/IEC: 60529.
9. Air Cell (Flexible air separator) – Oil side coating, Air side under Coating, Air side outer coating and coated fabric as per IS: 3400/ BS: 903/ IS: 7016.
10. OTI & WTI – Switch setting & operation, switch differential, switch rating.
11. Oil pump – Vacuum Test at 250 torr maximum, oil pressure test at 1 kg/cm² for 24 hrs., Temperature rise test by resistance method, IP-55 degree of protection for terminal box.
12. Cooling fan and motor assembly – Free air delivery, Temperature rise, sound level, running at reduced voltage, IP-55 degree of protection for terminal box as per IS: 13947/IEC: 60529.

14.2.5 **Pre-Shipment Checks at Manufacturer's Works**

- 14.2.5.1 Check for interchangeability of components of similar transformers for mounting dimensions.
- 14.2.5.2 Check for proper packing and preservation of accessories like radiators, bushings, dehydrating breather, rollers, buchholz relay, fans, control cubicle, connecting pipes, conservator etc.
- 14.2.5.3 Check for proper provision for bracing to arrest the movement of core and winding assembly inside the tank.
- 14.2.5.4 Gas tightness test to confirm tightness.
- 14.2.5.5 Derivation of leakage rate and ensure the adequate reserve gas capacity.
- 14.2.5.6 Measure and record the dew point of dry air at the time of filling and after 24 hours in the transformer tank. Dew point of dry air at the time of transformer dispatch should be better than (-) 30 deg C. Also the dew point of dry air cylinders attached for make up during transportation should be of the order of (-) 50 deg C.
- 14.2.5.7 Ensure following setting of impact recorder at the time of installation with Transformer unit before dispatch from factory:
 - 1g: Start recording
 - 2g: Warning
 - 3g: Alarm

Further, drop-out setting shall be 1g and threshold setting shall be in the range of 5g to 10g.

14.3 **Inspection and Testing at Site**

The Contractor/Manufacturer shall carry out a detailed inspection and testing programme for field activities covering areas right from the receipt of material stage upto commissioning stage. An indicative programme of inspection as envisaged by the Employer is given below. However, it is contractor's responsibility to draw up and carry out such a programme duly approved by the Employer. Testing of oil sample at site shall be carried out as per specification.

14.3.1 **Receipt and Storage Checks**

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

14.3.2 **Installation Checks**

- 14.3.2.1 Visual check for wedging of core and coils before filling up with oil and also check conditions of core and winding in general.
- 14.3.2.2 Inspection and performance testing of accessories like tap changers, cooling fans, oil pumps etc.
- 14.3.2.3 (i) Check the direction of rotation of fans and pumps.
(ii) Check the bearing lubrication.
- 14.3.2.4 Check whole assembly for tightness, general appearance, etc.
- 14.3.2.5 Oil leakage test
- 14.3.2.6 Capacitance and tan delta measurement of bushing before fixing/connecting to the winding, contractor shall furnish these values for site reference.
- 14.3.2.7 Leakage check on bushing before erection.
- 14.3.2.8 Measure and record the dew point of dry air in the main tank before assembly. Manufacturer shall submit dew point acceptable limits along with temperature correction factor and shall form part of instruction manual. In case dew point values are not within permissible limit suitable drying out process shall be applied for dry out of active part in consultation with the Manufacturer.

14.3.3 **Commissioning Checks**

- 14.3.3.1 Check the colour of silica gel in silica gel breather.
- 14.3.3.2 Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.
- 14.3.3.3 Check the bushing for conformity of connection to the lines etc,
- 14.3.3.4 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.
- 14.3.3.5 Check for the adequate protection on the electric circuit supplying the accessories.
- 14.3.3.6 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.

- 14.3.3.7 Check for cleanliness of the transformer and the surroundings.
- 14.3.3.8 2kV for 1 min. test between bushing CT terminal and earth.
- 14.3.3.9 Continuously observe the transformer operation at no load for 24 hours.
- 14.3.3.10 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.
- 14.3.3.11 Phase out and vector group test.
- 14.3.3.12 Ratio test on all taps.
- 14.3.3.13 Magnetising current test.
- 14.3.3.14 Capacitance and Tan delta measurement of winding and bushing.
- 14.3.3.15 DGA of oil just before commissioning and after 24 hours of energisation at site.
- 14.3.3.16 *The manufacturer shall carry out the Sweep Frequency Response Analysis SFRA) Test at their works and also during pre-commissioning at site. The values / data shall be furnished to KPTCL for future reference. The required instruments/equipments for conducting the SFRA test at Site shall be arranged by transformer manufacturer/Contractor.*
- 14.3.3.17 Contractor shall prepare a comprehensive commissioning report including all commissioning test results and forward to Employer for future record.

15.0 Technical Particulars / Parameters of Transformers – 400kV Transformer

Clause No.	Description	Unit	Technical Parameters	
1.1.	Voltage ratio		400/220/33	$(400/\sqrt{3})/(220/\sqrt{3})/33$
1.2.	Single / Three Phase Design		3 (THREE)	1 (SINGLE)
1.3.	Type of Transformer		Constant Ohmic impedance type (Refer Note 1)	
1.4.	Rated Capacity			
	HV	MVA	500	167
	IV	MVA	500	167

	LV (Tertiary): Active + Reactive loading	MVA	(1/3) rd of rated capacity of HV winding (*)	
1.5.	Applicable Standard		IEC 60076/IS 2026	IEC 60076/IS 2026
1.6.(a)	Cooling at different cooling		ONAN/ONAF/OFAF Or ONAN/ONAF/ODAF Or ONAN/ONAF1/ONAF2	
1.6.(b)	Rating at different cooling	%	60%/ 80%/ 100%	
1.7.	Cooler Bank Arrangement		2x50%	
1.8.	Frequency	Hz	50	50
1.9.	Impedance at 75 Deg C			
	HV – IV			
	Max. Voltage tap	%	10.3	10.3
	Principal tap	%	12.5	12.5
	Min. Voltage tap	%	15.4	15.4
	HV – LV			
	Principal tap (minimum)	%	60.0	60.0
	IV – LV			
	Principal tap (minimum)	%	45.0	45.0
	Tolerance on impedance (HV-IV)	%	As per IEC	
1.10.	Service		Outdoor	Outdoor
1.11.	Duty		Continuous	Continuous
1.12.	Overload Capacity		IEC-60076- 7/IS:6600	IEC-60076- 7/IS:6600
1.13.	Temperature rise over 50deg C ambient Temp			
i)	Top oil measured by thermometer	O _C	45	45
ii)	Average winding measured by resistance method	O _C	50	50
1.13a	Winding hotspot rise over yearly weighted temperature of 32 O _C	O _C	61	61
1.13b	Tank hotspot temperature	O _C	110	110
1.14.	Max. design Ambient temp	O _C	50	50
1.15.	Windings			
i)	System Fault level			
	HV	kA	63	63
	IV	kA	40	40
ii)a	Lightning Impulse withstand Voltage			
	HV	kV _p	1300	1300
	IV	kV _p	950	950
	LV	kV _p	250	250
	Neutral	kV _p	95	95

b	Chopped wave Lightning Impulse withstand Voltage			
	HV	kV _p	1430	1430
	IV	kV _p	1045	1045
	LV	kV _p	275	275
c	Switching Impulse withstand Voltage			
	HV	kV _p	1050	1050
	IV	kV _p	750	750
iii)	One Minute Power Frequency withstand Voltage			
	HV	kV _{rms}	570	570
	IV	kV _{rms}	395	395
	LV	kV _{rms}	95	95
	Neutral	kV _{rms}	38	38
1.15.	Neutral Grounding		Solidly Earthed	
1.16.	Insulation			
	HV		Graded	Graded
	IV		Graded	Graded
	LV		Uniform	Uniform
1.17.	Tertiary Connection		Grounded Delta (for unloaded Tertiary)	Ungrounded Delta
1.18.	Tan delta of winding	%	≤ 0.5	≤ 0.5
1.19.	Vector Group (3 –ph)		YNaOd11	YNaOd11
1.20.	Tap Changer		OLTC	OLTC
i)	Tap changer Location at winding		On common end of series winding for 400kV side voltage variation.	
ii)	Tap range		±10% of HV variation in the step of 1.25%	
iii)	Design		Constant flux voltage variation type as per Cl. 6.2 of IEC 60076 part-I	
iv)	Tap control		Full capacity - on load tap changer suitable for group / independent, remote /local electrical and local manual operation and bi-directional power flow	
1.21.	Bushing			
i)	Rated voltage			
	HV	kV	420	420
	IV	kV	245	245
	LV	kV	52	52
	Neutral	kV	36	36
ii)	Rated current (Min.)			
	HV	A	1250	1250
	IV	A	2000	2000

	LV	A	1250	1250
	Neutral	A	2000	2000
iii)	Lightning Impulse withstand Voltage			
	HV	kV _p	1425	1425
	IV	kV _p	1050	1050
	LV	kV _p	250	250
	Neutral	kV _p	170	170
iv)	Switching Impulse withstand Voltage			
	HV	kV _p	1050	1050
	IV	kV _p	850	850
v)	One Minute Power Frequency withstand Voltage			
	HV	kV _{rms}	695	695
	IV	kV _{rms}	505	505
	LV	kV _{rms}	105	105
	Neutral	kV _{rms}	77	77
vi)	Minimum total creepage distances			
	HV	mm	13020	13020
	IV	mm	7595	7595
	LV	mm	1612	1612
	Neutral	mm	1116	1116
vii)	Tan delta of bushings at ambient Temperature	%	< 0.5	< 0.5
viii)	Max Partial discharge level at U _m			
	HV	pC	< 10	< 10
	IV	pC	< 10	< 10
	LV	pC	< 10	< 10
1.22.	Max Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	< 100	< 100
1.23.	Noise level at rated voltage and at principal tap at No-Load and all cooling active	dB	< 80	< 80
1.24	Maximum Permissible Losses of Transformers		500MVA	167MVA
i)	Max. No Load Loss at rated voltage and frequency	kW	90	45
ii)	Max. Load Loss at rated current and at 75°C for HV and IV windings, at principal tap position.	kW	500	200
	Max. I ² R Loss at rated current and at 75°C for HV & IV at principal tap position	kW	375	140

iii)	Max. Auxiliary Loss at rated voltage and frequency	kW	15	06
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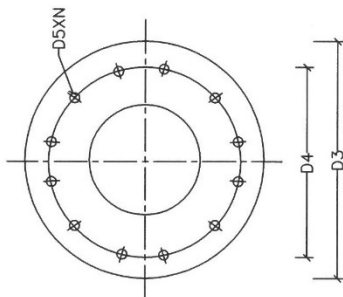
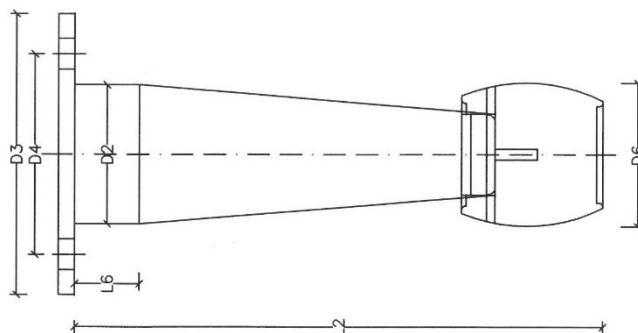
Notes:

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 & Bushing 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 IS:2026 part- 3/IEC 60076-3.
- (*) The tertiary shall be designed for 1/3rd of rated MVA and shall be suitable for withstanding mechanical and thermal stresses due to dead short circuit on its terminal. However, the cooling for continuous thermal rating of the tertiary winding shall be of at least 5MVA capacity.

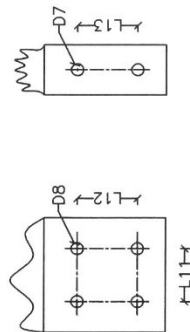
Annexure

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

BUSHING MOUNTING FLANGE DETAILS



BOTTOM CONNECTION DETAILS



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

VOLTAGE RATING (KV)	420	245	145	72.5	52
BIL Kv	1425	1050	650	325	250
CREEPAGE DISTANCE (MM)	13020	7595	4495	2248	1612
CURRENT RATING (A) (MIN.)	1250	1250	2000	800	2000
TYPE OF LEAD	SOLID STEM (SS)	SS	SS	SS	SS
L2±5	1640	1130	1230	800	695
L6 (MIN.)	400	300	300	300	100
D2 (MAX.)	350	270	165	115	165
D3±2	720	450	335	225	335
D4±1 (PCD)	660	400	290	185	290
D5xN	24x12	20x12	15x12	15x6	15x12
D6 (MAX)	350	270	180	115	115
L11	-	-	45	-	55
L12	-	-	40	-	40
L13	40	40	40	40	-
D7	Φ 14	Φ 14	Φ 14	Φ 14	Φ 14
D8	-	-	Φ 14	-	-
LENGTH & DIAMETER OF AIR END TERMINAL	125 & Φ 60	125 & Φ 60	125 & Φ 60	125 & Φ 60	125 & Φ 60

NOTE:

1. ALL DIMENSIONS ARE IN MM.
2. NO POSITIVE TOLERANCE WHERE MAX. DIMENSION SPECIFIED AND NO NEGATIVE TOLERANCE WHERE MINIMUM DIMENSION IS SPECIFIED.
3. FOR OTHER DETAILS OF OIL END TERMINAL FOR 2000A (145KV/245KV) SOLID STEM TYPE BUSHING, REFER FIG. 4 OF IS 12676.
4. FOR OTHER DETAILS OF OIL END TERMINAL FOR 2000A, 72.5KV SOLID STEM TYPE BUSHING, REFER FIG. 3B OF IS 12676.
5. FOR OTHER DETAILS OF OIL END TERMINAL FOR 800A AND 1250A (52KV/72.5KV/145KV/245KV/420KV) SOLID STEM TYPE BUSHING, REFER FIG. 3A OF IS 12676.

STANDARD DIMENSION FOR RIP CONDENSER BUSHINGS
(LOWER PORTION)

DRG.NO.KPTCL/TECH/RIP COND. BUSHINGS	DATE: 04.09.2021	SCALE:-MKS	SHEET 1 OF 1
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