3.	160 MVA	400/33-33 kV	Three Phase	Two
4.	125 MVA	400/33 kV	Three Phase	One
5.	160 MVA	220/33-33 kV *230/33-33 kV	Three Phase	Two
6.	125 MVA	220/33 kV *230/33 kV	Three Phase	One
7.	100 MVA	220/33 kV *230/33 kV	Three Phase	One
8.	100 MVA	132/33 kV *110/33 kV	Three Phase	One
9.	80 MVA	132/33 kV *110/33 kV	Three Phase	One
10.	50 MVA	132/33 kV *110/33 kV	Three Phase	One
11.	31.5 MVA	132/33 kV *110/33 kV	Three Phase	One

*For Tamil Nadu and Karnataka, as applicable

Note: The transformers of 400/33kV, 160MVA & 125MVA rating should be avoided as practice of using such low MVA rating transformers are not desirable at 400kV level.

It is desirable that Transformers of above ratings are only procured by utilities to have standard ratings across the country. The transformers of other ratings should be procured only under special circumstances, for example to match with the rating of existing transformer for parallel operation.

3.0 SPECIFIC TECHNICAL REQUIREMENTS

The technical parameters of these transformers are detailed in **Annexure-A: Specific Technical Requirements.**

4.0 GUARANTEED AND OTHER TECHNICAL PARTICULARS

The manufacturer shall furnish all the Guaranteed and other technical particulars for the offered transformer as called for in **Annexure–C: Guaranteed and Other Technical Particulars**. The particulars furnished by the manufacturer in this Annexure shall make basis for the design review. Any other particulars considered necessary may also be given in addition to those listed in that Annexure.

5.0 PERFORMANCE

5.1 Transformers shall be capable of operating under natural cooled condition up to the specified load. The forced cooling equipment, wherever specified, shall come into operation by pre-set contacts of winding temperature indicator and the transformer shall operate in forced cooling mode initially as ONAF (as specified) up to specified load and then as ODAF (or OFAF)

5.2 **In case of ONAN/ONAF cooling and ONAN/ONAF/ODAF (or OFAF) cooling, the cooling system shall be so designed that the transformer shall be able to operate at full load for at least ten (10) minutes in the event of total failure of power supply to cooling fans and oil pumps without the calculated winding hot spot temperature exceeding 140 deg C. If the Transformer is fitted with two cooler banks, each capable of dissipating 50 per cent of the loss at continuous maximum rating, it shall be capable of operating for 20 minutes at full load /continuous maximum rating in the event of failure of the oil circulating pump or fans/blowers associated with one cooler bank without the calculated winding hot spot temperature exceeding 140 deg C. The contractor shall submit supporting calculations for the above and the same shall be reviewed during design review**.

5.3 The transformer shall be **free from any Electrostatic Charging Tendency** (ECT) under all operating conditions and maximum oil velocity shall be such that it does not lead to static discharges inside the transformer while all coolers are in operation.

5.4 The transformers shall be capable of **operating continuously** at the rated MVA without danger, **at any tapping with voltage variation of ±10% corresponding to the voltage of that tapping**.

5.5 The transformers shall be capable of being over loaded in accordance with IEC 60076-7. There shall be no limitation imposed by bushings, tap changers etc. or any other associated equipment.

5.6 The **hotspot temperature in any location of the tank shall not exceed 110 degree** Celsius at rated MVA. This shall be measured during temperature rise test at manufacturer's works.

5.7 The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be 1.65 Tesla and under 10 % continuous overvoltage condition it shall be 1.815 Tesla at all tap positions.

5.8 The transformer and all its accessories including bushing/built in CTs etc. shall be designed to withstand the thermal and mechanical effects of any external short circuit to earth and of short circuits at the terminals of any winding without damage. **The transformer shall be designed to withstand the thermal stress due to short circuit for a duration of 2 seconds** and the same shall be verified during design review.

5.9 The following short circuit level shall be considered for the HV & LV System to which the transformers will be connected:

400kV system	- 63 kA for 1 sec (sym, rms, 3 phase fault)
220kV & 230kV system	- 50 kA for 1 sec (sym, rms, 3 phase fault)
132kV & 110 kV system	- 40 kA for 1 sec (sym, rms, 3 phase fault)
33kV system	- 25 kA for 3 sec (sym, rms, 3 phase fault)

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

5.10 Transformer shall be capable of withstanding thermal and mechanical stresses due to symmetrical and asymmetrical faults on any terminals. Mechanical strength of the transformer shall be such that it can withstand 3-phase, 2-phase and 1- phase to ground through fault with rated voltage applied to HV and/or LV terminals of transformer. The short circuit shall alternatively be considered to be applied to each of the HV, LV and tertiary transformer terminals as applicable. The tertiary terminals (if available) shall be considered not connected to system source. For short circuit on the tertiary terminals (if available), the in-feed from both HV & LV system shall be limited by the transformer self-impedance only and the rated voltage of HV and LV terminals shall be considered.

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

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

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

The air core reactance of HV winding of transformer shall not be less than 20%. External or internal reactors shall not be used to achieve the specified HV/LV or HV/LV1 and HV/LV2 (as applicable) impedances.

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

The tertiary winding shall be avoided for transformers designed with three (3) limbed cores. The tertiary windings, if provided, for transformers designed with five (5) limbed core shall be suitable for transferred surge from primary side and shall not be loaded. If terminal (s) of tertiary winding is brought out then it shall be insulated to avoid any accidental short circuiting.

5.13 **Radio Interference and Noise Level**

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

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

6.0 MAXIMUM LOSSES

The maximum permissible losses (No load loss, load loss, I^2R loss and auxiliary loss) at rated voltage/current (at 75 deg C) have been specified in Annexure-A for various ratings of transformers covered under this specification. Following **penalties** shall be levied on the manufacturer/contractor (as the case may be) if losses measured during routine test are found to be **within +2% tolerance of the losses specified in Annexure–A**, 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 losses specified in Annexure –A.

S. No	Differential of specified losses vs Measured losses	RATE (in INR per KW)
1	No load Loss	Rs. 4,00,000/KW
2	I^2R Losses/Load Losses (Differential of whichever loss is higher shall be considered for penalty)	Rs. 2,00,000/KW
3	Auxiliary Losses	Rs. 1,50,000/KW
Note: For a fraction of a kW, the penalty shall be applied on pro rata basis.		

7.0 DYNAMIC SHORT CIRCUIT TEST REQUIREMENT AND VALIDITY

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 in line with the requirement of CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations. **The criteria for similar transformer is specified in Annexure-J.** The relevant Test Report/certificate shall be enclosed along with bid. 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, the same shall be carried out on offered transformer.

A format (forms part of Annexure-J) filled with data of a typical sample case has been prepared for reference and guidance of utility to compare a Short Circuit tested transformer with the offered transformer in order to verify the similarity criteria as per Annexure J.

8.0 TYPE TESTS REQUIREMENT AND VALIDITY

Central Electricity Authority's "Guidelines for the validity period of type tests conducted on major electrical equipment in power transmission system" shall be followed for details regarding the validity of type tests.

9.0 DESIGN REVIEW

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

9.2 Design reviews shall be conducted by the purchaser or by an appointed consultant during the procurement process; however, the entire responsibility of design shall be with the manufacturer. **Purchaser may also visit the manufacturers works to inspect design, manufacturing and test facilities.**

9.3 The design review shall be finalised before commencement of manufacturing activity and shall be conducted generally following the "CIGRE TB 529: Guidelines for conducting design reviews for power transformers". However, salient points on design review has been specified in **"Chapter-2: Design Review"**.

9.4 **The manufacturer shall provide all necessary information and calculations to demonstrate that the transformer meets the requirements of mechanical strength and inrush current.**

9.5 The manufacturer will be required to **demonstrate the use of adequate safety margins for thermal, mechanical, dielectric and vibration etc. in design to take into account the uncertainties of his design and manufacturing processes.** The scope of such design review shall include but not limited to the requirement as mentioned at **Annexure – I**.

9.6 Each page of the design review document shall be duly signed by the authorised representatives of manufacturer and purchaser and shall be provided to the purchaser for record and reference before commencement of manufacturing.

10.0 SERVICE CONDITION

The transformer shall be designed for the following service conditions as specified by the utilities:

Sr. No.	Description	Parameters
i)	Site altitude	
ii)	Maximum ambient temperature	
iii)	Yearly weighted average cooling air ambient temperature	
iv)	Monthly average cooling air temperature of hottest month	
v)	Minimum cooling air temperature	
vi)	Wave shape of supply voltage	
vii)	Total Harmonic current	
viii)	Seismic zone and ground acceleration (both in horizontal & vertical direction)	
ix)	Combined voltage and frequency variation	
x)	Wind zone as per wind map provided in National Building Code	
xi)	Maximum humidity	
xii)	Minimum humidity	
xiii)	Average rainfall	
xiv)	Specific Creepage Distance of insulation in air	
xv)	Harmonics, if any	

In addition to the above, **utilities may specify additional site conditions** separately in tender documents [example: restricted ventilation (tunnels, enclosed area etc.), presence of fumes, vapours, steams, dripping of waters, salt spray and corrosive environment, excessive & abrasive dust, **superimposed DC current in neutral of the transformer**, high frequency switching transients, frequent energisation (>24 times a year), high solar radiation, frequent Short Circuits etc.].

11.0 CONSTRUCTION DETAILS

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

11.1 Tank & tank cover

11.1.1 The tank shall be of proven design of either **Bell type with bolted/ welded joint or conventional (preferable) with bolted/welded top**

cover. Bell type tank, if provided, shall have joint as close as possible to the bottom of the tank.

11.1.2 The tank shall be designed in such a way that **the transformer can be rested on concrete plinth foundation directly or on roller assembly.**

11.1.3 Tank shall be fabricated from tested quality low carbon steel of adequate thickness. Unless otherwise approved, metal plate, bar and sections for fabrication shall comply with IS 2062.

11.1.4 Tank shall be capable of withstanding, without damage, severe strains that may be induced under normal operating conditions or forces encountered during lifting, jacking and pulling during shipping and handling at site or factory. Tank, tank cover and associated structure should be adequately designed to withstand, without damage or permanent deflection / deformation, the forces arising out of normal oil pressure, test pressures, vacuum, seismic conditions and short circuit forces specified.

11.1.5 All seams and joints which are not required to be opened at site, shall be factory welded, and **shall be double welded** [i.e. with a continuous cord on both sides of the plate (inside and outside of the tank), bottom & cover of the tank, turrets, flanges, etc.] to ensure adequate strength. **Butt welds on parts that are mechanically stressed or under pressure must have full penetration.** Welding shall conform to IS 9595. The requirement of post weld heat treatment of tank/stress relieving shall be based on recommendation of IS 10801.

11.1.6 The welded joint shall be provided with flanges suitable for repeated welding. The joint shall be provided with a suitable gasket to prevent weld splatter inside the tank. Proper tank shielding shall be done to prevent excessive temperature rise at the joint.

11.1.7 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.

11.1.8 **Tank MS plates of thickness >12 mm should undergo Ultrasonic Test (UT)** to check lamination defect, internal impurities in line with ASTM 435 & ASTM 577.

11.1.9 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.

11.1.10 Suitable guides shall be provided for positioning the various parts during assembly or dismantling. Adequate space shall be provided between the covers & windings and the bottom of the tank for collection of any sediment.

11.1.11 Tank should be provided with adequately sized inspection covers, either in circular shape or in rectangular shape, preferably **at diagonally opposite sides of the tank** to access the active part **and one at each end of the tank cover for easy access of the** lower end of the bushings, earthing connections and tap changers etc. for inspection. Inspection covers shall be bolted type and shall not weigh more than 25 kgs. Handles shall be provided on the inspection cover to facilitate its lifting.

11.1.12 The tank cover shall be provided with pockets for oil and winding temperature indicators. The location of pockets (for OTI, WTI & RTDs including two spare pockets) shall be in the position where oil reaches maximum temperature. Further, it shall be possible to remove bulbs/probes 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.

11.1.13 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.

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

11.1.15 Minimum four symmetrically placed lifting lugs of adequate size 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 lug shall not be less than 2. Suitable haulage holes shall also be provided.

11.1.16 **A minimum of four jacking pads (not fouling with rail, rollers or other accessories) shall be provided in accessible position** to enable the transformer complete with oil to be raised or lowered using

hydraulic jacks. The location shall be such that it should not interfere with loading & unloading from trailer.

11.1.17 **Each jacking pad shall be designed with an adequate factor of safety to support at least half of the total mass of the transformer filled with oil in addition to maximum possible misalignment of the jacking force to the centre of the working surface.**

11.1.18 The tank shall be provided with suitable valves as specified in **Clause 18: Valves and Clause 26: "Fittings and accessories"** of this chapter. Location of valves shall be finalized during design review.

11.1.19 **The tank cover and bushing turret shall be fixed to the transformer using copper links in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.**

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

11.1.21 **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.

11.2 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.

11.3 Foundation, Roller Assembly and Anti Earthquake Clamping Device

11.3.1 **Transformer shall be placed on foundation either directly or on roller assembly.** For transformer to be placed directly on foundation, one set of rollers shall be provided for movement within the yard. The rollers for transformer are to be provided with flanged bi-directional wheels (with the facility to lock at 90^{o} position) 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.

11.3.2 **The rail track gauge shall be 1676 mm.**

11.3.3 To prevent movement during earthquake, suitable clamping devices shall be provided for fixing the transformer to the foundation.

11.3.4 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.

11.3.5 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.

11.3.6 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.

11.4 Conservator

11.4.1 The conservator of main tank shall have **air cell type** constant oil pressure system to prevent oxidation and contamination of oil due to contact with moisture. Conservator shall be **fitted with magnetic oil**

level gauge with potential free high and low oil level alarm contacts and prismatic oil level gauge.

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

11.4.3 The MOG and prismatic oil level gauge should not be obstructed with radiator bank and it should be clearly visible from ground.

11.4.4 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 100 deg C. The capacity of the conservator tank shall be such that the transformer shall be able to carry the specified overload without overflowing of oil.

11.4.5 The conservator shall be fitted with lifting lugs in such a position so that it can be removed for cleaning purposes. Suitable provision shall be kept to replace air cell and cleaning of the conservator as applicable.

11.4.6 The conservator shall be positioned so as not to obstruct any electrical connection to transformer.

11.4.7 Contact of the oil with atmosphere is prohibited by using a **flexible air cell of nitrile rubber reinforced with nylon cloth.** The temperature of oil in the conservator is likely to raise up to 100 Deg C during operation. As such air cell used shall be suitable for operating continuously at this temperature.

11.4.8 The connection of air cell to the top of the conservator is by air proof seal preventing entrance of air into the conservator. The main conservator tank shall be stencilled on its underside with the words **"Caution: Air cell fitted"**. Lettering of at least 150 mm size shall be used in such a way to ensure clear legibility from ground level when the transformer is fully installed. To prevent oil filling into the air cell, the oil filling aperture shall be clearly marked. The transformer rating and diagram plate shall bear a warning statement that the **"Main conservator is fitted with an air cell"**.

11.4.9 The transformer manual shall give clear instructions on the operation, maintenance, testing and replacement of the air cell. It shall also indicate shelf life, life expectancy in operation, and the recommended replacement intervals.

11.4.10 **The conservator tank and piping shall be designed for complete vacuum/ filling of the main tank and conservator tank**. Provision must be made for equalising the pressure in the conservator tank and the air cell during vacuum/ filling operations to prevent rupturing of the air cell.

11.4.11 The contractor shall furnish the leakage rates of the rubber bag/ air cell for oxygen and moisture. It is preferred that the leakage rate for oxygen from the air cell into the oil will be low enough so that the oil will not generally become saturated with oxygen. Air cells with well proven long life characteristics shall be preferred.

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

11.4.13 **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.

11.5 Piping works for conservator

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

11.5.2 The feed pipe to the transformer tank shall enter the cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the transformer side of the Buchholz relay, and straight for not less than three times that diameter on the conservator side of the relay. **This pipe shall rise towards the oil conservator, through the Buchholz relay, at an angle of not less than 3 degrees**. The feed pipe diameter for the main conservator shall be not less than 80mm. The Gas-venting pipes shall be connected to the final rising pipe between the transformer and Buchholz relay as near as possible in an axial direction and preferably **not less than five times pipe diameters from the Buchholz relay**.

11.5.3 No metal corrugated bellow (Flexible metal system) should be used in the feed pipe connecting main tank to conservator.

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

11.5.5 Pipe work shall neither obstruct the removal of tap changers for maintenance nor the opening of inspection/manhole covers.

11.6 Dehydrating Silica Gel Filter Breather

Conservator of Main Tank and OLTC shall be fitted with dehydrating silica gel filter breathers of adequate size. Connection shall be made to a point in the oil conservator not less than 50 mm above the maximum working oil level by means of a pipe with a minimum diameter of 25 mm. Breathers and connecting pipes shall be securely clamped and supported to the transformer, or other structure supplied by the manufacturer, in such a manner so as to eliminate undesirable vibration and noise. The design shall be such that:

a) Passage of air is through silica gel. Only Orange color silica gel shall be provided
b) Silica gel is isolated from atmosphere by an oil seal.
c) Moisture absorption indicated by a change in colour of the crystals.
d) Breather is mounted approximately 1200 mm above rail top level.
e) To minimise the ingress of moisture **three breathers (of identical size) for 220kV and above voltage class transformer/ and two breathers (of identical size) for below 220kV class transformer/ shall be connected in series for main tank conservator**. Manufacturer shall provide flexible connection pipes to be used during replacement of any silica gel breather.
f) To minimise the ingress of moisture, **two breather in series of identical size shall be connected to OLTC Conservator.** Manufacturer shall provide flexible connection pipes to be used during replacement of any silica gel breather.

Note: Regenerative maintenance free breather may also be used if desired by the utility.

11.7 Pressure Relief Device (PRD)

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

PRD shall be provided with **special shroud to direct the hot oil in case of fault condition.** It shall be provided with an outlet pipe which

shall be taken right up to the soak pit of the transformer. The size (Diameter) of shroud shall be such that it should not restrict rapid release of any pressure that may be generated in the tank, which may result in damage to equipment. Oil shroud should be kept away from control cubicle and clear of any operating position to avoid injury to personnel in the event of PRD operation.

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

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

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

11.8 Sudden Pressure Relay/ Rapid Pressure Rise Relay (if specified by the utility)

One number of Sudden Pressure Relay/ Rapid Pressure Rise Relay with alarm or trip contact (Terminal connection plug & socket type arrangement), if specified by the utility, shall be provided on tank of transformer/reactor. Operating features and size shall be reviewed during design review. **Suitable canopy** shall be provided to prevent ingress of rain water. Pressurised water ingress test for Terminal Box (routine tests) shall be conducted on Sudden Pressure Relay/ Rapid Pressure Rise Relay.

11.9 Buchholz Relay

Double float, reed type Buchholz relay complying with IS:3637 shall be connected through pipe between the oil conservator and the transformer tank with minimum distance of five times pipe diameters between them. Any gas evolved in the transformer shall be collected in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation and taking gas sample. A copper tube shall be connected from the gas collector to a

valve located about 1200 mm above ground level to facilitate sampling while the transformer in service. **Suitable canopy** shall be provided to prevent ingress of rain water. It shall be provided **with two potential free contacts** (Plug & socket type arrangement), **one for alarm/trip on gas accumulation and the other for tripping on sudden rise of pressure.**

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

11.10 Oil Temperature Indicator (OTI)

The transformer shall be provided with a dial type thermometer of about **150mm diameter for top oil temperature indication with angular sweep of 270°. Range of temperature should be 0-150°C with accuracy of ±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 and trip contacts** besides that required for control of cooling equipment (if any), 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 with epoxy coating at all sides. Instruments should meet **degree of protection of IP55** as per IS/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 OTI instrument by means of flexible stainless steel armour to protect capillary tubing. Temperature indicator dials shall have linear gradations to clearly read at least every 2 deg C. The setting of alarm and tripping contacts shall be adjustable at site.

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

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

Temperature transducer with PT100 sensor

RTD shall be provided with PT100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The PT100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per 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 SCADA system. The transducer shall be installed in the Individual Marshalling Box. Any special cable required for shielding purpose, for connection between PT100 temperature sensor and transducer, shall be in the scope of manufacturer. 4-20mA signal shall be wired to Digital RTCC panel/BCU for further transfer data to SCADA through IS/IEC 61850 compliant communications.

11.11 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, LV or LV1/LV2, Tertiary (if applicable)]. It shall have **angular sweep of 270°. Range of temperature should be 0-150°C with accuracy of ±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 1200 mm 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 winding temperature:

Temperature transducer with PT100 sensor for each winding

RTD shall be provided with PT100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The PT100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per 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 and Auxiliary CT shall be installed in the Individual Marshaling Box. Any special cable required for shielding purpose, for connection between PT100 temperature sensor and transducer, shall be in the scope of Contractor. 4-20mA signal shall be wired to Digital RTCC / BCU panel for further transfer data to SCADA through IS/IEC 61850 compliant communications.

11.12 Earthing Terminals

11.12.1 **Two (2) earthing pads** (each complete with two (2) nos. holes, M16 bolts, plain and spring washers) **suitable for connection to 75 x 12 mm galvanised steel grounding flat** shall be provided each at **position close to earth of the two (2) diagonally opposite bottom corners of the tank.**

11.12.2 **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 Box etc., (if provided), double earthing shall be provided through the tank for which provision shall be made through tank and connected through two flexible insulated copper link.

11.12.3 **Equipotential flexible copper links** of suitable size shall be provided **between turret & tank, between tank & cover or between Bell & lower tank.** Other components like - pipes, conservator support etc. connected to tank may also be provided with equipotential flexible copper link.

11.12.4 Each transformer unit should have provision for earthing and connection to grounding mat when not in service.

11.13 Core

11.13.1 **The core shall be constructed as per IS 3024 from non-ageing, Cold Rolled Grain Oriented (CRGO) silicon steel laminations. Indian transformer manufacturers shall use core material as per above specification with BIS certification.**

11.13.2 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.

11.13.3 **The hot spot temperature and surface temperatures in the core shall be calculated for over voltage conditions specified in the document and it shall not exceed 125 deg C and 120 deg C respectively.**

11.13.4 Core and winding shall be capable of withstanding the shock during transport, installation and service. Adequate provision shall be made to prevent movement of core and winding relative to tank during these conditions.

11.13.5 All steel sections used for supporting the core shall be thoroughly sand/ shot blasted after cutting, drilling and welding.

11.13.6 Each core lamination shall be insulated with a material that will not deteriorate due to pressure and hot oil.

11.13.7 The supporting frame work of the core shall be so designed as to avoid presence of pockets which would prevent complete emptying of tank through drain valve or cause trapping of air during oil filling.

11.13.8 Adequate lifting lugs shall be provided to enable lifting of active part (core & winding).

11.13.9 Core assembly shall be manufactured in such a way that lamination shall remain flat and finally assembled core shall be free from distortion.

11.13.10 **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.

11.13.11 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.

11.13.12 **Insulation of core to clamp/frame shall be tested at 2.5 kV 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.**

11.14 Windings

11.14.1 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.**

11.14.2 The **conductors** shall be of **electrolytic grade copper** free from scales and burrs. Oxygen content shall be as per IS 12444.

11.14.3 **Epoxy bonded Continuously Transposed Conductor (CTC) shall be used in main winding for rated current of 400 A or more.**

11.14.4 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.

11.14.5 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.

11.14.6 The insulation of transformer windings and connections shall be free from insulating compounds which are liable to soften, ooze out, shrink or collapse and shall be non-catalytic and chemically inactive in transformer oil during service.

11.14.7 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.

11.14.8 The coils would be made up, shaped and braced to provide for expansion and contraction due to temperature changes.

11.14.9 The windings shall be designed to withstand the dielectric tests specified. The type of winding used shall be of time tested. An analysis shall be made of the transient voltage distribution in the windings, and the clearances used to withstand the various voltages. Margins shall be used in recognition of manufacturing tolerances and considering the fact that the system will not always be in the new factory condition.

11.14.10 **The barrier insulation including spacers shall be made from high-density pre-compressed pressboard (1.15 gm/cc minimum for load bearing and 0.95 gm/cc minimum for non-load bearing) to minimize dimensional changes. Kraft insulating paper used on conductor should have density of >0.75 g/cc.**

11.14.11 Wherever required, electrostatic shield, made from material that will withstand the mechanical forces, will be used to shield the high voltage windings from the magnetic circuit.

11.14.12 All insulating materials and structures shall be protected from contamination and the effects of humidity during and after fabrication, and after receipt, by storing them in a separate, climate-controlled area. All blocks shall be installed such that the grain is oriented in the horizontal direction, perpendicular to the winding compressive forces. Aspect ratio of selected conductor shall be chosen suitably based on manufacturer experience to result in stable winding under normal and abnormal service condition after assembly.

11.14.13 All winding insulation shall be processed to ensure that there will be no detrimental shrinkage after assembly. All windings shall be pre-sized before being clamped.

11.14.14 **Winding paper moisture shall be less than 0.5%.**

11.14.15 Windings shall be provided with clamping arrangements which will distribute the clamping forces evenly over the ends of the winding.

11.14.16 **Either brazing/crimping type of connections are permitted for joints.** It shall be time proven and safely withstand the cumulative effect of stress which may occur during handling, transportation, installation and service including line to line and line to ground faults /Short circuits. Manufacturer shall have system which allows only qualified personnel to make brazing or crimping joints.

11.15 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.

11.16 Winding terminations into bushings

11.16.1 Winding termination interfaces with bushings shall be designed to allow for repeatable and safe connection under site conditions to ensure the integrity of the transformer in service.

11.16.2 The winding end termination, insulation system and transport fixings shall be so designed that the integrity of the insulation system generally remains intact during repeated work in this area.

11.16.3 Allowances shall be made on the winding ends for accommodating tolerances on the axial dimensions of the set of bushings and also for the fact that bushings may have to be rotated to get oil level inspection gauges to face in a direction for ease of inspection from ground level.

11.16.4 In particular, rotation or straining of insulated connections shall be avoided during the fastening of conductor pads (or other methods) on the winding ends onto the termination surfaces of the bushing.

11.16.5 Suitable inspection and access facilities into the tank in the bushing oil-end area shall be provided to minimize the possibility of creating faults during the installation of bushings.

12.0 PAINT SYSTEM AND PROCEDURES

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

13.0 INSULATING OIL

The insulating oil shall be **unused inhibited (Type A, High Grade) Transformer Oil conforming to IEC-60296-2020 & all parameters specified at Annexure–L,** while tested at oil supplier's premises. The contractor shall furnish test certificates from the supplier against the acceptance norms as mentioned at Annexure–L, prior to despatch of oil from refinery to site. Under no circumstances, poor quality oil shall be filled into the transformer and thereafter be brought up to the specified parameter by circulation within the transformer. The Unused Insulating Oil parameters including parameters of oil used at manufacturer's works, processed oil, oil after filtration and settling are attached at Annexure–L. The oil test results shall form part of equipment test report.

New generation insulating oils may also be considered, if so desired by the utility, provided any National or International standard is available for such oil.

A minimum of 5% of the oil quantity shall be supplied as spare (in addition to first filling) for maintaining required oil level in case of leakage in tank, radiators, conservator etc.

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

13.1 Particles in the oil (For 400 kV transformer)

The particle analysis shall be carried out in an oil sample taken **before carrying out FAT at manufacturer's works and after completion of the oil filtration at site.** The procedure and interpretation shall be in accordance with the recommendation of CIGRE report WG-12.17-

"Effect of particles on transformer dielectric strength". Particle limit as shown below shall be ensured by manufacturer, implying low contamination, as per CIGRE Brochure 157, Table 8. After filtration the oil is to be flushed and particle count to be measured.

Limiting value for the particle count are **1000 particle/100 ml with size ≥ 5 µm; 130 particle/100 ml with size ≥ 15 µm.**

14.0 BUSHINGS

14.1 **For various voltage class of transformer, type of bushings shall be as follows:**

Voltage Rating	**Bushing Type**
52 kV, 145 kV, 245 kV and 420 kV bushings	OIP/RIP/RIS
36 kV Bushings	Solid porcelain or oil communicating type

OIP: Oil Impregnated Paper (with porcelain/polymer housing); RIP: Resin Impregnated Paper (with polymer housing); RIS: Resin Impregnated Synthetic (with polymer housing)

14.2 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 and design review.

14.3 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 & oil sample valve

14.4 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.

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

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

14.7 Bushings of **identical rating of different makes shall be interchangeable** to optimise the requirement of spares. The standard dimensions for lower portion of the condenser bushings shall be as indicated in **Annexure-M**.

14.8 **Polymer insulator** shall be seamless sheath of a silicone rubber compound. The housing & weather sheds should have **silicon content of minimum 30% by weight**. It should protect the bushing against environmental influences, external pollution and humidity. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core. The technique being followed with detailed procedure and sampling shall be finalized during finalization of MQP. The weather sheds of the insulators shall be of alternate shed profile as per IS 16683-3/IEC 60815-3. The weather sheds shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections. The vulcanization for extrusion process shall be at high temperature and for injection moulding shall be at high temperature & high pressure. Any seams/ burrs protruding axially along the insulator, resulting from the injection moulding process shall be removed completely without causing any damage to the housing. The track resistance of housing and shed material shall be class 1A4.5 according to IS 9947. The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. **The polymer insulator shall be capable of high pressure washing.**

14.9 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.

14.10 The hollow silicone composite insulators shall comply with the requirements of 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).

14.11 Clamps and fittings shall be of hot dip galvanised/stainless steel.

14.12 Bushing turrets shall be provided with vent pipes, to route any gas collection through the Buchholz relay.

14.13 **No arcing horns** shall be provided on the bushings.

14.14 **Corona shield, wherever required, shall be provided** at bushing terminal (air end) to minimize corona.

14.15 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. 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.

14.16 Oil end portion of RIP/RIS type bushings shall be fitted with metal housing with positive dry air pressure or oil filled metal housing 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 need to be maintained in case of leakage. The recommendations of the bushing supplier shall also to be considered.

14.17 The terminal marking and their physical position shall be as per IS 2026.

14.18 **Tan delta measurement at variable frequency (in the range of 20 Hz to 350 Hz) shall be carried out on each condenser type bushing (OIP & RIP/ RIS) at Transformer manufacturing works as routine test before despatch** and the result shall be compared at site during commissioning to verify the healthiness of the bushing.