भारत सरकार
Government of India
विद्युत मंत्रालय
Ministry of Power
केन्द्रीय विद्युत प्राधिकरण
Central Electricity Authority
विद्युत प्रणाली अभियांत्रिकी एवं प्रौद्योगिकी विकास प्रभाग
Power System Engineering & Technology Development Division
3rd Floor, Sewa Bhawan, R.K. Puram
New Delhi – 66, Telephone: 011-26732358

विषय / **Subject: Invitation of comments on draft Standard Technical Specifications of Transformer(s) for Solar Park pooling station.**

महोदय/ Sir,

A Standardization Committee has been constituted by CEA under the Chairmanship of Chief Engineer (PSE&TD), CEA comprising members from transformer manufacturers, utilities, SECI and solar power park developers etc. for the preparation of Standard Technical Specifications of Transformer(s) for Solar Park pooling station considering importance of such transformer in present scenario when large scale integration of generation from renewable sources is taking place.

The standardisation will help the utilities/developers/ manufacturers across the country in many ways in terms of getting product of similar quality & reliability. The delivery will be faster and would establish uniform practices across the utilities, facilitate interchangeability of transformers of different make. Based on the discussions in the meeting of the committee, the draft Technical specifications of the transformer(s) have been prepared.

All utilities/stakeholders are requested to provide comments/valuable input on the draft specification by 22nd March, 2021 by post or email: [**ce-psetd@gov.in**] so that the document can be finalized and the work of technical committee can be completed within the assigned timeframe.

Encl: As above

File No.CEA-PS-14-169/1/2020-PSETD Division

Validity unknown

Digitally signed by BHANWAR SINGH MEENA
Date: 2021.03.05 12:57:46 IST

Yours faithfully,

(भंवर सिंह मीना / Bhanwar Singh Meena)
उप निदेशक / Deputy Director

Copy to: Director (IT), CEA-It is requested to upload document on the CEA website

Chapter-1

TECHNICAL SPECIFICATIONS OF POWER TRANSFORMERS FOR SOLAR PARK POOLING STATION

1.0 GENERAL

1.1 This chapter covers specification for design, engineering, manufacture, testing, delivery at site including all materials, accessories, unloading, handling, proper storage at site, erection, testing and commissioning of the Power Transformer for solar park pooling station.

1.2 For transportation, erection, testing and commissioning and condition monitoring & life cycle management, the document "Standard Specifications and Technical Parameters for Transformers and Reactors (66 kV & above Voltage Class)" issued by CEA may be referred.

1.3 The design and workmanship shall be in accordance with the best engineering practices to ensure satisfactory performance throughout the service life.

1.4 Any material and equipment not specifically stated in this specification but which are necessary for satisfactory operation of the equipment shall be deemed to be included unless specifically excluded and shall be supplied without any extra cost.

1.5 Components having identical rating shall be interchangeable.

2.0 STANDARD RATINGS OF TRANSFORMER

Standard ratings of transformer for Solar Park pooling stations shall be as given below:

Sr. No	MVA Rating	Line Voltage Rating	Phase	No. of Secondary windings
1.	315 MVA	400/33 kV	Three Phase	Two
2.	250 MVA	400/33 kV	Three Phase	Two

3.	160 MVA	400/33 kV	Three Phase	One
4.	125 MVA	400/33 kV	Three Phase	One
5.	160 MVA	220/33 kV *230/33 kV	Three Phase	One
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 1.7 T and under 10 % continuous over-voltage condition** it **shall be 1.9 Tesla at all tap positions.**

5.8 **The current density in any of the windings shall not exceed 3.5 A/sq.mm at all tap positions.**

5.9 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.

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

400kV system	- 63 kA for 1 sec (sym, rms, 3 phase fault)
220kV system	- 50 kA for 1 sec (sym, rms, 3 phase fault)
132kV system	- 40 kA for 1 sec (sym, rms, 3 phase fault)
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)**.

5.11 Transformer shall be capable of withstanding thermal and mechanical stresses due to 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 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.

5.12 **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.

5.13 **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.

5.14 **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, auxiliary loss and load 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. 10,00,000/KW
2	Load Losses	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.		

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

The offered transformer or the transformer, the design of which is similar to the offered transformer, should have been successfully type tested within last 5 years as on the last date of submission of bid.

Manufacturer may use same or different approved make of Bushings, Tap changer and other accessories used in type tested or short circuit tested unit in their transformer. Further, **type test report of transformer shall only be acceptable provided the offered transformer has been manufactured from the same plant**.

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-3: 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	
x)	Specific Creepage Distance of insulation in air	

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 The base of each tank shall be so designed that it shall be **possible to move the complete transformer unit by skidding in any direction without damage when using plates or rails** and the base plate shall have following minimum thickness.

Length of tank (m)	**Minimum plate thickness (mm)**
Flat bases	
Over 2.5 m but less than 5m	20
Over 5 m but less than 7.5m	26
Over 7.5 m	32

11.1.5 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.

11.1.6 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.

11.1.7 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.

11.1.8 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.

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

11.1.10 After fabrication of tank and before painting, **Non-destructive test (dye penetration test) is mandatory on the load bearing members** such as base plate joints, jacking pads and lifting devices etc.

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

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

11.1.13 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.

11.1.14 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.

11.1.15 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.

11.1.16 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.

11.1.17 **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.

11.1.18 **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.**

11.1.19 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.

11.1.20 **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.**

11.1.21 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.

11.1.22 **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

Transformer shall be placed on foundation either directly or on roller assembly.

11.3.1 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 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 In case rail is not required for smaller rating transformers, arrangement of unidirectional roller mounted on channel shall be provided and channel shall be locked with the plinth suitably.

11.3.5 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.

11.3.6 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.

11.3.7 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 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.

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

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

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

11.4.7 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"**.

11.4.8 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.

11.4.9 **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.

11.4.10 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.

11.4.11 **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.**

11.4.12 **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 or the opening of inspection or 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.
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 (for 220kV and above transformer/reactor)

One number of Sudden Pressure Relay/ Rapid Pressure Rise Relay with alarm or trip contact (Terminal connection plug & socket type arrangement) 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 from non-ageing, cold rolled high permeability grade or better grain oriented 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 1 giga 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.

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

11.14.3 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.

11.14.4 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.

11.14.5 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.

11.14.6 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.

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

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

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

11.14.10 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.

11.14.11 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.

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

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

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

11.14.15 **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-60396-2020 & 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.

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
145 kV, 245 kV and 420 kV bushings	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.

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.

14.19 **Tan δ value of OIP/RIP/RIS condenser bushing shall be 0.005 (max.) in the temperature range of 10°C to 40°C. If tan delta is measured at a temperature beyond above mentioned limit, necessary correction factor as per IEEE shall be applicable.**

15.0 Air insulated dry Cable Box for 33 kV XLPE cable (if applicable):

15.1 Cable boxes shall be of phase segregated air insulated type & shall be of sufficient size to accommodate Purchaser's cable & termination. Phase segregation shall be achieved by insulating barriers.

15.2 Cable boxes shall have bus bars / terminal connectors of adequate size & bolt holes to receive cable lugs.

15.3 Cable boxes shall be designed to accommodate all the cable joint fittings or sealing ends required by the manufacturers of the cables, including stress/cones or other approved means for grading the voltage stress on the terminal insulation of cables operating at voltages of 33 kV between phases.

15.4 The cable boxes shall be fitted with suitable non-ferrous wiping glands with combined armour and earthing clamps. The ends of all wiping glands shall be tinned before dispatch to site. Wiping glands for single core cables shall be insulated from the box. Wiping glands insulation shall be capable of withstanding a dry high voltage test of 2 kV AC for one minute. Sufficient wiping glands shall be provided for the termination of required number of cables.

15.5 Where cable boxes are provided for three core cables, the seating sockets on the two outer phases shall preferably be inclined towards the centre to minimize bending of the cable cores. Where there is more than one core per phase, the socket block shall be so designed as to minimize bending of the cable cores.

15.6 A suitable removable gland plate of non-magnetic material shall also be provided in the cable box.

15.7 The support from base for the cable box shall be of galvanized iron.

15.8 The contractor shall provide earthing terminals on the cable box, to suit Purchaser's GI flat.

15.9 Unless otherwise approved the creepage distances and clearance to earth and between phases shall not be less than those specified below.

Highest System Voltage kV	**Insulating medium**	**Clearance between phases (mm)**	**Clearance to earth direct (mm)**	**Creepage over porcelain to similar material (mm)**	**Creepage over cable surface (mm)**
36	Air	351	222	576	576

15.10 Terminals shall be marked in a clear and permanent manner.

15.11 Cable boxes shall have removable top cover & ample clearance shall be provided to enable either transformer or each cable to be subjected separately to high voltage test.

15.12 The minimum length provided for terminating 33kV cable shall be 1000 mm (from cable gland plate to the cable lug) for the cable boxes. The final cable size, number & length of terminating XLPE cable shall be furnished during detailed engineering.

15.13 Cable boxes shall be designed such that it shall be possible to move away the transformer without disturbing the cable terminations, leaving the cable box on external supports. Cable box shall have IP-55 protection as per IS:13974.

15.14 Unless otherwise specified main cabling jointing and filling of cable boxes will be carried out by the purchaser or his Contractor as the case may be.

16.0 NEUTRAL FORMATION AND EARTHING ARRANGEMENT

The neutral of the transformer shall be brought out through bushing. The neutral terminal of 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 a convenient location at the bottom of the tank, for making connection (using bimetallic strip of adequate size) to grounding mat through separate earth pits using two (2) numbers 75 x 12 mm galvanised steel flats. Aluminium clamps & connectors of suitable size shall be provided for connection with neutral of the transformer.

17.0 COOLING EQUIPMENT AND ITS CONTROL

17.1 Radiator based cooling for Power transformer

The transformer shall be designed with cooler system as specified in **Annexure-A** and with following provisions, as applicable.

17.1.1 The cooler shall be designed using **separately mounted radiator banks or tank mounted radiators**. Design of cooling system shall satisfy the performance requirements.

17.1.2 **In case of separately mounted radiator bank** arrangement, **radiator bank shall generally be placed on left side of the tank while watching from HV side of the transformer**. However, **the main tank shall have provision such that cooler banks can be placed on either side of the main tank** by simple reconnection without the need of any extra member/pipe maintaining the electrical clearances.

17.1.3 **The radiator shall be of sheet steel complying with IS 513 and minimum thickness 1.2 mm.** Each radiator bank shall be provided with the following accessories:

(a) Cooling Fans, Oil Pumps, Oil Flow Indicator (as applicable)
(b) Top and bottom shut off valve 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. 75x12 mm galvanised steel flats.
(g) Thermometer pockets fitted with captive screw caps at cooler inlet and outlet.
(h) Lifting lugs

17.1.4 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.

17.1.5 **One number standby fan** shall be provided **with each radiator bank**.

17.1.6 **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 galvanised wire guard. The exhaust air flow from cooling fan shall not be directed towards the main tank in any case.

17.1.7 **Two (2) nos., 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.

17.1.8 The changeover to standby oil pump in case of failure of service oil pump shall be automatic.

17.1.9 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.

17.1.10 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.

17.1.11 **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/IEC 60034-5.

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

17.1.13 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.

17.1.14 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 changeover of cooler control over entire operating range depending on types of cooling system like ONAN/ONAF/ODAF (or OFAF) or ONAN/ONAF. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.

17.1.15 Suitable manual control facility for cooler fans and oil pumps shall be provided. Selector switches and push buttons shall also be provided in the cooler control cabinet to disconnect the automatic control and start/stop the fans and pump manually.

17.1.16 Following lamp indications shall be provided in cooler control cabinet:

a) Cooler Supply failure (main)
b) Cooler supply changeover
c) Cooler Supply failure (standby)
d) Control Supply failure
e) Cooling fan supply failure for each bank
f) Cooling pump supply failure for each pump
g) Common thermal overload trip
h) Thermal overload trip for each fan/pump
i) No oil flow/reverse flow for pumps
j) Stand by fan/pump ON

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

17.1.17 The Cooler Control Cabinet/ Individual Marshalling Box shall have all necessary devices meant for cooler control and local temperature indicators. All the contacts of various protective devices mounted on the transformer and all the secondary terminals of the bushing CTs shall also be wired up to 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.

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

17.1.19 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.

18.0 VALVES

18.1 Type of valves shall be used for transformer as per following table. The location and size of valves for other application shall be finalised 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 (if applicable)	Butterfly
16	Valve for N2 injection (NIFPS) (if specified by utility)	Gate
17	Valve for NIFPS Drain (if specified by utility)	Gate
18	Valve for UHF Sensors (applicable for 400kV voltage class Transformer only)	Gate

18.2 **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.

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

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

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

18.6 Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently.

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

18.8 After testing, inside surface of all cast iron valves coming in contact with oil shall be applied with one coat of oil resisting paint/varnish with two coats of red oxide zinc chromate primer followed by two coats of fully glossy finishing paint conforming to IS: 2932 and of a shade (Preferably red or yellow) distinct and different from that of main tank surface. 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.

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

18.10 Valves or other suitable means shall be provided to fix various on line condition monitoring systems, if specified, to facilitate continuous monitoring. The location & size of the same shall be finalised during detail design review.

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

18.12 **Flow sensitive conservator Isolation valve (if specified by the utility)**

a) In order to restrict the supply of oil in case of a fire in transformer, flow sensitive valve shall be **provided to isolate the conservator oil from the main tank.** The valve shall be flow sensitive and shut off when the flow in the pipe is more than the flow expected in the permissible normal operating conditions. It shall **not operate when oil pumps are switched on or off**. This valve shall be located in the piping between the conservator and the buchholz relay and shall not affect the flow of oil from and to the conservator in normal conditions.

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

19.0 CABLING

19.1 All interconnecting control and power cables emanating from various parts of transformer 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. **Typical technical specification for cables is attached at Annexure-O**. The cross section of "control cable" shall be **1.5 sq.mm (minimum)** except for **CT circuits** which should be **2.5 sq.mm (minimum)**.

20.0 TAP CHANGING EQUIPMENT

The transformer shall be provided with Off Circuit (De-energized)/On Load Tap changing equipment as specified in Annexure-A and shall comply with IS 8468-1/IEC 60214-1.

20.1 Off Circuit Tap Changing (OCTC)/De-Energized Tap Changing (DETC) Equipment

20.1.1 The tap changer shall be **hand operated** for switching taps by operating external hand wheel.

20.1.2 Arrangement shall be made for securing & pad locking the tap changer in any of the working positions & it shall **not be possible for setting or padlocking it in any intermediate position**. An indicating device shall be provided to show the tap in use.

20.1.3 The cranking device for manual operation of the off circuit tap changing gear shall be removable & suitable for operation by a man standing on ground level. The mechanism shall be complete with the following:

(a) A mechanical operation indicator.

(b) Mechanical tap position indicator which shall be clearly visible from near the transformer.

(c) Mechanical stops to prevent over cranking of the mechanism beyond the extreme positions.

(d) The manual operating mechanism shall be labeled to show the direction of operations for raising the secondary voltage & vice versa.

(e) A warning plate indicating "The switch shall be operated only when the transformer has been de-energized" shall be fitted.

20.1.4 Measurement of Tan Delta values of OCTC to be done before installing in the transformer.

20.1.5 Following signals to be provided:

(a) Out of step digital position indicator, showing mismatch between tap positions of transformers in three phases.

(b) An analog signal (4-20 mA) for tap position of transformer.

20.2 On Load Tap Changing (OLTC) Equipment

20.2.1 Main OLTC Gear Mechanism

20.2.1.1 The transformer as specified in **Annexure-A** 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 (Part 1& 2). The requirement of voltage regulation (on HV), location (physical and electrical) of tap winding, range of voltage variation, no. of steps etc. shall be as given in **Annexure-A**.

20.2.1.2 The **OLTC** shall be of **high speed transition resistor type**. OLTC shall be motor operated suitable for local as well as remote operation. The diverter switch or arcing switch s

20.2.1.3 hall be designed so as to ensure that its operation once commenced shall be completed independently of the control relays or switches, failure of auxiliary supplies etc. To meet any contingency which may result in incomplete operation of the diverter switch, adequate means shall be provided to safeguard the transformer and its ancillary equipment. **The current diverting contacts shall be housed in a separate oil chamber not communicating with the oil in main tank of the transformer 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.

20.2.1.4 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.

20.2.1.5 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.

20.2.1.6 The OLTC oil chamber shall have oil filling and drain valve, oil sampling valve, relief vent and level glass. Oil sampling valve, 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.

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

20.2.1.8 As an alternative to conventional OLTC with traditional diverter switch immersed in oil (where arcing takes place in oil), vacuum type OLTC (where arcing takes place in a hermetically sealed vacuum interrupter) may also be provided. However, provisions as specified above shall be followed as far as applicable.

20.2.2 Local OLTC Control Cabinet (Drive Mechanism Box)

20.2.2.1 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.

20.2.2.2 **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 (preferably at a height less than1800mm). The mechanism shall be complete with the following:

(a) Mechanical tap position indicator, which shall be clearly visible near the transformer.

(b) A mechanical operation counter of at least five digits shall be fitted to indicate the number of operations completed and shall have no provision for resetting.

(c) Mechanical stops to prevent over-cranking of the mechanism beyond the extreme tap positions.

(d) 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.

(e) The manual operating mechanism shall be labelled to show the direction of operation for raising the voltage and vice-versa.

(f) An electrical interlock to cut-off a counter impulse for reverse step change being initiated during a progressing tap change, until the mechanism comes to rest and resets circuits for a fresh position.

20.2.2.3 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 operating AC supply shall not affect the tap changer. Thermal device or other means shall be provided to protect the motor and control circuit.

20.2.2.4 The Local OLTC Drive Mechanism Box shall house all necessary devices meant for OLTC control and indication. It shall be complete with the following:

(a) A circuit breaker/contactor with thermal overload devices for controlling the AC Auxiliary supply to the OLTC motor

(b) Emergency Push Button to stop OLTC operation

(c) Cubicle light with door switch

(d) Anti-condensation metal clad heaters to prevent condensation of moisture

(e) Padlocking arrangement (or locking arrangement suitable for long term operation) for hinged door of cabinet

(f) All contactors relay coils and other parts shall be protected against corrosion, deterioration due to condensation, fungi etc.

(g) The cabinet shall be tested at least IP 55 protection class.

20.2.2.5 In case auxiliary power supply requirement for OLTC Drive Mechanism (DM) Box is different than station auxiliary AC supply, then all necessary converters shall be provided.

20.2.2.6 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.

20.2.2.7 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.

20.2.2.8 OLTC local control cabinet shall be provided with tap position indication for the transformer. Drive Mechanism shall be equipped with a fixed resistor network capable of providing discrete voltage steps or provide 4-20mA transducer outputs for tap position indication in Common Marshalling Box (CMB) (for single phase unit) and input to digital RTCC/relevant BCU (as applicable)/SCADA system. The tap position indicator shall also be provided in control room.

20.2.2.9 'Local-remote' selector switch shall be provided in the local OLTC control cabinet. In Local mode, all electrical commands from remote (i.e. from CMB, digital RTCC, SCADA, SAS 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 Driving Mechanism (DM) Box. In remote mode electrical commands from CMB/ digital RTCC/SCADA/SAS etc. shall be executed. The remote-local selector switch shall be having at-least two spare contacts per position.

20.2.2.10 The following minimum LED indications shall be provided in DM box:

(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) 415V Standby AC supply ON

20.2.2.11 The following minimum contacts shall be available in DM Box and 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

20.2.2.12 All relays, switches, fuses etc. shall be mounted in the OLTC local control cabinet and shall be clearly marked/ labelled for the purpose of identification. Both ends of all the wires (control & power) connected to Drive Mechanism Box must be provided with proper ferrule nos. for tracing and maintenance.

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

20.2.3 Remote Control & Monitoring of OLTC

For substations/ pooling stations having Substation Automation System, Control & monitoring of OLTC shall be carried out through Substation Automation System. Following functionalities specified for digital RTCC shall be realised in soft logic in Substation Automation System. All hardwire signals from/to OLTC shall be wired to Bay Control Units (BCUs) provided by the owner/contractor, as applicable.

20.2.3.1 The digital RTCC relay shall have Automatic Tap Changer control and monitoring relay with Automatic Voltage Regulating features to remotely control and monitor OLTC.

20.2.3.2 Each digital RTCC relay shall be used to control one unit of transformer. No. of relays including spare relay, if any, shall be specified by the utility as per requirement.

20.2.3.3 All digital relays can be housed in the BCU panel.

20.2.3.4 **Digital RTCC relay** shall be **microprocessor based** adopting the latest state of the art design & technology with **in-built large LCD** (or better) display for ease of programming and viewing. The unit supplied shall be field programmable so that in the event of change in transformer location, it could be customized to suit site conditions without sending back to works. The programming shall be menu driven and easily configurable. If it is designed with draw out type modules, it should take care of shorting all CT inputs automatically while drawing out. The CT/VT ratio shall be field programmable and Relay shall display the actual HV Voltage and current considering suitable multiplying factors. The system shall be self-sufficient and shall not require any additional devices like parallel balancing module etc.

20.2.3.5 It shall be **possible to communicate/integrate with all digital RTCC relays of different make located at different locations in the substation** by making hardwire and using IS/IEC 61850 communication link.

20.2.3.6 The digital RTCC relay shall have Raise/Lower push buttons, Manual/ Automatic mode selection feature, Local/Remote selection feature, Master / Follower/ Independent/ Off mode selection feature for control of OLTC. Touch screen option in the relay (instead of electrical push button/switch) is also acceptable.

20.2.3.7 The digital RTCC Relay shall have multiple selectable set point voltages and it shall be possible to select these set points from SCADA/ SAS, with a facility to have the possibility of additional set points command from SCADA/ SAS.

20.2.3.8 **In Manual Mode**: In this mode, power system voltage based automatic control from digital RTCC relay shall be blocked and commands shall be executed manually by raise/lower push buttons.

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

20.2.3.10 **Master/Follower/Independent/Off mode**

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

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

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

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

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

20.2.3.11 **Raise/Lower control:** The remote OLTC scheme offered shall have provision to raise or lower taps for the Transformers.

20.2.3.12 Digital RTCC relays shall communicate with SCADA using IS/IEC 61850 through fibre optic port to monitor, parameterise and control the OLTC. Any software required for this purpose shall be supplied. The supplied software shall not have restriction in loading on multiple computers for downloading and analyzing the data. Software shall indicate the current overview of all measured parameters of the connected transformer in real time.

20.2.3.13 Communication between the Digital RTCC relays to execute the commands for parallel operation shall be implemented using required communication protocol. Suitable communication hardware shall be provided to communicate up to distance of 1 km between digital RTCC relays. Scope shall also include communication cables between digital RTCC relays. Cables as required for parallel operation of OLTCs of all transformers (including existing transformers wherever required) from Digital RTCC relays shall be considered included in the scope.

20.2.3.14 The Digital RTCC relay shall have additional programmable Binary Inputs (minimum 7 Nos.) and Binary outputs (minimum 7 Nos.) for future use. It shall be possible to have additional module for Binary Input / output as well as Analogue input module depending upon requirement.

20.2.3.15 The relays shall ensure completion of lowering/raising of the OLTC tap, once the command is issued from the relay. "Step-by-Step" operation shall be ensured so that only one tap change from each tap changing pulse shall be effected. If the command remains in the "operate" position, lock-out of the mechanism is to be ensured.

20.2.3.16 The relay shall incorporate an under voltage / over voltage blocking facility which shall make the control inoperative if voltage falls/ rises by percentage value of set point value with automatic restoration of control when nominal voltage rises / falls to value.

20.2.3.17 The relay shall have facility to monitor operating hours of tap changer and register the tap changer statistics. In the statistics mode, the relay shall display the no. of tap changing operations occurred on each tap.

20.2.3.18 The relay shall have 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. Any monitoring system problem shall initiate the alarm.

20.2.3.19 Following minimum indications/alarms shall be provided in Digital RTCC relay either through relay display panel or through relay LEDs:

(a) INCOMPLETE STEP alarm
(b) OLTC motor overload protection alarm
(c) Supply to DM Motor fail alarm
(d) OLTC IN PROGRESS alarm
(e) Local / Remote Selector switch positions in DM Box
(f) OLTC upper/lower limits reached alarm
(g) OLTC Tap position indications for transformer units
(h) 415V, AC Mail Supply Fail.
(i) 415V, AC Standby Supply Fail

20.2.3.20 In case of parallel operation, OLTC out of step alarm shall be generated in the digital RTCC relay for discrepancy in the tap positions.

21.0 SCADA INTEGRATION (if applicable)

All the online monitoring equipment i.e. Optical Temperature Sensors & Measuring Unit, Online Dissolved Gas (Multi-gas) and Moisture Analyzer, On-line insulating oil drying system (Cartridge type) etc. provided for individual transformer, shall be IS/IEC 61850 compliant (either directly or through a Gateway). These monitoring equipment are required to be integrated with SAS through managed Ethernet switch conforming to IS/IEC 61850. This Ethernet switch shall be provided in IMB. The switch shall be powered by redundant DC supply (as per available Station DC supply). Ethernet switch shall be suitable for operation at ambient temperature of 50 Deg C. All required power &

control cables including optical cable, patch chord (if any) upto IMB, all the cables from RTCC to DM and any special cable between IMB to switchyard panel room/control room shall be in the scope.

However, fiber optic cable, power cable, control cables, as applicable, between IMB to switchyard panel room/control room and power supply (AC & DC) to MB and integration of above said IS/IEC-61850 compliant equipment with Substation Automation System may be a part of sub-station contract.

Cooling and OLTC of transformers shall also be monitored and controlled from SCADA. List of Signal exchange between Transformer and SCADA may be mutually agreed between the owner and manufacturer. Owner/contractor, as applicable, shall ensure provision of adequate number of redundant Bay control Units (BCUs).

22.0 CONSTRUCTIONAL FEATURES OF COOLER CONTROL CABINET/ INDIVIDUAL MARSHALLING BOX/ OUTDOOR CUBICLE/DIGITAL RTCC PANEL

22.1 Each transformer unit shall be provided with local OCTC/OLTC Drive Mechanism Box (DMB), Cooler Control Cabinet/Individual Marshalling Box, and **Digital RTCC panel** (as applicable).

22.2 Individual **Marshalling Box (IMB) and Cooler Control Box** shall be **tank mounted** or ground mounted. All cabinets except CMB & Digital RTCC panel shall be tank mounted. All separately mounted cabinets and panels shall be free standing floor mounted type and have domed or sloping roof for outdoor application. The gland plate shall be at least 450 mm above ground level.

22.3 The Cooler Control Cabinet (CCC)/Individual Marshalling Box (IMB) , and **all other outdoor cubicles (except OLTC Drive Mechanism box)** shall be made **of stainless steel sheet of minimum Grade SS 304 and of minimum thickness of 1.6 mm. Digital RTCC panel** shall be made of **CRCA sheet of minimum thickness of 2.0 mm** and shall be painted suitably as per **Annexure–K**.

22.4 The degree of protection shall be **IP: 55 for outdoor and IP: 43 for indoor** in accordance with IS/IEC: 60947.

22.5 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/Digital 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 and IS: 3400.

22.6 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.

22.7 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.

23.0 AUXILIARY POWER SUPPLY FOR OLTC, COOLER CONTROL AND POWER CIRCUIT

23.1 **Two auxiliary power supplies of 415 volt, three phase four (4) wire** shall be provided by the Purchaser **at Cooler Control Cabinet / Marshalling Box**. All loads shall be fed by one of the two sources through an electrically interlocked automatic transfer scheme housed in the Cooler Control Cabinet/Marshalling Box.

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

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

23.4 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
415 V	±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	--
110 V	95 V to 120 V	DC	Isolated 2 wire system	--
48 V	--	DC	2 wire system (+) earthed	--

Combine variation of voltage and frequency shall be limited to ±10%.

23.5 Design features of the transfer scheme shall include the following:

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

24.0 BUSHING CURRENT TRANSFORMER AND NEUTRAL CURRENT TRANSFORMER

24.1 Current transformers shall comply with IS 16227 (Part 1 & 2)/IEC 61869 (part 1 & 2).

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

24.3 Current transformer secondary leads shall be brought out to a weather proof terminal box near each bushing. These terminals shall be wired out to common marshalling box using separate cables for each core.

24.4 Technical Parameters of Bushing CTs and Neutral CTs are provided at **Annexure–B.** The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection. **Bushing Current Transformer parameters indicated in this specification are tentative and liable to change within reasonable limits. Purchaser's approval shall be obtained before proceeding with the design of bushing current transformers.**

24.5 Secondary resistance and magnetising current characteristics of PX class (protection) CT of same rating shall be similar. This is applicable for Neutral CT (outdoor) also and shall be reviewed during detail engineering.

25.0 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; required numbers of hydraulic jacks 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. Utility may add/remove tools as per their requirement.

26.0 FITTINGS & ACCESSORIES

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

<u>For Transformer:</u>

(a) Conservator for main tank with aircell, oil filling hole and cap, isolating valves, drain valve, magnetic oil level gauge, prismatic oil level gauge and dehydrating silica gel filter breather with flexible connection pipes to be used during replacement of any silica gel breather.

(b) Conservator for OLTC (for transformer) with drain valve, oil surge relay, filling hole with cap, magnetic oil level gauge, prismatic oil level gauge and dehydrating breather (for transformer only) with flexible connection pipes to be used during replacement of any silica gel breather.

(c) Pressure relief devices with special shroud to direct the hot oil

(d) Sudden pressure relief relay (for 220 kV and above Transformer)

(e) Buchholz relay (double float, reed type) with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm/trip contacts.

(f) Conservator air cell rupture detection relay

(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 & Oil temperature indicators (local & remote)

(k) Cover lifting eyes, transformer lifting lugs, jacking pads, 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) Rating and diagram plates (in English & Hindi or as specified by the utility) on transformers and auxiliary apparatus

(n) Roller Assembly (flanged bi-directional wheels)

(o) One complete set of all metal blanking plates & covers

(p) On load tap changing gear, OLTC/Off Circuit Tap Changer (OCTC) DM Box, individual marshalling box, Cooler control cabinet, and Digital RTCC Panel as applicable

(q) Cooling equipment including fans & pumps (as applicable)

(r) Bushing current transformers, Neutral CT (if applicable)

(s) Oil/water flow indicators (if applicable)
(t) Terminal marking plates

(u) Valves schedule plate

(v) Bottom oil sampling valve, Drain valves (provided to drain each section of pipe work independently), Filter valves at top and bottom with threaded male adaptors, Shut off valves on the pipe connection between radiator bank & the main tank, Shut off valves on both sides of Buchholz relay, Sampling gas collectors for Buchholz relay at accessible height, Valves for Radiators, Valve for vacuum application, Valves for cable box (if applicable), Valve for on line DGA (if applicable), valves for Drying out system (if applicable), Flow sensitive Conservator Isolation Valve (if applicable), Gate Valve (4 Nos. of min. 50 NB) for UHF sensors for PD Measurements (applicable for 400kV voltage class Transformer only), valves for firefighting system (as applicable) and other valves as specified in the specification.

(w) 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 .

(x) 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.

(y) Haulage/ lifting lugs

(z) Suitable terminal connectors on bushings

(aa) Suitable neutral bus connection
(bb) Suitable terminal connectors of surge arrester for NGR

(cc) Brass/tinned copper grounding bar supported from the tank by using porcelain insulator and flexible conductor for earthing of neutral, HV & LV terminals as per specification

(dd) Oil Sampling Bottle & Oil Syringe (if specified)

27.0 INSPECTION AND TESTING

The manufacturer shall draw up and carry out a comprehensive inspection and testing programme in the form of detailed quality plan duly approved by Purchaser for necessary implementation during manufacture of the equipment. Details regarding Quality Assurance Programme covering quality assurance, inspection and testing have been covered in **Chapter-4: Quality Assurance Programme.**

28.0 DRAWINGS/DOCUMENTS/CALCULATIONS

The list of drawing/documents/calculations to be submitted by the manufacturer is given in **Annexure-H.**

All utilities are advised to digitalize drawing approval process to speed up drawings & MQP submittals, comments, re-submittals and final approval.

29.0 RATING & DIAGRAM PLATE

The transformer shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the appropriate items indicated below. The entries on the plate shall be in English in indelibly marked.

Information to be provided on the plate:

For Transformer:

Manufacturer's name, country and city where the transformer was assembled					
MVA Rating, Voltage ratio, Type of transformer (for example 315MVA 400/220/33kV Auto Transformer)					
Type of Cooling			Applicable Standard		
Rated Power at different cooling			Rated frequency	Hz	
HV	MVA	--/-- /--	Number of phases		
LV (for single LV winding) / (LV1 & LV2) for two LV windings	MVA		% Impedance / Ohmic Impedance		

Rated Voltage			(a) HV-LV*		
HV	kV		Min. tap	%	
Tertiary winding Voltage (if applicable)	kV		Principal Tap	%	
LV(for single LV winding) / (LV1 & LV2) for two LV windings	kV		Max. Tap	%	
Rated Current			(b)		
HV	A		(c)		
LV (for single LV winding)	A		Vector Group		
(LV1 & LV2) for two LV windings	A		Core mass	Kg	
Rated Thermal Short Circuit withstand capability Current and Duration	kA (sec)		Copper Mass		
Basic Insulation Level (Lightening Impulse/Switching Impulse/Power Frequency Withstand Voltage)			(a) HV	Kg	
HV	kVp/ kVp/ kVrms		(b)		
Tertiary winding	kVp/ kVp/ kVrms		(c) LV*	Kg	
LV (for single LV winding) / (LV1 &	kVp/		(d) Regulating	Kg	

LV2) for two LV windings	kVp/ kVrms				
Neutral	kVp/ kVp/ kVrms		Core & Coil Mass	Kg	
Guaranteed Temperature rise over ambient temperature of 50 Deg. C			Transportation Mass	Kg	
(a) Top Oil	^{0}C		Tank & Fitting mass		
(b) Winding	^{0}C		Type & total mass of insulating oil	Kg	
Vacuum withstand Capability of the tank	mm of Hg		Total mass	Kg	
OLTC make and rating (current & Voltage class)			Quantity of oil in OLTC	Ltrs	
Noise level at rated voltage and at principal tap	dB		Transformer oil Quantity	Ltrs	
Tan delta of winding			Paint Shade		
Moisture content	ppm		No load loss at rated voltage & frequency	KW	
Manufacturer's Serial number			Load loss at rated current & frequency (at 75^{0}C) for HV & LV winding	KW	
Year of manufacture					

Work Order No.			Auxiliary loss at rated voltage & frequency	KW	
Purchaser's Order No. & Date					
OGA Drg. No.					
Vector Group Diagram					
Winding Connection diagram (Connection between all windings including tap windings, ratings of built-in current transformers, etc. shall be presented on the diagram)					
Table giving details of Tap Chnager like tap position Nos. and corresponding tapping voltage, tapping current & connection between terminals for different tap positions etc.					
Details of Current Transformers (e.g. Bushing CTs, CT for WTI) installed in transformer like the location, core Nos., ratio(s), accuracy class, rated output (VA burden), knee point voltage, magnetizing current, maximum CT secondary resistance, terminal marking and application of the current transformer					
Warning: "Main conservator is fitted with an air cell"					
Tie-in-resistor has been used in OLTC (if applicable)					
Purchaser's Name					

When a transformer is intended for installation at high altitude, the altitude, power rating and temperature rise at that altitude shall be indicated on the nameplate.

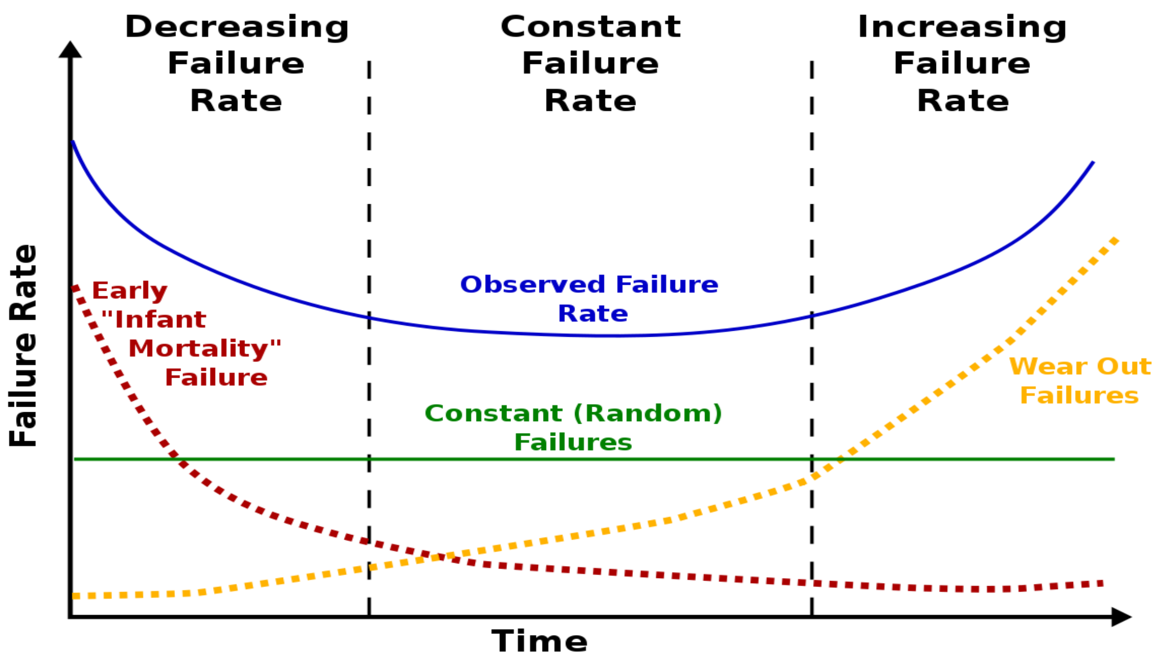
Plates with identification and characteristics of auxiliary equipment according to standards for such components (bushings, tap-changers, current transformers, cooling equipment etc.) shall be provided on the components themselves.

30.0 RESPONSIBILITIES OF MANUFACTURER AND UTILITY/ USER DURING WARRANTY PERIOD OF TRANSFORMER :

30.1 The long term performance of transformer depends on design/technology, quality of material used, robustness & consistency of manufacturing process, installation, operation and maintenance etc.

The erection, testing and commissioning of transformer shall be performed under strict supervision of representative of OEM and provisions specified in **Chapter 5– Transportation, erection, testing & commissioning** shall be followed.

30.2 Transformer failure generally follows the Bathtub Curve as shown below:



30.3 As can be seen from the Bath Tub curve, the "Infant mortality" failures, which are caused due to manufacturing related defects/issues that occur in the first few years of service (say 1 or 2 years). But continued successful operation of transformer primarily depends on operating conditions and O&M practices being followed by utilities. Improper maintenance or negligence on the part of user e.g. non-replenishment of saturated silica gel, non-release of air trapped after air-cell commissioning, oil seepages, lack of routine maintenance, failure to check tan-delta & capacitance of winding and bushing, absence of thermal scanning of terminal interfaces, lack of DGA monitoring etc., can also lead to serious consequences. It can therefore be said that the responsibility of manufacturer and maintenance & monitoring obligations of the end user are equally important for a long and trouble free service life of transformer. Moreover, any abnormality observed during operation needs to be addressed immediately. The transparency in sharing of information, mutual co-operation and discussion on issues/problems between user and manufacturer are the only way to resolve many of these problems. The manufacturer can take this as an opportunity to understand the issues and can improve on the design & manufacturing practices. Similarly, the utility has the opportunity to understand the deficiency from their side and should rectify/try to improve on their actions as a responsible user. There is no single conclusive test based on which utility should take drastic steps regarding replacement/rejection of component/equipment.

30.4 The utilities should create their maintenance plans so that they adhere to the recommended O&M procedures of the OEMs.

30.5 When failures or operational problems occur within the warranty period, the manufacturer must take all necessary measures to help minimize operational difficulties and outages whenever possible. The following abnormalities should be brought to the notice of manufacturer and the manufacturer shall respond/ attend immediately, investigate and rectify the problem or advise the utility for further course of action.

a) Fault inside the transformer and OLTC (including oil migration) involving a shutdown of transformer at site after commissioning is to be attended by manufacturer immediately. It is the responsibility of the OEM to take immediate necessary action (e.g. any replacement/repair of component required with co-ordination from any third party, if required) for bringing back the transformer into service. The root cause analysis shall be undertaken by OEM and details shall be shared with utility for the benefit of both user and OEM.

b) In case of DGA Status 3 (as per IEEE-C57.104) i.e. the concentration of any fault gas is exceeding the values in Table -2 of IEEE-C57.104 (Refer Chapter 6 of the document) or the abnormal trend in variation of key fault gases is observed, the utility should immediately consult OEM for advice and for further course of action.

The transformer with DGA Status-3 does not necessarily give any conclusive information regarding health of transformer or indicate that transformer is faulty. It can only be concluded that its behaviour is somewhat unusual and warrants additional investigation and/or precautions. The transformer should be placed under increased surveillance. Other diagnostic tests should also be conducted to supplement the DGA for taking further course of action in consultation with manufacturer.

c) In case, the winding tan delta goes beyond 0.005 or increases more than 0.001 per annum w.r.t. pre-commissioning values, the utility is to inform manufacturer for advice and for further course of action.

d) In case, the tan delta of bushing(s) goes beyond 0.005 or increases more than 0.001 per annum w.r.t. pre-commissioning values when measured in the temperature range of 10°C to 40°C (If tan delta is measured at a temperature beyond above mentioned limit, necessary correction factor as per IEEE shall be applicable.), the utility is to inform manufacturer for advice and for further course of action.

e) In case, the moisture content goes above 10 ppm at any temperature during operation including full load, the utility is to inform manufacturer for advice and for further course of action.

f) Any major deviation in Sweep Frequency Response Analysis (SFRA) should be brought to the notice of manufacturer for advice and for further course of action.

g) Leakage of Oil from transformer shall be construed as a serious quality lapse on the part of the Original Equipment Manufacturer (OEM). No leakage of oil is expected during the operating life of the transformer and that should be ensured accordingly by OEM during design & construction of tank & other gasketted joints. In case of any leakage of oil during warranty period, the same shall be reported in writing to the OEM immediately and OEM shall have to attend and rectify the leakage within a period of 30 days from the date of notice, at the cost of the OEM.

h) The utility shall carryout all diagnostic tests just before completion of warranty period to ensure the healthiness of transformer and any abnormality in test results shall be informed to the manufacturer for immediate action and advice.

31.0 PHYSICAL INTERCHANGEABILITY OF TRANSFORMER OF DIFFERENT MAKE

Block foundation shall be adopted to facilitate the physical inter-changeability of transformers of different make on same foundation thereby the outage time of replacement of spare/new transformer would be minimized. The design shall take into account the provision of soak pit and oil collecting pit for transformer. The details are given at **Annexure-N.**

32.0 LIST OF CODES/ STANDARDS/ REGULATIONS/ PUBLICATIONS

The list of Codes/Standards/Regulations/Publications which are generally used for manufacturing, testing, installation, maintenance, operation etc. of transformer is given at **Annexure-P.**

CHAPTER-2

DESIGN REVIEW

1.0 Introduction

Design Review is a planned exercise to ensure both parties to the contract- manufacturer and purchaser- understand the application, purchaser specifications, applicable standards and Guaranteed Technical Particulars (GTP) furnished by vendor. It is a scrutiny of design (specific aspects of the electrical, mechanical and thermal design), materials & accessories and manufacturing processes so as to ensure that offered guaranteed technical particulars, are thoroughly met to ensure quality and reliability. The exercise broadly facilitates and emphasize the following:

- Manufacturer understands the application, project requirement, the purchaser's technical requirement, and specifications to ensure that the design meets / complies those requirements.

- Purchaser understands that manufacturer uses proven materials, design tools, methodology and experience to assure that the product will meet purchaser's requirement in all respect.

- Identify any new (prototype) features introduced by manufacturer and evaluate their reliability and risks.

- To understand relevant design margins (calculated design withstand strength versus stress during tests and long service) to meet test requirements and life time performance as per manufacturer's design practice and experience.

- A good opportunity for a clear & mutual understanding and to exchange experiences that can be used to improve the current design and future specifications.

- Allow the purchaser to have clear understanding of the design, technical capabilities, experience of manufacturer and the manufacturing & testing facilities of manufacturer.

- Clarifications of various tests and mutual agreement on method of tests and special acceptance of tolerance (e.g. Wave shape of impulse wave, connection for switching surge test etc.).

- Mutual agreement between the purchaser & the manufacturer for the confidentiality of information, which are proprietary in nature.

- Transportability to site. Any constraint and stringent limitation is to be highlighted, if any.

- Service conditions. If any abnormal service condition exists customer has to point out.

2.0 Stages of Design Review (DR)

Design Review (DR) may be required at following stages depending on the nature of contract:

(A) Pre-Tender Design Review

- Technical capability and manufacturing experience of vendor

- Factory capability assessment by buyer as required (CIGRE TB 530: Guide for conducting Factory Capability Assessment for Power Transformers can be a good reference)

(B) Tender Stage Design Review –Technical Evaluation of offer

- The bidder has to comply with the parameters provided in the specification/document. Deviation, if any, shall be clearly brought for the information of the purchaser. The purchaser shall scrutinize the deviations in line with the technical & commercial requirement and shall evaluate the bid accordingly.

(C) Contract Design Review

The design review shall be carried out for the offered design of transformer under the scope and Manufacturer shall submit all design documents and drawings required for the purpose.

- Purchaser in consultation with the manufacturer shall carry out Design Review (DR) of parts and accessories (make, model, specifications for bushing, tap-changer, instruments etc.) as per technical requirements and specifications for enabling the manufacturer to order key raw materials and major accessories.

- Review of the electrical design including dielectric, losses, short circuit, noise and thermal performance and mechanical layout design including lead routing and bushing termination after route survey (if any) shall be carried out for enabling the manufacturer to order key raw materials and major accessories.

- Typical data/parameters indicated in the **Annexure-C** shall be filled by the manufacturer and reviewed by the purchaser during design review.

- Examination of all relevant type test reports of transformers including its fitting and accessories.

- Checking of drawings and documents for the scope listed in **Annexure-I.**

3.0 Mode of Design review

- Design review is initiated by purchaser or appointed representative. Purchaser should ensure that those participating representative in the review on his behalf have the necessary expertise to understand and evaluate the design and production considerations under the proposal.

- Minutes of design review will be part of contract documents, but the discussions and information exchanged during design review process shall be kept confidential and purchaser or appointed representative shall not disclose or share design review details to anyone without written consent of Original Equipment Manufacturer (OEM).

- After completion of design review, a summary report indicating list of items with actions required to be taken is to be sent to manufacturer for correction and inclusion of any omissions.

- Purchaser may also visit the manufacturer's works to inspect design, manufacturing and test facilities at any time.

- Manufacturer, if desired by purchaser, should give in advance sufficient design data to purchaser to prepare for the design review meetings.

- **"Guidelines for conducting design reviews for transformers" CIGRE Technical Brochure 529-2013 may be followed. The document/brochure broadly covers the following:**

  ❖ The manufacturer should demonstrate how their design will function reliably within the operating requirements including transient conditions and meet the performance guarantees and present evidence of calculations/analysis performed in order to ensure that the specified requirements will be met.

- ❖ The manufacturer should describe the core design, explaining how it will perform within the operating parameters. Core flux density at rated and maximum voltage and frequency shall be reviewed with special reference to the maximum permissible limit to avoid overfluxing in any part of the core assembly including magnetic shunts and safety margins for the particular core construction type employed.

- ❖ The manufacturer should describe each of the windings in sufficient detail to provide a clear understanding of the physical arrangements.

- ❖ The manufacturer should demonstrate how the insulation is designed to withstand the imposed stresses, i.e. indicate insulation structure, corresponding stress and resultant dielectric strength, including safety factors (margins).

- ❖ The manufacturer will provide a list of the make and type of insulating materials used for the windings, leads and supports.

- ❖ The manufacturer should describe how the windings will be adequately cooled.

- ❖ The manufacturer should present a description of the thermal model of the windings and a summary of the calculated temperatures for the various specified ratings/loading, including any overload and cooling conditions. The calculation of hot spot temperatures of the tank, core etc. to be discussed and demonstrate their experience by using 2D or 3D electro-thermal calculation using Finite-Element Method (FEM) etc.

- ❖ The manufacturer should demonstrate the ability to withstand the electromagnetic forces and the thermal stresses produced during the flow of a short-circuit current without damage.

- ❖ The manufacturer should describe the general assembly and mechanical features for the core mechanical construction, coil clamping including the clamping pressure used for sizing and providing short circuit withstand capability and maintenance of winding compression during coil drying, core drying and assembly.

- ❖ The manufacturer will describe their methods for moisture removal from the insulation ensuring the design dimensions of the coils are achieved and moisture content is <0.5%.

- ❖ The manufacturer should describe the arrangements used for the winding leads and interconnections.

- ❖ The manufacturer should describe how they achieve the control of the leakage flux outside core and coils assembly, including Type of shielding (collectors, rejectors), design and materials used.

- ❖ The manufacturer and customer should have a mutual and clear understanding for the requirements for the sound level. Accurate calculation of core & tank resonance frequencies allows accurate prediction of the noise level at the design stage and later avoids serious noise level problems later.

- ❖ The manufacturer should provide general construction including tank details, details of gaskets, location of manholes & PRD, external cooling system, conservator/preservation system, provision for fire protection system etc.

- ❖ The intended shipping process should also be reviewed.

4.0 Calculation of Losses, weight of core and current density of winding conductor

For the benefit of the utility the formula for calculation of No-Load loss and Load loss, weight of core and current density of winding conductor has been provided below. In addition, a typical example of calculation of flux density, core quantity/ weight, no-load loss and weight of copper has been provided in **Annexure-F**.

Calculation of no-load losses:

- No-Load losses = core loss in W/kg corresponding to flux density as per lamination mill test report (extrapolated) x net weight of core x building factor

- Flux density (T) = rated voltage (v) x10^4/ (4.44 x no. of turns x net core area (cm^2) x frequency (Hz))

- Net core area = [{0.785x (nominal core diameter)^2 x filling factor}- area of cooling duct, insulation] x space factor

- Building factor = extra loss factor over the test report value due to handling and fabrication stress (>1)

- Space factor = Reduction factor (depends on thickness) to take care of the insulation provided over the laminations (<1)

- Filling factor = per unit area occupied by core material in the nominal core circle area (<1)

- Nominal diameter of core = diameter of circle touching the corners of lamination steps

Calculation of load-losses at reference temperature & principal tap position:

- Load loss at principal tap = I^2R loss + Winding Eddy loss + Structural stray losses

- I^2R loss = Resistance at 75°C x (phase current)^2 x no. of phases

- Resistance (R)= Resistance of winding (R_W) + Resistance of leads (R_L)

  $R_W = W \times D \times \pi / (k \times S)$
  $R_L = L / (k \times S)$

  Where,

  W= Number of turns
  D= mean winding diameter
  S= cross section area of all parallel conductor
  K= Electrical conductivity of conductor/leads for reference temperature of 75°C.
  L= Length of lead

Winding eddy losses = Estimated from empirical formulae or electromagnetic software

Structural stray losses = Estimated from empirical formulae or electromagnetic software.

Calculation of weight of core:

Weight of core = (Total periphery of core) x (net core area) x (density of CRGO material)

Calculation of current density of winding conductor:

Current density = A/S
Where A= Current in winding for specified tap position
S= (Cross-sectional area of the individual conductor) x (no. of parallel conductor)

[The individual conductor area needs to be adjusted for corner radius as per IS 13730 (part 27)]

5.0 References:

(a) CIGRE Technical Brochure No. 529 -2013 Guide lines for conducting design reviews for Power Transformers
(b) CIGRE Technical Brochure No. 673-2016 Guide on Transformer Transportation
(c) IEEE Standard C57.156-2016 Guide for tank rupture mitigation of oil immersed transformers
(d) CIGRE Technical Brochure No. 530-2013 Guide for conducting factory capability assessment for Power Transformers
(e) IEEE Standard C57.150-2012 Guide for Transformer Transportation
(f) IS 2026 Power Transformers-Part 5 Ability to withstand short circuit

CHAPTER- 3

QUALITY ASSURANCE PROGRAMME

1.0 INTRODUCTION

The best way to achieve continuous improvement in quality in any manufacturing organization is to develop a quality plan and the persons responsible for quality implementation should religiously follow the defined quality plan.

Quality of a transformer/reactor can be improved by taking effective steps at the initial stage itself which include 'use of high quality raw materials' and 'improved manufacturing processes'. It is needless to mention that the performance of a transformer/reactor largely depends on the excellence of design. However, all good designs may not yield good end products unless they are well supported by good materials, good and healthy machines and skilled workmen (operators)/ workmanship.

To ensure that the equipment and services are in accordance with the specifications, the transformer/reactor manufacturer shall adopt suitable Quality Assurance Programme (QAP) to control such activities at all points, as necessary. Such programmes shall be outlined by the manufacturer and shall be finally accepted by the Purchaser or its authorised representative after discussions. The Quality Assurance programme shall be generally in line with latest ISO-9001 (Quality Management System), ISO-14001 (Environmental Management System) and OHSAS 18001 (Occupational Health and Safety Management System). A Quality Assurance Programme of the manufacturer shall generally cover the following:

a) Organisation structure for the management and implementation of the proposed Quality Assurance Programme
b) Quality System Manual
c) Design Control System
d) Documentation Control System
e) Qualification and experience data for key Personnel
f) The procedure for purchase of materials, parts, components and selection of sub-supplier's services including vendor analysis, source inspection, incoming raw material inspection, verification of materials purchased etc.
g) List of manufacturing facilities available
h) Level of automation achieved and list of areas where manual processing exists

i) List of areas in manufacturing process, where stage inspections are normally carried out for quality control and details of such tests and inspections.
j) System for shop manufacturing and site erection control including process controls and fabrication and assembly controls
k) System for Control of non-conforming items and for corrective & preventive actions based on customers' feedback.
l) Inspection and test procedure both for manufacture and field activities
m) System for Control of calibration of testing and measuring equipment and the indications of calibration status on the instrument
n) System for Quality Audits
o) System for indication and appraisal of inspection status
p) System for authorising release of manufactured product to the Purchaser
q) System for handling storage and delivery
r) System for maintenance of records
s) Furnishing of quality plans for manufacturing and field activities detailing out the specific quality control procedure adopted for controlling the quality characteristics relevant to each item of equipment/component
t) System of various field activities i.e. unloading, receipt at site, proper storage, erection, testing & commissioning

The manufacturer shall use state-of-the-art technology and dirt, dust and humidity controlled environment during various processes of manufacturing and testing to ensure that end product is of good quality and will provide uninterrupted service for intended life period. All manufacturers, are expected to develop their manufacturing facility at par with the leading manufacturers with best global practices. **An indicative list for facilities needed to be available at manufacturer's works has been provided at *Annexure-G*. In case the manufacturers do not have the required facilities as given in *Annexure-G*, it may be ensured by the manufacturers that the same shall be made available and put into use within two years of release of this document.**

2.0 GENERAL REQUIREMENTS - QUALITY ASSURANCE

2.1 All materials, components and equipment required for transformer/reactor manufacturing shall be procured, manufactured, erected, commissioned and tested at all stages, as per a comprehensive Quality Assurance Programme, the detailed Quality Plans for manufacturing and field activities shall be drawn up by the manufacturer/ contractor (as applicable) and will be submitted to Purchaser for approval.

2.2 Manufacturing Quality Plan will detail out for all the components and equipment, various tests/inspection, to be carried out as per the requirements of purchaser specification and standards mentioned therein and quality practices and procedures followed by Manufacturer's/Sub-supplier's/Sub-supplier's Quality Control Organisation, the relevant reference documents and standards, acceptance norms, inspection documents raised etc., during all stages of materials procurement, manufacture, assembly and final testing/performance testing. The Quality Plan shall be submitted to purchaser, for review and approval. **Typical Manufacturing Quality Plan (MQP) is provided at Annexure-E** for reference. Any change in practice or acceptance norms (with reference to various tests / parameters in respective National / International standard) would be suitably incorporated by manufacturer from time to time and submit the same for approval of purchaser / utility.

2.3 List of testing equipment available with the manufacturer for stage/final testing of transformer/reactor and test plant limitation, if any, for the acceptance and routine tests specified in the relevant standards shall be furnished by the manufacturer. These limitations shall be very clearly brought out in 'The schedule of deviations' for specified test requirements.

2.4 The transformer/reactor manufacturer, along with Quality Plans, shall also furnish copies of the reference documents/plant standards/acceptance norms/tests and inspection procedure etc., as referred in Quality Plans. These Quality Plans and reference documents/standards etc. will be subject to Purchaser's approval without which manufacturer shall not proceed. These approved documents shall form a part of the contract. In these approved Quality Plans, Purchaser shall identify Customer Hold Points (CHP), i.e. test/checks which shall be carried out in presence of the Purchaser's authorised representative and the work will not proceed without consent of Purchaser in writing. All deviations to approved quality plans and applicable standards must be documented and referred to Purchaser along with technical justification for approval and dispositioning.

2.5 All material used for equipment manufacture shall be of tested quality as per relevant codes/standards. Details of results of the tests conducted to determine the mechanical properties; chemical analysis and details of heat treatment procedure, if any and actually followed shall be recorded on certificates and time temperature chart, as applicable. Tests shall be carried out as per applicable material standards and/or agreed details.

2.6 No material shall be despatched from the manufacturer's works before the same is accepted, subsequent to pre-despatch final inspection including verification of records of all previous tests/inspections by Purchaser's authorised representative and duly authorised for despatch.

2.7 The manufacturer shall list out all major items/equipment/components to be manufactured in house as well as procured from sub-supplier. All the sub-suppliers proposed by the manufacturer for procurement of major bought out items including castings, forging, semi-finished and finished components/equipment etc., list of which shall be drawn up by the manufacturer and finalized with the Purchaser and shall be subject to Purchaser's approval. The manufacturer's proposal shall include vendor's facilities established at the respective works, the process capability, process stabilization, quality systems followed, experience list, etc. along with his own technical evaluation for identified sub-suppliers enclosed and shall be submitted to the Purchaser for approval in sufficient time so as not to impede the progress of work on the facilities.

2.8 For components/equipment procured by the manufacturer for the purpose of the contract, after obtaining the written approval of the Purchaser, the manufacturer's purchase specifications and inquiries shall call for quality plans to be submitted by the suppliers. The quality plans called for from the sub-suppliers shall set out, during the various stages of manufacture and installation, the quality practices and procedures followed by the vendor's quality control organisation, the relevant reference documents/standards used, acceptance level, inspection of documentation raised, etc. Such quality plans of the successful vendors shall be finalised with the Purchaser and such approved Quality Plans shall form a part of the purchase order/contract between the manufacturer and sub-suppliers.

2.9 Purchaser reserves the right to carry out quality audit and quality surveillance of the systems and procedures of the manufacturer's or their sub-supplier's quality management and control activities. The manufacturer shall provide all necessary assistance to enable the Purchaser carry out such audit and surveillance.

2.10 The manufacturer shall carry out an inspection and testing programme during manufacturing in his work and that of his sub-supplier and at site to ensure the mechanical accuracy of components, compliance with drawings, conformance to functional and performance requirements, identity and acceptability of all materials parts and equipment. Manufacturer shall carry out all tests/inspection required to establish that the items/equipment conform to requirements of the specification and the relevant codes/standards specified in the specification, in addition to carrying out tests as per the approved quality plan.

2.11 Quality audit/surveillance/approval of the results of the tests and inspection will not, however, prejudice the right of the Purchaser to reject the equipment if it does not comply with the specification, when erected or does not give complete satisfaction in service and the above shall in no way limit the liabilities and responsibilities of the manufacturer in ensuring complete conformance of the materials/equipment supplied to relevant specification, standard, data sheets, drawings (approved by the Purchaser), and minutes of various meetings with customer / Purchaser etc.

2.12 Any repair/rectification procedures to be adopted to make the job acceptable shall be subject to the approval of the Purchaser/authorised representative.

2.13 The Manufacturer / Sub-suppliers shall carry out routine test on 100% item at manufacturer / sub-supplier's works. The quantum of check / test for routine & acceptance test by purchaser shall be generally as per criteria / sampling plan defined in referred standards. Wherever standards have not been mentioned quantum of check / test for routine / acceptance test shall be as agreed during detailed engineering stage.

2.14 The manufacturer/ contractor (as applicable) shall submit to the Purchaser Field Welding Schedule for field welding activities (if applicable) along with all supporting documents, like welding procedures, heat treatment procedures, Non-Destructive Test (NDT) procedures etc. before schedule start of erection work at site.

2.15 **Transformer/reactor manufacturer shall also provide Field Quality Plans** that will detail out for all the equipment, the quality practices and procedures etc. to be followed by the manufacturer's representative or authorised agency, during various stages of site activities starting from receipt of materials/equipment at site till commissioning.

2.16 All welding and brazing shall be carried out as per procedure drawn and qualified in accordance with requirements of ASME Section IX/BS-4870 or other International equivalent standard acceptable to the Purchaser. All welding / brazing procedures adopted/used at shop, will be made available to purchaser during audit / inspection. Procedures to be adopted at site will be submitted to purchaser for approval.

2.17 **All brazers, welders and welding operators employed on any part of the contract either in Manufacturer's/his sub-supplier's works or at site or elsewhere shall be qualified as per ASME Section-IX or BS-4871 or other equivalent International Standards acceptable to the Purchaser.**

2.18 Any of the offered software, if applicable shall not of β-version and be also free from all known bugs and should be with cyber security certificate.

3.0 QUALITY ASSURANCE DOCUMENTS

3.1 The manufacturer shall be required to submit the QA Documentation in hard copies and DVD ROMs/Pen Drive containing soft copy, as identified in respective quality plan.

3.2 Each QA Documentation shall have a project specific Cover Sheet bearing name & identification number of equipment and including an index of its contents with page control on each document. The QA Documentation file shall be progressively completed by the manufacturer's sub-supplier to allow regular reviews by all parties during the manufacturing.

3.3 Typical contents of QA Documentation is as below:-

a) Quality Plan for various components and accessories. A typical quality plan for key components of transformer is provided at **Annexure-E**.
b) Material mill test reports on components as specified by the specification and approved Quality Plans.
c) Manufacturer's works test reports/results for testing required as per applicable codes and standard referred in the specification and approved Quality Plans.
d) Non-destructive examination results/reports including radiography interpretation reports. Sketches/drawings used for indicating the method of traceability of the radiographs to the location on the equipment.
e) Heat Treatment Certificate/Record (Time- temperature Chart), if any.
f) All the accepted Non-conformance Reports (Major/Minor)/deviation, including complete technical details /repair procedure).
g) Customer Hold Points (CHP)/Inspection reports duly signed by the Inspector of the Purchaser and Manufacturer for the agreed Customer Hold Points.
h) Certificate of Conformance (COC) wherever applicable.
i) Material Dispatch Clearance Certificate (MDCC)

3.4 Similarly, the manufacturer/contractor (as applicable) shall be required to submit hard copies and DVD/ Pen Drive containing soft copy, containing QA Documentation pertaining to field activities as per Approved Field Quality Plans and other agreed manuals/ procedures, prior to commissioning.

3.5 Before offering for Factory Acceptance Test of any equipment, the Supplier shall make sure that the corresponding quality document or in the case of protracted phased deliveries, the applicable section of the quality document file is completed. The supplier will then notify the Inspector regarding the readiness of the quality document (or applicable section) for review:

a) If the result of the review carried out by the Inspector is satisfactory, the Inspector shall stamp the quality document (or applicable section) for release.
b) If the quality document is unsatisfactory, the Supplier shall endeavour to correct the incompleteness, thus allowing to finalize the quality document (or applicable section) by time compatible with the requirements as per contract documents. When it is done, the quality document (or applicable section) is stamped by the Inspector.

Note:- *The word 'Inspector' shall mean the authorised representative and/or an outside inspection agency acting on behalf of the purchaser to inspect and examine the materials and workmanship of the works during its manufacture or erection.*

4.0 QUALITY DURING INSPECTION & TESTING (including virtual inspection) AND INSPECTION CERTIFICATES

4.1 Inspection, audit, assessment, test measurement and comparison all describe the same phenomena of examining carefully to some established criteria. Inspector should be prepared with the following documents:

a) Contract documents together with technical specifications
b) Basic guideline regarding the scope of inspection
c) Approved drawings and reference standards (ISS/IEC/BS etc.)
d) Previous inspection reports of transformers of similar rating (if available)
e) Type test certificates (if already conducted).

4.2 The Inspector shall have access at all reasonable times to inspect and examine the materials and workmanship of the works during its manufacture or erection and if part of the works is being manufactured or assembled on other premises or works, the Manufacturer shall obtain for the Inspector permission to inspect as if the works were manufactured or assembled on the Manufacturer's own premises or works.

4.3 The Manufacturer shall give the Inspector ten (10) days written notice of any material being ready for testing. Such tests shall be to the Manufacturer's account. The Inspector, unless the witnessing of the tests is virtually waived and confirmed in writing, will attend such tests within ten (10) days of the date on which the equipment is noticed as being ready for test/inspection.

4.4 **Virtual Stage inspection & Factory Acceptance Test (FAT)**

The conventional practice of witnessing Stage inspection and Factory Acceptance Test (FAT) of transformers and reactors as per technical specification of the utility/purchaser requires physical presence of utility's/purchaser's representative/inspector at manufacturer's works and involves considerable co-ordination efforts and planning by both utility/purchaser and manufacturers, especially in special situations like Covid-19 pandemic. The self-certification/waiver of FAT is not desirable. Under the situation like Covid-19 or if there is mutual agreement between the manufacturer & the utility/purchaser, manufacturer can offer virtual stage inspection or FAT or both, with similar experience/confidence as on-site witness, as an alternative to conventional method.

4.4.1 The resources required for virtual inspection/testing:

The following resources should form part of virtual inspection/testing:

(a) High speed Wi-Fi Internet

(b) Necessary electronic devices like Mobiles, Tabs or iPads, portable cameras, computers for test equipment or instruments, Conference call setup with laptop, cameras in test lab and test bay for clear view of the test bay as well as transformer/reactor under test, connection leads and measuring equipment etc. For better clarity and transparency, wherever possible, screens of computers for test equipment or instruments should be paralleled for direct view of the customer. Example – Loss Measurement system, PD test System, HV Test System etc.

(Note: Issues of screen blinking may be observed during chopped wave lightning impulse due to earthing issues and should be ignored)

(c) Qualified engineers well-conversant with technology shall be deployed to effectively handle online stage inspection/FAT.

(d) Online applications like Microsoft Teams, Skype, Google meet, Google hangout, WhatsApp, etc.

(e) Measuring Instruments with valid calibration certificates

(f) Recording facility of all the activities performed during stage inspection/FAT as well as photography of recording of important readings should form part of the Stage/Final inspection reports of the product.

(g) The manufacturer shall nominate a nodal officer, who shall be responsible for coordinating with the utility/purchaser and camera operators for visual arrangement/facilities spread across different locations within the manufacturer's works.

(h) Different sections like Core - coil assembly area, winding area, tank inspection area etc. shall be provided with adequate no. of cameras or portable cameras can be used for clear and proper visualisation of the test object.

(i) During stage inspection/FAT, the position of cameras (with zoom in/out facility) shall be done in such a way that the test object, measuring instruments and test equipment are clearly visible.

4.4.2 Procedure for virtual inspection / testing:

(a) Manufacturer's QA/QC in-charge will plan, verify the process checklist and ensure that the Stage inspection/Routine/FAT are conducted as per approved quality plan in line with the Technical Specification.

(b) Manufacturer will submit soft copies of Photographs and Calibration Certificates with proper index sheet duly certified from their end in order to demonstrate readiness of Transformer/Reactor for inspection/testing.

(c) The Date and time and arrangement for online stage inspection/FAT shall be finalised in consultation with the utility/purchaser.

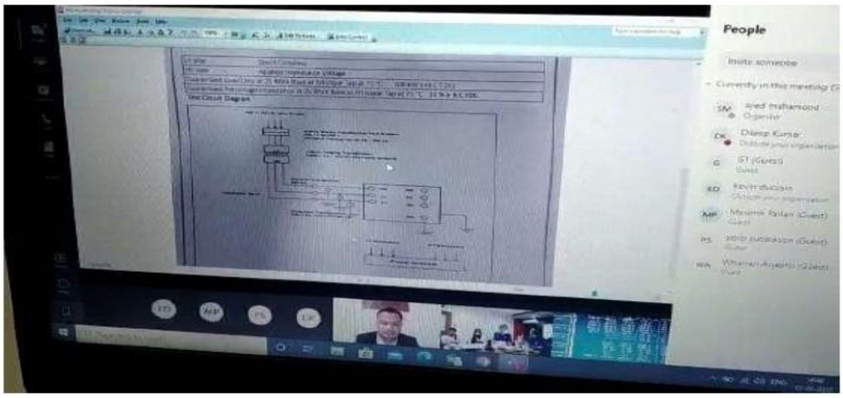
(d) Online inspection/FAT shall be done through online application platform like – Microsoft Teams, Skype, Google meet, Google hangout, WhatsApp, etc., considering the system compatibility and security in consultation with the utility/purchaser. Online recording facility of the activities performed or witnessed must be available at manufacturer's end at all time for customer's reference/review/record.

(e) Utility's/purchaser's approval shall be taken in advance for the virtual stage inspection/FAT including the specific online application platform that will be used.

(f) Whenever required the Mock trial may be carried out at manufacturer's work to get hands on experience before offering to customer.

(g) All issues must be discussed and resolved before commencement of inspection/tests.

(h) The Test circuits and Test procedure shall be shared with utility's/purchaser's inspector for clarity & better understanding.



(i) Application link and security password shall be shared with the utility's/purchaser's inspecting officer on the same day of inspection and password must be secured to maintain the confidentiality.

(j) While conducting remote FAT, due care must be taken to keep the data safe while transmitting from factory to utility's/ purchaser's inspector through a web-based application. There are various Cybersecurity requirements and InfoSec protocols, which should be adhered to for safety like Database Security, Strong Password Policy, Access Control, Restricted Access via 2-Factor Authentication for utility/purchaser, Single Session or Timed Sessions, Resetting Passwords, Password Expiry Policy, Validations for 3rd Party participants, Authentication for users/test engineers etc.

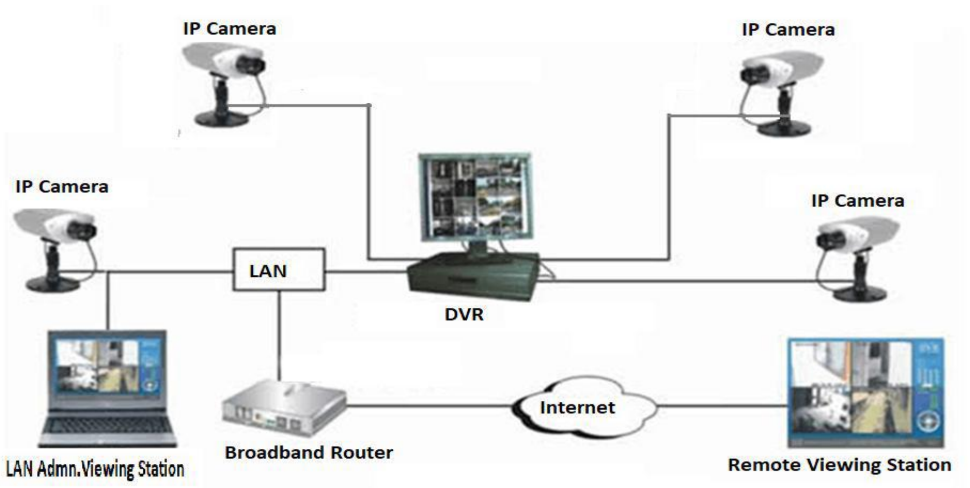
(k) All tests shall be conducted as per relevant latest standards/procedures mentioned in the Technical Specification. The readings recorded in each test will be shown to remote-end inspector live for witness/acceptance. At the end of each test, either side shall discuss the summary of test results to avoid ambiguity at later stage. During Temperature Rise test, the HOT resistance has to be measured at the time of shutdown of power supply to Transformer. The camera position shall be suitably placed, so that the readings are visible without any obstruction by the working personnel. As far as possible, resistance measurement should be done inside the Control Room to avoid any obstructions or interfere of personnel.

(l) During testing, one camera shall always be focused towards test bay area where the transformer / reactor is under test for online overview of connections. If one camera is not enough to see both transformer and test leads, more no. of cameras shall be deployed. This will enable complete testing connection overview to inspecting officer all the time.

(m) The camera must be operated by the authorised person of the manufacturer as per the direction of the inspection team [representatives of utility/purchaser]. The inspection team should have the facility to communicate directly with the manufacturer's representative for a thorough & effective inspection including the physical verification of the dimension, surface defect etc.

(n) The image quality shall be good enough for assessment of the condition of the transformer which may affect the quality & performance of transformer. The factors affecting image quality include:
- Poor image resolution.
- Image out of focus.
- Inadequate lighting /Glare from strong light source/shadows
- Frequent loss of connectivity between the Inspection team and the onsite Video monitors.

(o) The Two-way Audio-Video communication Scheme for stage inspection/FAT of transformer/reactor through web shall be as follows:



(p) The camera should be focused for continuous visibility of the test values in the meters so that the utility's/purchaser's inspector can see the test values throughout the Inspection.

(q) During the stage Inspection/FAT, test results/readings & test connections shall be recorded and mailed to the utility's/ purchaser's inspector.

(r) The manufacturer has to prepare test report on daily basis during testing period by the end of each day. Test Reports must be issued by the testing in charge of manufacturer indicating list of Tests carried out and the test results.

(s) For long duration tests (Temperature rise and partial discharge and impulse), manufacturer shall ensure that Cameras shall be provided near transformer/reactor under test and the Power analyser or equipment's computer so that the readings can be seen simultaneously.

(t) After completion of inspection, OEMs representative should sign off from the application.

(u) After getting stage inspection Clearance from utility/purchaser, the transformer/reactor may be moved to next stage of manufacturing process and after getting FAT Clearance from utility/purchaser, the transformer/reactor may be moved for processing of dispatch to site.

(v) All video recording of the inspection shall be done and it shall be shared with the utility / purchaser and also to be maintained by manufacturer/OEM for future reference.

(w) The MoM of the stage inspection/FAT shall be prepared by the manufacturer/OEM and all points discussed & agreed including rectification/punch points, completion date etc. shall be communicated to the utility/purchaser.

(x) Final Stage inspection report/FAT reports, supporting documents and photographs should be submitted to utility / purchaser for their future reference and record.

The online virtual inspection & testing process at manufacturer's/OEM's premises will benefit both manufacturer and the utility/purchaser in terms of time, money & manpower/human resources and would be easier and faster.

4.5 The Inspector shall within ten (10) days from the date of inspection as defined herein give notice in writing to the Manufacturer, or any objection to any drawings and all or any equipment and workmanship which is in his opinion not in accordance with the contract. The manufacturer shall give due consideration to such objections and shall either make modifications that may be necessary to meet the said objections or shall inform in writing to the Inspector giving reasons therein, that no modifications are necessary to comply with the contract.

4.6 When the factory tests have been completed successfully at the manufacturer's or sub-supplier's works, the Inspector shall issue a certificate to this effect within ten (10) days after completion of tests but if the tests are not witnessed by the Inspector, the certificate shall be issued within ten (10) days of the receipt of the Manufacturer's test certificate by the Inspector.

4.7 In all cases where the contract provides for tests whether at the premises or works of the Manufacturer or any sub-suppliers, the Manufacturer, except where otherwise specified shall provide free of charge such items as labour, material, electricity, fuel, water, stores, apparatus and instruments as may be reasonably demanded by the Inspector to carry out effectively such tests on the equipment in accordance with the Manufacturer and shall give facilities to the Inspector to accomplish testing.

4.8 The inspection by the Inspector and issue of Inspection Certificate thereon shall in no way limit the liabilities and responsibilities of the manufacturer in respect of the agreed Quality Assurance Programme forming a part of the contract.

4.9 All inspection, measuring and test equipment used by manufacturer shall be calibrated periodically depending on its use and criticality of the test/measurement to be done. The manufacturer shall maintain all the relevant records of periodic calibration and instrument identification, and shall produce the same for inspection by purchaser. In case repair is carried out in the measuring and test equipment it should be compulsorily re-calibrated. All calibrated measuring and test equipment must be properly sealed after calibration to stop any kind of manipulation with the equipment. Wherever mutually agreed between manufacturer & Purchaser, the manufacturer shall re-calibrate the measuring/test equipment in the presence of the Inspector.

4.10 Preparation of inspection report is the concluding part of inspection. Every inspection agency has its own style of preparation of inspection report. However, since it is a quality document, we must ensure that all relevant information and enclosures are made available along with the report. The inspection report has mainly three parts:

a) The first part contains details of equipment, contract detail, quantity offered, sampling, observation noted during inspection, remark on test results etc.
b) The second part contains reports on physical verification.
c) The third part of the report contains the routine test results of the inspected transformers, temperature rise test results, if carried-out, and few demonstrative sample calculations e.g. Load Loss calculation at normal and extreme taps, Temperature rise calculation, Noise level calculation etc.

5.0 INSPECTION AND TESTING

The inspection envisaged by the purchaser is given below. However, the manufacturer shall draw up and carry out a comprehensive inspection and testing programme in the form of detailed quality plan duly approved by Purchaser for necessary implementation during manufacture of the equipment. All accessories and components of transformer shall be purchased from source, approved by the 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 the purchaser.

5.1 Factory Tests

5.1.1 The manufacturer shall carry out all type & routine tests specified in “**Annexure-D** and **Annexure-E”.** All tests shall be done in line with latest IS: 2026/IEC 60076 or as per procedure specified in this document**.** Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the manufacturer.

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

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

5.1.4 In case, any failure observed during factory testing involving winding/ winding shield/ static shield ring, then affected winding of all phases shall be replaced by new one mutually agreed between manufacturer & Purchaser.

5.1.5 Tank Tests

(A) Oil Leakage Test

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

(B) Vacuum Test

All transformer/reactor tanks shall be subjected to the specified vacuum. The tank designed for full vacuum (760 mm of mercury at sea level) 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)
Up to 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

(C) Pressure Test

All transformer/reactor tanks, its radiator, conservator and other fittings together or separately shall be subjected to a **pressure corresponding to twice the normal head of oil or normal oil head pressure plus 35 KN/ sq.m whichever is lower, measured at the base of the tank and maintained for eight hours**. The permanent deflection of flat plates after the excess pressure has been released shall not exceed the figure specified above for vacuum test.

5.2 Stage Inspection

5.2.1 **Stage inspection** will be carried out by the Inspector **on Core, Winding, core-coil assembly & Tank during the manufacturing stages** of the transformer/reactor. The manufacturer will have to call for the stage inspection and shall arrange the inspection at manufacturer's premises or manufacturer's sub-supplier's premises, as applicable, free of cost.

5.2.2 **Stage inspection will be carried out on at least one Transformer/reactor** against an offer of minimum 50% of the ordered quantity as mentioned in delivery schedule. On the basis of satisfactory stage inspection, manufacturer will proceed further.

5.2.3 The manufacturer will offer the core for stage inspection and get approval from purchaser during manufacturing stage. **The BIS certified prime core materials are only to be used.** The manufacturer has to produce following documents at the time of stage inspection for confirmation of use of prime core materials.

a) Invoice of supplier
b) Mills' approved test certificates
c) Packing list
d) Bill of lading
e) Bill of entry certificate by custom.
f) Description of material, electrical analysis, physical inspection, certificate for surface defects, chemical composition certificate, thickness and width of the materials
g) Place of cutting of core materials

To avoid any possibility of mixing of 'Prime material' with any other second grade/ defective material, **the imported packed slit coils of CRGO materials shall be opened in the presence of the Inspector. Only after the inspection and approval from**

purchaser, the core material will be cut in-house or sent to external agency for cutting individual laminations. In case the core is sent to external agency for cutting, the Inspector will have full access to visit such agency for the inspection of the cutting of core. Core material shall be directly procured either from the manufacturer or through their accredited marketing organisation of repute and not through any agent.

5.2.4 Typical example for calculation of flux density, core quantity, no-load loss and weight of copper during stage inspection is given in the **Annexure-F.**

5.3 Type Tests on fittings

Following fittings shall conform to type tests and the type test reports shall be furnished along with drawing of the equipment/fittings.

a) Bushing (Type test as per IS/IEC:60137) (Seismic withstand test for 400 kV and above voltage class)
b) OLTC (Test as per IS 8468/IEC:60214 and degree of protection test for IP-55 on Driving mechanism box)
c) Buchholz relay
d) OTI and WTI
e) Pressure Relief Device (including degree of protection test for IP 55 in terminal box)
f) Sudden Pressure Relay (including degree of protection test for IP 55 in terminal box)
g) Magnetic Oil Level gauge & Terminal Box degree of protection test for IP-55.
h) 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
i) Marshalling & common marshalling box and other outdoor cubicle (IP-55 test)
j) Bus post Insulators
k) Oil pump
l) Cooling fan & motor assembly
m) RTCC Panel (IP-43 test)

6.0 Pre-Shipment Checks at Manufacturer's Works

The following pre-shipment checks shall be done at manufacturer's works:

6.1 Check for inter-changeability of components of similar transformers/reactors for mounting dimensions.

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

6.3 Ensure following setting of impact recorder at the time of installation with transformer/reactor unit before despatch 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.

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

6.5 Gas tightness test to confirm tightness and record of dew point of dry air inside the tank. Derivation of leakage rate and ensure the adequate reserve dry air capacity.

6.6 Due security arrangements to be ensured during transportation to avoid pilferage and tempering with the valves and other accessories used while dry air filling.

Annexure-A

SPECIFIC TECHNICAL REQUIREMENT

TRANSFORMERS

1.0 250 MVA & 315 MVA, 400/33 kV 3-Phase Power Transformer

S. No	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line-to-Line)	kV	400/33	
2.	Rated Capacity			
	HV	MVA	250	315
	LV1	MVA	125	157.5
	LV2	MVA	125	157.5
	Tertiary	MVA	Tertiary winding may be provided if transformer is of 5 limbs construction.	
3.	No of phases		3-phase	
4.	No of Secondary windings		Two windings	
5.	Vector Group		YNynyn0	
6.	Type of transformer		Power transformer	
7.	Applicable Standard		IEC 60076/ IS 2026	
8.	Cooling type		ONAN / ONAF / ODAF (or OFAF)	
9.	Rating at different cooling	%	60 / 80 / 100	
10.	Cooler Bank Arrangement		2 X 50%	
11.	Frequency	Hz	50	
12.	Tap Changer (OLTC) / OCTC		-5% to +5% in steps of 1.25% for HV variation	
13.	Location of tap changer		On HV neutral end	

14.	Impedance at 75°C, at highest MVA base (at MVA of HV winding)		
i)	HV-LV1 & HV-LV2:		
	Max. Voltage tap	%	30.2
	Principal tap	%	28
	Min. Voltage tap	%	26
ii)	LV1-LV2	%	40 (min.)
iii)	Tolerance on Impedance	%	As per IEC, unless specified otherwise
15.	Service		Outdoor
16.	Duty		Cyclic
17.	Overload Capacity		IEC-60076-7
18.	Temperature rise over 50°C ambient temp.		
i)	Top oil measured by thermometer	^{O}C	45
ii)	Average winding measured by resistance method	^{O}C	50
19.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{O}C	61
20.	Tank Hotspot Temperature	^{O}C	110
21.	Maximum design ambient temperature	^{O}C	50
22.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	LV1 & LV2	kV_p	250

	HV Neutral	kV_p	95
	LV Neutrals	kV_p	250
	Tertiary (if provided)	kV_p	250
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	LV1 & LV2	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	LV1 & LV2	kV_{rms}	95
	HV Neutral	kV_{rms}	38
	LV Neutrals	kV_{rms}	95
	Tertiary (if provided)	kV_{rms}	95
v)	Neutral Grounding (HV & LV)		Solidly grounded
vi)	Insulation		
	HV		Graded
	LV1 & LV2		Uniform
vii)	Tertiary Connection (if provided)		Ungrounded Delta
viii)	Tan delta of winding	%	≤ 0.5
23.	Bushing		
i)	Rated voltage		
	HV	kV	420
	LV1 & LV2	kV	52
	HV Neutral	kV	36
	LV Neutrals	kV	52
	Tertiary (if provided)	kV	52

ii)	Rated current		
	HV	A	1250
	LV1 & LV2	A	3150
	HV Neutral	A	2000
	LV Neutrals	A	2000
	Tertiary (if provided)	A	1250
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	LV1 & LV2	kV_p	250
	HV Neutral	kV_p	170
	LV Neutrals	kV_p	250
	Tertiary (if provided)	kV_p	250
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	LV1 & LV2	kV_{rms}	105
	HV Neutral	kV_{rms}	77
	LV Neutrals	kV_{rms}	105
	Tertiary (if provided)	kV_{rms}	105
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	LV1 & LV2	mm	1612

	HV Neutral	mm	1116
	LV Neutrals	mm	1612
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	LV1 & LV2	pC	10
24.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
25.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
26.	Termination details		To be provided by the purchaser as per its requirement

27.	**Maximum Permissible Losses of Transformers**		**250 MVA**	**315 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**Losses based on maximum flux density of 1.7 T at rated MVA, voltage & frequency and maximum current density of 3.5 A/mm² at all taps may be provided by the Manufacturers.**	
ii)	Max. Load Loss at rated current and at 75°C for HV and LV windings, at principal tap position	kW		
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW		

2.0 125 MVA & 160 MVA, 400/33 kV 3-Phase Power Transformer

S. No.	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line-to-Line)	kV	400/33	
2.	Rated Capacity (HV & LV)	MVA	125	160
3.	No of phases		3-phase	
4.	No of secondary windings		One winding	
5.	Vector Group		YNyn0	
6.	Type of Transformer		Power Transformer	
7.	Applicable Standard		IEC 60076 / IS 2026	
8.	Cooling		ONAN / ONAF	
9.	Rating at different cooling	%	70 / 100	
10.	Cooler Bank Arrangement		2 X 50%	
11.	Frequency	Hz	50	
12.	Tap Changer (OLTC)/OCTC		-5% to +5% in steps of 1.25% for HV variation	
13.	Location of tap change		On HV neutral end	
14.	Impedance at 75°C at highest MVA base			
	Max. Voltage tap	%	16.2	
	Principal tap	%	15	
	Min. Voltage tap	%	14	
15.	Tolerance on Impedance	%	As per IEC, unless specified otherwise	
16.	Service		Outdoor	
17.	Duty		Cyclic	
18.	Overload Capacity		IEC-60076-7	
19.	Temperature rise over 50°C ambient temp			
i)	Top oil measured by thermometer	^{O}C	45	
ii)	Average winding measured by resistance method	^{O}C	50	
20.	Winding hot spot rise over yearly weighted temperature of 32°C	^{O}C	61	
21.	Tank Hotspot Temperature	^{O}C	110	
22.	Maximum design ambient temperature	^{O}C	50	
23.	Windings			
i)	Lightning Impulse withstand Voltage			
	HV	kV_p	1300	
	LV	kV_p	250	
	HV Neutral	kV_p	95	

	LV Neutral	kV_p	250
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	LV	kV_{rms}	95
	HV Neutral	kV_{rms}	38
	LV Neutral	kV_{rms}	95
v)	Neutral Grounding (HV & LV)		Solidly grounded
vi)	Insulation		
	HV		Graded
	LV		Uniform
vii)	Tan delta of winding	%	≤0.5
24.	Bushing		
i)	Rated voltage		
	HV	kV	420
	LV	kV	52
	HV Neutral	kV	36
	LV Neutral	kV	52
ii)	Rated current		
	HV	A	1250
	LV	A	3150
	HV Neutral	A	2000
	LV Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	LV	kV_p	250
	HV Neutral	kV_p	170
	LV Neutral	kV_p	250
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	LV	kV_{rms}	105
	HV Neutral	kV_{rms}	77

	LV Neutral	kV_{rms}	105	
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5	
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)	
	HV	mm	13020	
	LV	mm	1612	
	HV Neutral	mm	1116	
	LV Neutral	mm	1612	
viii)	Maximum Partial discharge level at U_m			
	HV	pC	10	
	LV	pC	10	
25.	Maximum Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100	
26.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80	
27.	Termination details		To be provided by the purchaser as per its requirement	
28.	**Maximum Permissible Losses of Transformers**		**125 MVA**	**150 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**Losses based on maximum flux density of 1.7 T at rated MVA, voltage & frequency and maximum current density of 3.5 A/mm² at all taps may be provided by the Manufacturers.**	
ii)	Max. Load Loss at rated current and at 75°C for HV and LV windings, at principal tap position	kW		
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW		

3.0 (a) 100 MVA, 125 MVA & 160 MVA, 220/33 kV 3-ph Power Transformer
(b) 100 MVA, 125 MVA & 160 MVA, 230/33 kV 3-ph Power Transformer

Cl. No.	Description	Unit	Technical Parameters		
1.	Voltage ratio (Line-to-Line)	kV	(a) 220/33 (b) 230/33		
2.	Rated Capacity (HV & LV)	MVA	100	125	160
3.	No of phases		3 (Three)		
4.	No of secondary windings		One winding		
5.	Vector Group		YNyn0		
6.	Type of transformer		Power transformer		
7.	Applicable Standard		IEC 60076 / IS 2026		
8.	Cooling type		ONAN / ONAF		
9.	Rating at different cooling	%	70 / 100		
10.	Frequency	Hz	50		
11.	Cooler Bank Arrangement		2 X 50%		
12.	Tap Changer				
i)	Type		On-load tap changer /OCTC		
ii)	Tap range and steps		-5% to +5% in steps of 1.25% for HV variation		
iii)	Location of tap changer		On HV neutral end		
13.	Impedance at 75°C, at highest MVA base				
i)	Max. Voltage tap	%	16.2		
ii)	Principal tap	%	15.0		
iii)	Min. Voltage tap	%	14.0		
iv)	Tolerance on Impedance		As per IEC		
14.	Service		Outdoor		
15.	Duty		Cyclic		
16.	Overload Capacity		IEC-60076-7		
17.	Temperature rise over 50°C ambient Temp				
i)	Top oil measured by thermometer	^{O}C	45		
ii)	Average winding measured by resistance method	^{O}C	50		
18.	Winding hot spot rise over yearly weighted temperature of 32°C	^{O}C	61		
19.	Tank Hotspot Temperature	^{O}C	110		
20.	Maximum design ambient temperature	^{O}C	50		
21.	Windings				

i)	Lightning Impulse withstand Voltage		
	HV	kV_p	950
	LV	kV_p	170
	HV Neutral	kV_p	95
	LV neutral	kV_p	170
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1045
	LV	kV_p	187
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	395
	LV	kV_{rms}	70
	HV Neutral	kV_{rms}	38
	LV neutral	kV_{rms}	70
v)	Neutral Grounding (HV & LV)		Solidly grounded
vi)	Insulation		
	HV		Graded
	LV		Uniform
vii)	Tan delta of winding	%	≤ 0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	245
	LV	kV	36
	HV Neutral	kV	36
	LV Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	LV	A	3150
	HV Neutral	A	3150
	LV neutral	A	3150
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1050
	LV	kV_p	170
	HV Neutral	kV_p	170
	LV neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		

	HV	kV_{rms}	505		
	LV	kV_{rms}	77		
	HV Neutral	kV_{rms}	77		
	LV Neutral	kV_{rms}	77		
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5		
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)		
	HV bushing	mm	7595		
	LV bushing	mm	1116		
	HV neutral / LV neutral	mm	1116		
viii)	Maximum Partial discharge level at U_m				
	HV	pC	10		
23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100		
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80		
25.	Termination details		To be provided by the purchaser as per its requirement		
26.	**Maximum Permissible Losses of Transformers**		**100**	**125**	**160**
i)	Max. No Load Loss at rated voltage and frequency	kW	**Losses based on maximum flux density of 1.7 T at rated MVA, voltage & frequency and maximum current density of 3.5 A/mm² at all taps may be provided by the Manufacturers.**		
ii)	Max. Load Loss at rated current and at 75°C for HV and LV windings at principal tap position	kW			
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW			

4.0

(a) 80 MVA & 100 MVA, 132/33 kV, 3-Phase Power Transformer
(b) 80 MVA & 100 MVA, 110/33 kV, 3-Phase Power Transformer

S. No.	Description	Unit	TECHNICAL PARAMETERS	
1.	Voltage ratio (Line-to-Line)	kV	(a) 132/33 (b) 110/33	
2.	Rated capacity (HV and LV)	MVA	80 MVA	100 MVA
3.	No of phases		3 (Three)	
4.	Vector Group		YNyn0	
5.	Type of transformer		Power Transformer	
6.	Applicable Standard		IEC 60076 / IS 2026	
7.	Cooling type		ONAN/ONAF	
8.	Rating at different cooling	%	70 / 100	
9.	Cooler Bank Arrangement		1 X 100%	
10.	Frequency	Hz	50	
11.	Tap changer			
i)	Type		On-load tap changer (CFVV)/OCTC	
ii)	Tapping range and steps		-5% to +5% in steps of 1.25% for HV variation	
iii)	Location of tap changer		On HV neutral end	
12.	HV-LV Impedance at 75 °C, at highest MVA base			
i)	Max. Voltage tap	%	13.2	
ii)	Principal tap	%	12.5	
iii)	Min. Voltage tap	%	11.8	
13.	Tolerance on Impedance	%	As per IEC	
14.	Service		Outdoor	
15.	Duty		Cyclic	
16.	Overload Capacity		IEC 60076-7	
17.	Temperature rise over 50°C ambient temp.			

i)	Top oil measured by thermometer	^{O}C	45
ii)	Average winding measured by resistance method	^{O}C	50
18.	Winding hot spot rise over yearly weighted temperature of 32 °C		61
19.	Tank hot spot temperature		110
20.	Maximum design ambient temperature	^{O}C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	650 (132 kV) 550 (110 kV)
	LV	kV_p	170
	HV Neutral	kV_p	95
	LV Neutral	kV_p	170
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	715 (132 kV) 605 (110 kV)
	LV	kV_p	187
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	540 (132 kV) 460 (110 kV)
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	275 (132 kV) 230 (110 kV)
	LV	kV_{rms}	70
	HV Neutral	kV_p	38
	LV Neutral	kV_p	70
v)	Neutral Grounding (HV and LV)		Solidly grounded
vi)	Insulation		
	HV		Graded
	LV		Uniform
vii)	Tan delta of winding	%	≤0.5%
22.	Bushings		

i)	Rated voltage			
	HV	kV	145	
	LV, LV Neutral & HV Neutral	kV	36	
ii)	Rated current (Min.)			
	HV	A	1250	
	LV	A	3150	
	HV Neutral & LV Neutral	A	3150	
iii)	Lightning Impulse withstand Voltage			
	HV	kV_p	650	
	LV, HV Neutral and LV Neutral	kV_p	170	
iv)	One Minute Power Frequency withstand Voltage			
	HV	kV_{rms}	305	
	LV, HV Neutral and LV Neutral	kV_{rms}	77	
v)	Tan delta of bushing at ambient Temperature	%	≤ 0.5	
vi)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)	
	HV	mm	4495	
	LV, HV Neutral and LV Neutral	mm	1116	
vii)	Maximum Partial discharge level at U_m on HV and LV	pC	10	
23.	Maximum Partial discharge level at 1.58*Ur/√3	pC	100	
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	75	
25.	Termination details		To be provided by the purchaser as per its requirement	
26.	**Maximum Permissible Losses of Transformers**		**80 MVA**	**100 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**Losses based on maximum flux density of 1.7 T at rated MVA, voltage & frequency and maximum current density of 3.5**	
ii)	Max. Load Loss at rated current and frequency and at 75°C at principal tap between HV & LV	kW		

iii)	Max. Auxiliary Loss at rated voltage and frequency	kW	**A/mm² at all taps may be provided by the Manufacturers.**

5.0

(a) 31.5 MVA and 50 MVA, 132/33 kV, 3-Phase Power Transformer
(b) 31.5 MVA and 50 MVA, 110/33 kV, 3-Phase Power Transformer

S. No.	Description	Unit	TECHNICAL PARAMETERS
1.	Voltage ratio (Line-to-Line)	kV	(a) 132/33 (b) 110/33
2.	Rated capacity (HV and LV)	MVA	
3.	No of phases		3 (Three)
4.	Vector Group		YNyn0
5.	Type of transformer		Power Transformer
6.	Applicable Standard		IEC 60076 / IS 2026
7.	Cooling type		ONAN
8.	Cooler Bank Arrangement		1 X 100%
9.	Frequency	Hz	50
10.	Tap changer		
i)	Type		On-load tap changer (CFVV)/OCTC
ii)	Tapping range and steps		-5% to +5% in steps of 1.25% for HV variation
iii)	Location of tap changer		On HV neutral end
11.	HV-LV Impedance at 75 °C, at highest MVA base		
i)	Max. Voltage tap	%	13.2
ii)	Principal tap	%	12.5
iii)	Min. Voltage tap	%	11.8
12.	Tolerance on Impedance	%	As per IEC
13.	Service		Outdoor
14.	Duty		Continuous
15.	Overload Capacity		IEC 60076-7
16.	Temperature rise over 50°C ambient temp.		
iii)	Top oil measured by thermometer	^{O}C	45

iv)	Average winding measured by resistance method	^{O}C	50
17.	Winding hot spot rise over yearly weighted temperature of 32 °C		61
18.	Tank hot spot temperature		110
19.	Maximum design ambient temperature	^{O}C	50
20.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	650 (132 kV) 550 (110 kV)
	LV	kV_p	170
	HV Neutral	kV_p	95
	LV Neutral	kV_p	170
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	715 (132 kV) 605 (110 kV)
	LV	kV_p	187
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	540 (132 kV) 460 (110 kV)
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	275 (132 kV) 230 (110 kV)
	LV	kV_{rms}	70
	HV Neutral	kV_p	38
	LV Neutral	kV_p	70
v)	Neutral Grounding (HV and LV)		Solidly grounded
vi)	Insulation		
	HV		Graded
	LV		Uniform
vii)	Tan delta of winding	%	≤0.5%
21.	Bushings		
i)	Rated voltage		
	HV	kV	145

	LV, LV Neutral & HV Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	1250
	LV	A	1250
	HV Neutral & LV Neutral	A	1250
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	650
	LV, HV Neutral and LV Neutral	kV_p	170
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	305
	LV, HV Neutral and LV Neutral	kV_{rms}	77
v)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vi)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	4495
	LV, HV Neutral and LV Neutral	mm	1116
	Maximum Partial discharge level at U_m on HV	pC	10
22.	Maximum Partial discharge level at 1.58*Ur/√3	pC	100
23.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	75
24.	Termination details		To be provided by the purchaser as per its requirement
25.	**Maximum Permissible Losses of Transformers**		**31.5 MVA** / **50 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**Losses based on maximum flux density of 1.7 T at rated MVA, voltage & frequency and maximum current density of 3.5 A/mm² at all taps may be provided by the Manufacturers.**
ii)	Max. Load Loss at rated current and frequency and at 75°C at principal tap between HV & LV	kW	
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW	

TECHNICAL PARAMETERS OF BUSHING CURRENT TRANSFORMERS

1.0 Parameters of Current Transformer for 315MVA / 250MVA (3-Ph), 400/33 kV Transformers

Description	**Current Transformer Parameters**			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	1000/1	1000/1	3000/1	3000/1
CORE 2	600/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	1000V, PX / PS	1000V, PX / PS	3000V, PX / PS	3000V, PX / PS
CORE 2	0.2S Class 20VA ISF≤5	-	-	-
Maximum CT Secondary Resistance				
CORE 1	2.5 Ohm	2.5 Ohm	7.5 Ohm	7.5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	60 mA	60 mA	30 mA	30 mA
CORE 2	-	-	-	-

Notes:

1. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
2. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.

2.0 Parameters of Current Transformer for 160MVA / 125MVA (3-Ph), 400/33 kV Transformers

Description	**Current Transformer Parameters**			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	1000/1	1000/1	3000/1	3000/1
CORE 2	300/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	1000V, PX / PS	1000V, PX / PS	3000V, PX / PS	3000V, PX / PS
CORE 2	0.2S Class 20VA ISF≤5	-	-	-
Maximum CT Secondary Resistance				
CORE 1	2.5 Ohm	2.5 Ohm	7.5 Ohm	7.5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	60 mA	60 mA	30 mA	30 mA
CORE 2	-	-	-	-

Notes:

1. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
2. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.

3.0 Parameters of Current Transformer for 160 MVA / 125MVA (3-Ph), 220 (or 230)/33 kV Transformers

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	800/1	800/1	3000/1	3000/1
CORE 2	600/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	800V, PX / PS	800V, PX / PS	3000V, PX / PS	3000V, PX / PS
CORE 2	0.2S Class 20VA ISF≤5	-	-	-
Maximum CT Secondary Resistance				
CORE 1	2 Ohm	2 Ohm	7.5 Ohm	7.5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	30 mA	30 mA
CORE 2	-	-	-	-

Notes:

1. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
2. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.

4.0 Parameters of Current Transformer for 100MVA (3-ph), 220 (or 230)/33 kV Transformers

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	800/1	800/1	2000/1	2000/1
CORE 2	400/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	800V, PX / PS	800V, PX / PS	2000V, PX / PS	2000V, PX / PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	-	-
Maximum CT Secondary Resistance				
CORE 1	2 Ohm	2 Ohm	5 Ohm	5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	30 mA	30 mA
CORE 2	-	-	-	-

Notes:

1. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
2. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.

5.0 Parameters of Current Transformer for 80MVA / 100 MVA (3-ph), 132 (or 110)/33kV Transformers

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	800/1	800/1	3000/1	3000/1
CORE 2	600/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	800V, PX / PS	800V, PX / PS	3000V, PX / PS	3000V, PX / PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	-	
Maximum CT Secondary Resistance				
CORE 1	2 Ohm	2 Ohm	7.5 Ohm	7.5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	30 mA	30 mA
CORE 2	-	-	-	-

Notes:

1. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
2. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.

6.0 Parameters of Current Transformer for 31.5MVA/ 50MVA MVA (3-ph) 132 (or110)/33kV Transformers

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	800/1	800/1	1000/1	1000/1
CORE 2	400/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	800V, PX / PS	800V, PX / PS	1000V, PX / PS	1000V, PX / PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	-	
Maximum CT Secondary Resistance				
CORE 1	2.0 Ohm	2.0 Ohm	2.5 Ohm	2.5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	30 mA	30 mA
CORE 2	-	-	-	-

Notes:

1. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
2. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.

GUARANTEED AND OTHER TECHNICAL PARTICULARS FOR POWER TRANSFORMERS
(To be filled in by the manufacturer)

A. GENERAL

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufa-cturer
1.	General Information i) Supplier ii) Name of Manufacturer iii) Place of Manufacture (Country & City) iv) Type of transformer (Core/Shell)			
2.	Applications i) Indoor/Outdoor ii) 2wdg/3wdg iii)			
3.	Corrosion Level at Site i) Light ii) Medium iii) Heavy iv) Very Heavy			
4.	Site altitude above mean sea level	M		--
5.	Seismic zone and ground acceleration at site (both in horizontal & vertical direction)			--
6.	Maximum and minimum ambient temperature at site			
7.	Applicable Standards i) IEC: 60076 ii) IS : 2026 iii) Any other, please specify			
8.	Rated Capcity / Full load rating (HV/LV (or LV1/LV2)	MVA		
9.	3-Phase			
10.	Rated No Load Voltages (HV/LV (or LV1/LV2)/ Tertiary	kV		
11.	Currents at normal tap (HV/LV(or LV1/LV2)/ tertiary	Amp		
12.	Rated Frequency	Hz		
13.	Connections and phase displacement symbols (Vector Group)			
14.	Weight Schedules (Minimum with no negative			

	tolerance)			
	i) Active part (Core + coil)	Kg		
	ii) Insulating Oil (excluding mass of extra oil)	Kg		
	iii) Tank and Fittings	Kg		
	iii) Total weight	Kg		
	iv) Transportaion Weight	Kg		
	v) Overall dimensions L x B x H	mm		
	vi) Size of heaviest package L x B x H	mm		
	vii) Weight of heaviest package	Kg		
	viii) Weight of 5% extra oil	Kg		
	ix) Weight of core	Kg		
	x) Weight of copper (HV/Tertiary/LV(or LV1/LV2/ Regulating)	Kg		
	xi) Insulating Oil volume (excluding 5% extra oil)	Ltrs		
	xii) Quantity of oil in OLTC	Ltrs		
15.	Transport limitation			
16.	LV Winding i) Stabilizing tertiary (Yes/No) ii)			
17.	Tappings i)Type (OLTC/OCTC) and make of tap changer ii)Position of Tapping on the winding iii)Variation on iv)Range of variation v)No. of Steps vi) Whether control suitable for : • Remote/local operation • Auto/manual operation vi)Parallel Operation Requirements	%		
18.	Impedance and Losses			
	i) Guaranteed No load loss at rated voltage and frequency	kW		
	Tolerance (to be considered for loss evaluation)	%		
	ii) Guranteed I^2R Loss at rated current & frequency (at 75^{0}C) at principal tap	kW		
	iii) Eddy current and stray loss at rated current & frequency (at 75^{0}C) at principal tap	kW		
	iv) Load Loss(I^2R+Eddy and Stray) at rated current & frequency (at 75^{0}C) at principal tap	kW		
	Tolerance (to be considered for loss evaluation)	%		
	v) Guaranteed Auxiliary loss at rated voltage and	kW		

	frequency			
	Tolerance (to be considered for loss evaluation)	%		
	vi) Calculated Fan Loss	kW		
	vii) Air core reactance of HV winding	%		
	viii)Guaranteed Impedance (at Highest MVA base)	%		
	(a) HV-Tertairy (at Pricipal tap) (b) HV-LV (or LV1/LV2) (at Pricipal tap) (c) Tertairy -LV(at Pricipal tap)			
	Tolerance			
	ix) Impedance at extreme tappings at Highest MVA base [for HV-LV for two winding transformer] a) Max. Voltage tap b) Min. Voltage tap	%		
	Tolerance	%		
	x) Zero sequence impedance at principal tap (for 3-phase transformers)			
19.	Capacitance to earth for HV/Tertiary/LV (or LV1/LV2)	pF		
20.	Regulation at full load at 75 ^{0}C winding temperature at: a) upf b) 0.8 pf			
21.	Guaranteed maximum Magnetizing Current at rated Voltage	%		
22.	Efficiency : At 100% load upf 0.8 lead 0.8 lag At 75% load upf 0.8 lead 0.8 lag At 50% load upf 0.8 lead 0.8 lag	%		
23.	Load at Maximum efficiency	%		
24.	Any limitations in carrying out the required test? If Yes, State limitations			
25.	Fault level of system (in kA) and its duration (in sec)	kA (sec)		
26.	Calculated short Circuit current (in kA) withstand capability for 2 seconds without exceeding temperature limit (i.e. Thermal ability to withstand SC current)	kA		
27.	Test current (in kA) and duration (in ms) for short Circuit current test (i.e. Dynamic ability to withstand SC)	kA & msec		
28.	Over fluxing withstand time (due to combined voltage & frequency fluctuations): 110% 125%	msec		

	140% 150% 170%			
29.	Free space required above the tank top for removal of core			
30.	Maximum Partial discharge level at 1.58 Ur/√3	pC		

B. MAGNETIC SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	Core Type: i) 3 Phase 3 Limb (3 wound limbs) ii) 3 Phase 5 Limb (3 wound limbs) iii)			
2.	Type of Core Joint: i) Mitred ii) Step Lap			
3.	CRGO : i) Make & Country of Origin ii) Thickness, mm iii) Max. Specific loss at 1.7 T, 50Hz, in Watts/kg iv) Grade of core as per BIS v) Insulation between core lamination vi) BIS certified (Yes/No)			
4.	Minimum Gross & Net Area of: i) Core ii) Limb iii) Yoke iv) Unwound limb (May be verified during manufacturing stage – at the discretion of buyer)	cm^2		
5.	Stacking Factor	%		
6.	Voltage per turn	V		
7.	Apparent Core Density for Weight Calculation			
8.	Minimum Net Weight of Silicon Steel Lamination CRGO (may be verified during manufacturing stage by calculation)	kg		
9.	Maximum Flux density at 90%, 100% and 110% voltage and frequency (may be verified during manufacturing stage by calculation)	T		
10.	W/kg at working flux density			
11.	Building Factor Considered			

12.	Calculated No Load Loss at rated voltage and Frequency (Net Weight x W/kg x Building factor)	kW		
13.	Magnetizing inrush current	Amp		
14.	No load current at normal ratio and frequency for : 85% of rated voltage 100% of rated voltage 105% of rated voltage	Amp		
15.	Core Isolation test	kV		
16.	Core bolt in limb / yoke	Yes/ No		
17.	Core bolt insulation withstand voltage for one minute	kV		
18.	Maximum temperature rise of any part of core or its support structure in contact with oil	^{0}C		

C. CONDUCTING SYSTEM

Sl. No.	Description	Unit	Offered by manufacturer			
			HV	**IV**	**LV**	**Regulating**
1.	Type of Winding Helical/Disc/Layer/inter wound					
2.	Type of Conductor PICC/CTC/CTCE/CTCEN/BPICC					
3.	Minimum Yield Strength of Conductor for 0.2% elongation	N/mm^2				
4.	Maximum Current density at CMR and conductor area at any tap: i) HV ii) Tertiary iii) LV (or LV1/LV2)	A/mm^2 & sq. mm				
5.	Maximum current density under short circuit: i) HV ii) Tertiary iii)LV (or LV1/LV2)	A/mm^2				
6.	Bare Weight of copper without paper insulation and lead (Minimum)	Kg				
7.	Per Phase Maximum resistance of winding at rated tap at 75 ^{0}C	ohm				
8.	Number of Turns/Phase					
9.	Insulating material used for HV/IV/LV winding					

10.	Insulating material used between : i) HV and IV winding ii) IV and LV winding iii) LV winding and core iv) Regulating winding and adjacent winding/core					
11.	Details of special arrangement provided to improve surge voltage distribution in the winding					
12.	Dielectric Shielding used: i) Interleaved winding ii) Wound in Shield iii) Others					
13.	Magnetic Shielding used: i) Yoke Shunt on core clamp ii) Magnetic shunt on tank iii) Electromagnetic (Copper/Aluminum) shield on tank iv) Others					
14.	Noise level when energized at normal voltage and frequency without load	dB				

D. COOLING SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufac-turer
1.	Type of Cooling [ONAN/ONAF (or) ONAN / ONAF / OFAF (or ODAF)]			
2.	Percentage Rating Corresponding to Cooling Stages (HV/Tertiary/LV (or LV1/LV2)			
3.	No. of Cooler banks (2x50% / 1x100% etc.)			
4.	Temperature gradient between windings and oil			
5.	Time in minutes for which the transformer can run at full load without exceeding maximum permissible temperature at reference ambient temperature when supply to fans is cut off	min		
6.	Guaranteed Maximum Temperature rise at 1000 mts. altitude and at actual altitude at site at ambient temperature at cooling specified at sl. No. 1: i) Top Oil by thermometer ii) Average Winding by resistance iii) Winding hot spot	^{0}C		

7.	Type of Cooler: i) Radiator Bank ii)) iii) Tank Mounted iv) Header Mounted v) Separately Mounted vi) Degree of Protection of terminal box			
8.	Cooling Fans: i) Type ii) Size iii) Rating (kW) iv) Supply voltage v) Quantity (Running + Standby) per cooler bank vi) Whether fans are suitable for continuous operation at 85% of their rated voltage calculated time constant: • natural cooling • forced air cooling vii) Degree of Protection of terminal box			
9.	Oil Pumps: i) Type ii) Size iii) Rating (lpm and kW) iv) Supply voltage v) Quantity (Running + Standby) per cooler bank vi) Efficiency of motor at full load vii) Temperature rise of motor at full load viii) BHP of driven equipment			
10.	Coolers (Oil to Air): i) Quantity (Running + Standby) ii) Type and Rating			
11.	Coolers (Oil to Water): i) Quantity (Running + Standby) ii) Type and Rating iii) Oil flow rate (lpm) iv) Water flow rate (lpm) v) Nominal Cooling rate (kW) vi) Material of tube			
12.	Radiators: i) Width of elements (mm) ii) Thickness (mm) iii) Length (mm) iv) Numbers			
13.	Cooler loss at rated output, normal ratio, rated voltage,	kW		

	rated frequency at ambient temperature of 50°C			

E. DIELECTRIC SYSTEM

Sl. No.	Description	Unit	Offered by manufacturer				
1.	Geometric Arrangement of winding with respect to core e.g: Core-Tertiary-LV-HV-Reg Coarse-Reg Fine						
2.	Regulating Winding: i) Body Tap ii) Separate						
3.	HV Line Exit point in winding: i) Top ii) Center						
4.	Varistors used across Windings If yes, Details	Yes/ No					
5.	Insulation Levels of windings		HV	Tertiary	LV (or LV 1/ LV 2)	HV -N	LV-N
	i) Lightning Impulse withstand voltage (1.2/50μs)	kV_p					
	ii) Chopped wave Lightning Impulse withstand voltage	kV_p					
	iii) Switching Impulse withstand voltage (250/2500μs)	kV_p					
	iv) Power frequency withstand voltage (one minute / 5 minutes)	kV_{rms}					
6.	Tan delta of windings at ambient temperature	%					

F. ACCESSORIES

Sl. No.	Description	Unit	Offered by manufacturer	Specified by Buyer
1.	Tap Changers			
	i) Control a-Manual b-Automatic c-Remote d-Local			
	ii) Voltage Class and Current Rating of Tap Changers			
	iii) Make and Model			
	iv) Make and Type of Automatic Voltage			

	Regulator (AVR)						
	v) Tie-in resistor requirement (to limit the recovery voltage to a safe value) and its value						
	vi) OLTC control and monitoring to be carried out through Substation Automation System	Y/N					
	vii) Power Supply for control motor (No. of Phases/Voltage/Frequency)						
	viii) Rated Voltage for control circuit (No. of Phases/Voltage/Frequency)	V					
2.	Tank						
	i) Tank Cover: Conventional/Bell/Bottom Plate						
	ii) Material of plate for tank						
	iii) Plate thickness : side, bottom, cover	Mm					
	iv) Rail Gauge	Mm					
	v) Minimum Clearance height from rail for lifting Active Part	Mm					
	vi) Wheels : Numbers/Plane/Flanged/Uni-Directional/Bi-Directional/Locking Details						
	vii) Vacuum withstand Capability (a) Tank (b) Radiators/Conservator/Accessories	mm of Hg					
	viii) High Pressure withstand Capability (a) Tank (b) Radiators/Conservator/Accessories	mm of Hg					
	ix) Radiator fins / conservator plate thickness	Mm					
	x) Tank Hot spot temperature	^{O} C					
3.	Bushings:		HV	IV	LV	HV-N LV-N	
	i) Termination Type a-Outdoor b-Cable Box (oil/Air/SF_6) c-Plug in Type						
	ii) Type of Bushing: OIP/RIP/RIS/oil communicating						
	iii) Bushing housing - Porcelain / polymer						
	iv) Rated Voltage Class	kV					
	v) Rated Current	A					
	vi) Lightning Impulse withstand voltage (1.2/50µs)	kV_p					
	vii) Switching Impulse withstand voltage (250/2500µs)	kV_p					

	v) One minute Power frequency withstand voltage (dry & wet)	kV_{rms}					
	viii) Minimum Creepage Distance	Mm					
	ix) Quantity of oil in bushing and specification of oil used						
	x) Make and Model						
	xi) Tan delta of bushings	%					
	xii) Max Partial discharge level at U_m	pC					
	xiii) Terminal Pad details						
	xiv) Weight of assembled bushings	Kg					
	xv) Whether terminal connector for all bushings included in the scope of supply						
4.	Minimum clearances between bushings (for HV, Tertiary and LV) (a) Phase to phase (b) Phase to ground						
5.	Indicator / Relay						
	i) Winding temperature thermometer/ indicator: Range Accuracy						
	ii) Oil temperature thermometer/ indicator: Range Accuracy						
	iii) Temperature sensors by fiber optic (if provided)						
	iv) Oil actuated/gas operated relay						
	v) Oil level Indicators: Main Conservator OLTC Conservator						
	vi) Oil Sight Window: Main Tank Main Conservator OLTC Conservator						
6.	Conservator: i) Total volume ii) Volume between highest and lowest visible oil levels						
7.	Conservator Bag (air cell) i) Material of air cell ii) Continuous temperature withstand capacity of air cell						
8.	Air cell rupture relay provided	Yes / No					

9.	Pressure Relief Device: i) Number of PRDs provided ii) Location on the tank iii) Operating pressure of relief device			
10.	Sudden Pressure Relay / Rapid Pressure rise relay provided; if yes, i) Location on the tank ii) Operating pressure	Y/N		
11.	Dehydrating Breathers(Type & No. of breathers) (a) For main Conservator tank (b) For OLTC conservator			
12.	Flow sensitive Conservator Isolation Vlave Provided	Y/N		
13.	Tap Changer protective device			
14.	Type and material of gaskets used at gasketed joints			
15.	Bushing CTs: (HV side and /LV side) i) Voltage class ii) No. of cores iii) Ratio iv) Accuracy class v) Burden vi) Accuracy limit factor vii) Maximum resistance of secondary winding viii) Knee point voltage ix) Current rating of secondaries	 kV VA Ω V A		
16.	Neutral CTs: i) Voltage class ii) No. of cores iii) Ratio iv) Accuracy class v) Burden vi) Accuracy limit factor vii) Maximum resistance of secondary winding viii) Knee point voltage ix) Current rating of secondaries	 kV VA Ω V A		
17.	Transformer Oil i) IS 335 / IEC60296 / as per specification ii) Inhibited/ un-inhibited iii) Mineral / Natural Ester / Synthetic Ester iv) Spare oil as percentage of first filling v) Manufacturer vi) Quantity of oil (before filling and before commissioning) vii) Moisture content (mg/L or ppm) viii) Tan delta (Dielectric Dissipation Factor) at 90°C			

	ix) Resistivity (Ω-cm)) x) Breakdown Voltage (before and after treatment) (kV) xi) Interfacial tension at 20 °C (N/m) xi) Pour point (°C) xii) Flash point(°C) xiii) Acidity (mg KOH/gm) xiv) Inhibitors (for inhibited oil) (%) xv) Oxidation Stability			
18.	Press Board: i) Make ii) type			
19.	Conductor Insulating Paper i) Kraft paper ii) Thermally upgraded Kraft paper iii) Nomex			
20.	Provision for fire protection system (as per spec), if yes, provide details	Y/N		
21.	Insulation of core bolts, washers, end plates etc.			
22.	Weights and Dimensions: i) Weights: a. Core b. Windings c. Tank d. Fittings e. Oil f. Total weights of complete transformers with oil and fittings ii) Dimensions; a. Overall Height above track b. Overall length c. Overall breadth iii) Minimum bay width required for installation of the transformer iv) Weight of the heaviest package of the transformer arranged for transportation			
23.	Lifting Jacks i) Number of jacks included ii) Type and Make iii) Capacity iv) Pitch v) Lift vi) Height in close position			

24.	Rail Track gauges i) 2 Rails or 3 rails or 4 rails ii) Distance between adjacent rails on shorter axis iii) Distance between adjacent rails on longer axis			

Annexure-D

Test Plan for Transformers

No.	Test	U_m ≤ 170kV	U_m > 170kV
1.	Measurement of winding resistance at all taps	Routine	Routine
2.	Measurement of voltage ratio at all taps	Routine	Routine
3.	Check of phase displacement and vector group	Routine	Routine
4.	Measurement of no-load loss and current measurement at 90%, 100% & 110% of rated voltage and rated frequency	Routine	Routine
5.	Magnetic balance test (for three phase Transformer only) and measurement of magnetizing current	Routine	Routine
6.	Short Circuit Impedance and load loss measurement at principal tap and extreme taps	Routine	Routine
7.	Measurement of insulation resistance & Polarization Index	Routine	Routine
8.	Measurement of insulation power factor and capacitance between winding to earth and between windings	Routine	Routine
9.	Measurement of insulation power factor and capacitance of bushings	Routine	Routine
10.	Full wave lightning impulse test for the line terminals (LI)	Type (for Um<= 72.5kV) Routine (for 72.5kV< Um≤170 kV)	-
11.	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
12.	Lightning impulse test for the neutral terminals (LIN)	Type	Type

13.	Switching impulse test for the line terminal (SI) (Not applicable for Um≤72.5 kV)	Type	Routine
14.	Applied voltage test (AV)	Routine	Routine
15.	Line terminal AC withstand voltage test (LTAC) (Not applicable for Um≤72.5 kV)	Routine	Type
16.	Induced voltage withstand test (IVW)	Routine	-
17.	Induced voltage test with PD measurement (IVPD)	Routine*	Routine
18.	Measurement of transferred surge on Tertiary due to HV lightning impulse	–	Type
19.	Measurement of transferred surge on Tertiary due to HV Switching impulse	-	Type
20.	Test on On-load tap changer (Tap changer fully assembled on the transformer)	Routine	Routine
21.	Measurement of dissolved gasses in dielectric liquid	Routine	Routine
22.	Check of core and frame insulation	Routine	Routine
23.	Leak testing with pressure for liquid immersed transformers (tightness test)	Routine	Routine
24.	Appearance, construction and dimension check	Routine	Routine
25.	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.	Routine	Routine
26.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine	Routine
27.	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine	Routine
28.	Tank vacuum test	Routine	Routine
29.	Tank pressure test	Routine	Routine
30.	Check of the ratio and polarity of built-in current transformers	Routine	Routine
31.	Temperature rise test	Type	Type
32.			
33.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)	Routine	Routine

34.	Over excitation test (applicable for 765 kV transformer only)	-	Routine
35.	Measurement of Zero seq. reactance (for three phase Transformer only)	Type	Type
36.	Measurement of harmonic level in no load current	Type	Type
37.	Determination of acoustic sound level	Type	Type
38.			
39.	Dynamic Short circuit withstand test	as specified in the specification	

*The requirements of the IVW test can be incorporated in the IVPD test so that only one test is required.

Test Procedures (for Transformer)

General

Tests shall be carried out as per following procedure. However, IS 2026/IEC 60076 (with latest amendments) shall be followed in general for other tests. Manufacturer shall offer the transformer unit for type testing with all major fittings including radiator bank, Marshalling Box, Common Marshalling Box, RTCC (as applicable) assembled.

1. Core assembly dielectric and earthing continuity test

After assembly each core shall be tested for 1 minute at 2000 Volts between all yoke clamps, side plates and structural steel work (core to frame, frame to tank & core to tank).

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

2. Measurement of winding resistance

After the transformer has been under liquid without excitation for at least 3 h, the average liquid temperature shall be determined and the temperature of the winding shall be deemed to be the same as the average liquid temperature. The average liquid temperature is taken as the mean of the top and bottom liquid temperatures. Measurement of all the windings including compensating (in case terminal is available at outside) at normal and extreme taps.

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

3. No-load loss and current measurement

As per IEC 60076-1:2011 clause 11.5

4. Measurement of short-circuit impedance and load loss

The short-circuit impedance and load loss for a pair of windings shall be measured at rated current & frequency with voltage applied to the terminals of one winding, with the terminals of the other winding short-circuited, and with possible other windings open circuited. The difference in temperature between the top and bottom liquid shall not exceed 5 K. To obtain this result more rapidly, the liquid may be circulated by a pump. Loss measurement for all combinations (HV-IV, HV-LV, IV-LV and at Normal and extreme taps).

5. Short term heat run test (Not Applicable for unit on which temperature rise test is performed)

In addition to the type test for temperature rise conducted on one unit, each cooling combination shall routinely be subjected to a short term heat run test to confirm the performance of the cooling system and the absence of manufacturing defect such as major oil flow leaks that may bypass the windings or core.

DGA samples shall be taken at intervals to confirm the gas evolution.

For ODAF or OFAF cooling, the short term heat run test shall be done with the minimum number of pumps for full load operation in order to shorten the temperature build up. Each short term heat run test is nevertheless expected to take about 3 hours.

For ODAF or OFAF cooled transformers an appropriate cross check shall be performed to prove the effective oil flow through the windings. For this purpose the effect on the temperature decay by switching the pumps off/ on at the end of the heat run should demonstrate the effectiveness of the additional oil flow. Refer to SC 12, 1984 cigre 1984 SC12-13 paper by Dam, Felber, Preiniger et al.
Short term heat run test may be carried out with the following sequence:

- Heat run test with pumps running but oil not through coolers.
- Raise temperature to 5 deg less than the value measured during temperature rise test.
- Stop power input and pumps for 6 minutes and observe cooling down trend
- Restart pumps and observe increased cooling trend due to forced oil flow

This test is applicable for the Transformer without Pump also (ONAN or ONAF rating). For such type of transformer test may be carried out with the following sequence:

Arrangement shall be required with pump of suitable capacity (considering the oil velocity) without cooler bank.

- Raise the oil temperature 20-25 deg C above ambient.
- Stop power input and pumps for 6 minutes and observe cooling down trend.
- Restart pumps and observe increased cooling trend due to forced oil flow.

6. Temp. Rise Test as per IEC: 60076

Headspace extraction and Gas chromatographic analysis on oil shall also be conducted before, during and after this test and the values shall be recorded in the test report. The sampling shall be in accordance with IEC 60567.

The temperature rise test shall be conducted at a tap for the worst combination of loading (3-Winding Loss) for the Top oil of the transformer.

3-Winding Loss = HV (Max MVA) + LV (Max MVA).

The Contractor before carrying out such test shall submit detailed calculations showing losses 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.

The Temperature rise type test results shall serve as a "finger print" for the units to be tested only with short term heat run test.

Headspace extraction and Gas chromatographic analysis on oil shall also be conducted before, during and after this test and the values shall be recorded in the test report. The sampling shall be in accordance with IEC 60567.

Oil sample shall be drawn before and after heat run test and shall be tested for dissolved gas analysis. Oil sampling to be done 2 hours prior to commencement of temperature rise test. Keep the pumps running for 2 hours before and after the heat run test. Take oil samples during this period. For ONAN/ONAF cooled transformers, sample shall not be taken earlier than 2 hours after shut down. The acceptance norms with reference to various gas generation rates shall be as per IEC 61181.

The DGA results shall generally conform to IEC/IEEE/CIGRE guidelines.

i. Test conditions for temperature rise test:

- This test shall be generally carried out in accordance with IEC 60076-2
- For each cooling combination with cooler bank, tests shall be done on the maximum current tap for a minimum of 12 hours for ONAN/ONAF and 24 hours for ODAF or OFAF with saturated temperature for at least 4 hours while the appropriate power and current for core and load losses are supplied.
- The total testing time, including ONAN heating up period, steady period and winding resistance measurements is expected to be about 48 hours.

- DGA tests shall be performed before and after heat run test and DGA results shall generally conform to IEC/IEEE/CIGRE guidelines.

ii. Test records:

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

iii. General:

- Purchaser's order number and transformer site designation.
- Manufacturer's name and transformer serial number.
- Rating of transformer
- MVA
- Voltages and tapping range
- Number of phases
- Frequency
- Rated currents for each winding
- Vector Group
- Cooling Type
- Measured no-load losses and load losses at 75° C.
- Altitude of test bay.
- Designation of terminals supplied and terminals strapped.

iv. Top oil temperature rise test:

A log of the following quantities taken at a minimum of 30 minute intervals:

- time
- Voltage between phases
- Current in each phase and total power
- Power in each phase and total power
- Ambient temperature
- Top oil temperature
- Cooler inlet and outlet oil temperatures
- Hot spot temperatures (make use of probes) (if applicable)
- Colour photographs of the four sides and top of the transformer together with the corresponding series of thermal images (colour) during starting of the test then after every four hours till the temperature stabilised and finally during temperature stabilised for each rating (ONAN/ONAF/ODAF (or OFAF); ONAN/ONAF).

Notes:
The probes may be left in position provided the reliability and integrity of unit will not be jeopardized during its long life expectancy.

v. Winding temperature rise test

- Record the 'cold' resistance of each winding and the simultaneous top oil and ambient air temperatures, together with the time required for the effect to disappear.
- Record the thermal time constant of the winding.
- Log the half-hourly readings of the quantities as for the top oil temperature rise test.
- Provide a table of readings, after shut-down of power, giving the following information;

  a) Time after shut- down:
  b) Time increment:
  c) Winding resistance: At least 20 minutes reading
  d) Resistance increment:
  e) X, where x is the time after shut-down divided by the thermal time constant of the winding: and
  f) Y, where Y = 100 (1-e –x)
  (Any graphical/computer method used to determine the temperature of a winding by extrapolation to the instant of power shut-down shall produce a linear curve.)

- Provide a record of all calculations, corrections and curves leading to the determination of the winding temperatures at the instant of shut-down of power.
- Record any action taken to remedy instability of the oil surge device during initiation of the oil circulating pumps.

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

7. Dielectric Tests

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

a) Lightning impulse tests (LIC, LIN)
b) Switching impulse (SI)
c) Applied voltage test (AV)
d) Line terminal AC withstand test (LTAC)
e) Induced voltage test with partial discharge measurement (IVPD)

8. Measurement of transferred surge on LV or Tertiary due to HV Lightning impulse

Following tests shall be carried out with applying 20% to 80% of rated Impulse & Switching impulse (upto 60% for IV, Sr. No. 7 & 8 of below table) voltage. Finally, measured value shall be extrapolated for 100% rated voltage.

Table for Transfer surge (Impulse) at Max, Nor. and Min. Voltage Tap

Sr. No.	Impulse Type	Voltage applied	Earthed Points	Open / not earthed point	Measurement Point
1	FW	1.1	2.1, N & 3.2	-	3.1
2	FW	1.1	2.1, N & 3.1	-	3.2
3	SW	1.1	N & 3.2	2.1	3.1
4	SW	1.1	N & 3.1	2.1	3.2
5	FW	2.1	1.1, N & 3.2	-	3.1
6	FW	2.1	1.1, N & 3.1	-	3.2
7	SW	2.1	N & 3.2	3.2	3.1
8	SW	2.1	N & 3.1	3.1	3.2

Similar tests to be conducted for switching surge transformer at Max, Nor. and Min. Voltage Tap.

Where 1.1 : HV Terminal
2.1 : IV Terminal
3.1 & 3.2 : LV or Tertiary Terminal

Acceptance criteria

Transfer surge at Tertiary should not exceed 250kVp at any conditions for 400kV Voltage class Transformer. For other transformer it shall be below the impulse level of LV winding.

9. Chopped wave & full wave lightning impulse test for the line terminals (LIC & LI) and Switching impulse test

Chopped wave lightning impulse and Switching impulse test shall be performed at normal and extreme taps on Unit-1, Unit-2 and Unit-3 respectively for 1-Ph unit, otherwise R ph, Y Ph and B Ph respectively for 3-Ph unit. All the parameters as per IEC shall be mentioned in the report.

10. Measurement of power taken by fans and oil pumps (100 % cooler bank)

Losses of each fan and pumps including spare shall be measured at rated voltage and frequency. Fans and Pumps shall be mounted with cooler bank as per approved drawing during measurement. Serial No, Applied voltage, measured current, frequency and make shall be furnished in the test report.

11. Short duration (LTAC) AC withstand test (LTAC)

For 765kv Class transformer, the IV terminal voltage shall be shall be raised to 570kVrms or below so that maximum HV voltage shall be shall be limited to 970kV rms. Test method shall be as per IEC.

12. Dynamic short circuit withstand test

The test shall be carried out as per IEC 60076-5. Dynamic short circuit test shall be carried out in HV-LV combination at nominal & extreme tap positions. For LV winding, dynamic short circuit shall be carried out on HV. Type tests shall be carried out before short circuit test. Following shall also be conducted before and after Short Circuit test:

i) Dissolved gas analysis
ii) Frequency response analysis
iii) All routine tests

Detail test procedure shall be submitted by contractor & shall be approved before short circuit test.

13. Routine tests on Bushings: Routine test on bushings shall be done as per IEC 60137.

****

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
A	**Raw Material & Components**							
1.	Winding Conductor (PICC)/ (CTC)/ Lead wires	(a) Visual & Dimensional check of Conductor: Thickness & width of bare conductor, thickness of paper, surface covering, no. of conductors, finish of conductor and finish of PICC/CTC	One sample per type per lot	IS 1897 IS 13730 As per approved drawing	Bare conductor: Width(mm) Tolerance (in ± mm) Up to 3.15 - 0.03 3.16 to 6.30 - 0.05 6.31 to 12.5 - 0.07 12.51 to 16 - 0.10 > 16 - 0.13 Thickness (mm) Tolerance (in ±mm) For Width (mm) (2-16) (16-40) 0.8 to 3.15 - 0.03 0.05 3.15 to 6.30 - 0.05 0.07 6.30 to 10 - 0.07 0.09 Insulated conductor: Paper Covering thickness (mm) Tolerance (%) 0.25 to 0.5 - 10 Over 0.5 to 1.3 - 7.5 Over 1.3 - 5	P	V	W/V
		(b) Resistivity at 20 deg.C		IS 13730	For annealed conductor: 0.01727 ohm/mm^2/m (max) For half hard conductor: 0.01777 ohm-mm^2/m (max)	P	V	W/V
		(c) Insulation test for bunched conductor/between strands of CTC (if applicable)		IS 13730	Maximum Charging current 1A at 250V AC/ 500V DC for 1 minute.	P	V	W/V
		(d) Elongation test for annealed conductors (if applicable)		IS 7404 IS 13730	Thickness (mm) elongation % Up to 2.5 30 (min.) >2.5-5.6 32 (min.)	P	V	-
		(e) Proof strength of work hardened conductor		IS 7404 IS 13730	As per design requirement	P	V	-

TC --- Test Certificate PD- Perpendicular Direction CD- Cross Direction MD- Machine Direction PICC-Paper Insulated Copper Conductor CTC- Continuously Transposed Conductor

* Category of Responsibility: P - Actual Test Performance V - Verify and Accept W - Witness Actual testing, verify and accept

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility* Sub-Vendor	Manufacturer	Customer
		(f) Radius of corner of bare conductor		IS 7404 IS 13730	Thickness (mm) — Corner Radius (mm) Up to 1.0 - 0.50 x nominal thickness 1.01 to 1.60 - 0.50 1.61 to 2.24 - 0.65 2.25 to 3.55 - 0.80 3.56 to 5.60 - 1.00 (Tolerance ±25%)	P	V	V
		(g) Copper purity		As per plant standard	OEM Standard	V	V	V
		(h) Oxygen Content		As per plant standard	OEM Standard	V	V	V
		(i) Epoxy Bonding Strength (Bonded CTC)		As per plant standard	As per plant standard	P	V	V
2.	Kraft Insulating Paper (for covering of PICC/CTC)	(a) Visual check & Measurement of Thickness	One sample per type per lot	IEC 60554-3-1 IEC 60554-3-5 IEC 60554-2, Methods of Test	Paper to be smooth, unglazed surface, free from dust particles and no surface defect Thickness tolerance within specified value ±10%	P	V	--
		(b) Density			Nominal value ±0.05 gm/cm^3			
		(c) Substance (grammage)			Thickness(µm) — Sub(g/m^2) 50 — 40 65 — 52 75 — 60 90 — 72 Tolerance: For material ≤45 g/m^2 ±10% For material >45 g/m^2 ±5%			
		(d) Moisture Content			8 % max			
		(e) Tensile Index (Machine Direction)			93 NM/gm (min)			
		(f) Tensile Index (Cross-machine Direction)			34 NM/gm (min)			
		(g) Elongation at Break (MD)			As per IEC 60554-3-1			
		(h) Elongation at Break (CD)			As per IEC 60554-3-1			
		(i) Electric Strength in Air			As per IEC 60554-3-1			
		(j) Ash Content			1 % max			
		(k) PH of Aqueous extract			6 to 8			
		(l) Conductivity of Aqueous extract			10 mS/m (max)			
		(m) Air Permeability			0.5 to 1.0 µm/Pa.s			
		(n) Tear Index (MD)			5 mN m^2/g (min)			
		(o) Tear Index (CD)			6 mN m^2/g (min)			
		(p) Water Absorption (Klemn Method)			10 %			

TC --- Test Certificate PD- Perpendicular Direction CD- Cross Direction MD- Machine Direction PICC-Paper Insulated Copper Conductor CTC- Continuously Transposed Conductor

* Category of Responsibility: P - Actual Test Performance V - Verify and Accept W - Witness Actual testing, verify and accept

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(q) Heat Stability i) Reduction of Degree of Polymerization ii) Reduction of Bursting Strength iii) Increase of Conductivity of Aqueous extract.			Type test report			
		(r) DP Value			As per IEC 60554/Manufacturer's std. practice			
		(s) Storage Period			As per Manufacturer's std. practice			
		(t) Storage in controlled Environment			As per Manufacturer's std. practice			
3.	Thermally upgraded Paper/Aramid Paper (if applicable)	Manufacturer's std. practice			As per Manufacturer's std. practice			
4.	(i) CRGO Mother coil / Laminations	Check following documents (a) Invoice of Supplier (b) Mill's Test certificate (c) Packing List (d) Bill of Lading (e) Bill of Entry (f) manufacturer's identification slip/unique numbering of prime CRGO coil	Each Lot (100% of coils)	IS 3024 IS 649 IEC 60404 ASTM 4343	As per approved design	P	V	V
		Check points:						
		(a) Visual check, check for coil width & thickness from nameplate	10% of coils		Visually defect free, as per design requirement			
		(b) Cutting Burr	One sample per lot		Less than 20 micron burr/ As per IS/ mutual agreement while ordering			
		(c) Bend / Ductility test			As per IS 649/IS 3024 Completion of one 160^{o} bend without fracture			
		(d) Surface insulation resistivity check			Average value: 10 $\Omega\ cm^2$ (min.) Individual value: 05 $\Omega\ cm^2$ (min.)			
		(e) Accelerated Aging test (type test)			4% (max.) increase in measured specific total loss			
		(f) Test on stacking factor			As per table no. 4 of IS 3024			
		(g) Test for specific Watt loss test	One sample from offered lot	IS 3024	As per table no. 2 of IS 3024	--	P	V
		(h) Magnetic Polarisation		IS 3024	As per appropriate tables of IS 3024	--	P	V
		(i) Grade of CRGO		Approved drawing/ Document	Approved Drawing/Document/ Manufacturer standard	P	V	V
		(j) Permeability at 800 A/m				P	V	V

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility* Sub-Vendor	Manufacturer	Customer
				Test Method IS 3024/ IS 649				
		(k) Compliance to Quality Control Order of DHI		IS 3024		P	V	V
5.	Pre-compressed Press Board/ Laminated pre-compressed pressboard	(a) Visual & dimensional check, thickness, width and length	One sample of each size (thickness) per lot of pressboard	IEC 60641-3-1 IEC60763-3-1 IEC 60641-2, IEC60763-2 Methods of Test	No surface defects	P	V	V
		(b) Apparent Density (g/cm³)			Up to 1.6 mm TK - 1.0-1.2 >1.6-3 mm - 1.1-1.25 >3-3.6 mm - 1.15-1.30 >6-8 mm - 1.2-1.3			
		(c) Compressibility in air (C) (in %)			Up to 1.6 TK- 10 % >1.6-3 mm - 7.5 % >3-3.6 mm - 5 % >6-8 mm - 4 %			
		(d) Reversible part Compressibility in air (C_{rev}) (in %)			Up to 1.6 TK- 45 %; >1.6-3 mm - 50 % >3-3.6 mm - 50 %; >6-8 mm - 50 %			
		(e) Oil Absorption			Up to 1.6 mm TK - 11 min > 1.6-3 mm - 9 min > 3 - 3.6 mm - 7 min > 6-8 mm - 7 min			
		(f) Moisture Content			6% max. / As per relevant std. & Manufacturer's std. practice			
		(g) Shrinkage in air (MD, CD & PD)			MD - 0.5 % max, CD- 0.7 % max, Thick – 5 % max			
		(h) pH of aqueous extract			6-9 for solid boards			
		(i) Conductivity of aqueous extract			Up to 1.6 - 5 max (mS/m) > 1.6-3 mm- 6 max, > 3-3.6 mm - 8 max > 6-8 mm TK - 8-10 max			
		(j) Dielectric Strength in Air			Up to 1.6 - 12 kV/ mm > 1.6-3 mm - 11 kV/mm > 3-3.6 mm - 10 kV / mm > 6-8 mm TK - 9 kV/mm			
		(k) Dielectric Strength in Oil			Up to 1.6 - 40 kV/ mm > 1.6-3 mm - 35 kV/mm > 3-3.6 mm - 30 kV / mm > 6-8 mm TK - 30 kV/mm			
		(l) Ash Content (%)			1 % maximum			
		(m) Elongation (MD, CD)			MD CD			

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						Sub-Vendor	Manufacturer	Customer
					Up to 1.6 - 3 % 4 % >1.6-3 mm - 3 % 4 % >3-3.6 mm - 3 % 4 % >6-8 mm TK - 3 % 4 %			
		(n) Tensile strength (MD, CD)			As per relevant std./ Manufacturer's std. practice			
		(o) Internal Ply Bond strength (for laminated pre compressed boards) • Dried (tested at 23°C) • Dried (tested at 120°C retention) • Oil impregnated (tested at 23°C) • Aged for 1 week at 120°C in oil (tested at 23°C retention)			As per relevant std./ Manufacturer's std. practice			
		(p) Flexural strength (MD, CD) (for Laminated pre compressed Boards) (MPa)			As per relevant std./ Manufacturer's std. practice			
		(q) Contamination Dielectric Liquids (for laminated pre compressed press boards) • Neutralization value (mg KOH/g) • Sludge content (mg/l) • Dissipation factor			As per relevant std./ Manufacturer's std. practice			
6.	Perma-wood	(a) Visual & dimensional check, thickness, width & length	One sample of each size per lot	IS 3513 IS 1708 IS 1736 IS 1998 IEC 61061 Approved document	Shall be free from surface defect	P	V	V
		(b) Density			0.8 to 1.3 gm/cc			
		(c) Moisture content			IS 3513/IS 1708			
		(d) Oil Absorption at 90 °C			Min 5%			
		(e) Dielectric Strength at 90 °C			Min 60 KV			
		(f) Tensile strength			Min for LD - 700 KV /cm^2			
		(g) Compressive strength test			Min for LD - 1400 KV /cm^2			
		(h) Shear strength age-wise			Min for LD - 450 KV /cm^2			
		(i) Thickness			Thickness (mm) Tolerance (±mm) 10 to 25 - 1.2 26 to 50 - 1.4 51 to 150 - 2.0			
		(j) Shrinkage (MD, CD) (k) pH Value (l) Breakdown voltage, parallel to the laminations			IEC 61061/Plant standard			
7.	Porcelain Bushings (Hollow)	(a) Visual & dimensional check.	10% Sample per lot As per IS/	IS 3347 IS 8603 IEC 60137	As per approved drawing, IS 3347/IS 8603	P	V	V
		(b) Power frequency voltage withstand test			As per IS 3347/IS 8603/ IEC 60137			

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						Sub-Vendor	Manufacturer	Customer
			IEC					
8.	Polyester Resin Impregnated Glass Fiber Tape	(a) Visual Check	One sample per lot per size	IS 15208	Free from visual defect	P	V	--
		(b) Verification of shelf life			To be used within self-life period not to be used after expiry of period			
		(c) Dimensional Check • Thickness • Width			• 0.25 to 0.35 mm (± 0.07) / as per manufacturer's design • 20 to 50 mm (± 2)			
		(d) Tensile Strength			200 N/mm (min)			
		(e) Resin Content			27 (± 3%)			
		(f) Softening point of resin			Max 200 °C			
		(g) Storage Condition			As per cl. 15.3 of IS 15208			
		(h) Elongation			4% (Max)			
9.	Lacquer (in case it is used)	Manufacturer's std. practice			As per Manufacturer's std. practice	P	V	--
10.	Condenser Bushing (OIP/RIP/RIS)	**Routine Test**	100%	IEC 60137				
		(a) Visual and Dimensional check			No visible damage	P	W	W
		(b) Lightening impulse withstand test (if applicable)			As per IEC 60137			
		(c) Measurement of dielectric dissipation factor and capacitance at room temperature			Tan Delta - 0.5%		P	V
		(d) Dry power frequency voltage withstand test			As per approved GTP	P	W	V
		(e) Measurement of Partial Discharge (PD)			As per IEC - No flash-over/ puncture		W	V
		(f) Pressure Test (for OIP condenser bushing)			No leakage	P	W	V
		(g) Test tap insulation test			As per IEC 60137			
		(h) Tightness test			No leakage	P	W	V
		(i) Creepage distance			As per approved GTP	P	W	W
		(j) Test of oil before carrying out routine test on bushing (for OIP bushing) • BDV			• BDV: Min 70 kV • Water content: Max 5 ppm • Tan Delta at 90^0C Max:0.0025	P	W	V

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		• Water content • Tan delta at 90°C • IFT at 27°C			• IFT at 27°C: Min 0.04 N/m			
		Method & Positioning of Storage			As per bushing manufacturer's guideline		P	--
11.	Buchholz Relay	**Routine test**	100%	IS 3637		P	W	V
		(a) Type & make			As per approved drawing			
		(b) Porosity			No leakage			
		(c) High voltage			2 KV for 1 min. withstand			
		(d) Insulation resistance			Minimum 10 MΩ by 500 V DC megger			
		(e) Element test			No leakage at 1.75 Kg /cm^2 oil pressure for 15 mins			
		(f) Gas volume test at 5° ascending towards conservator			GOR - 1: 90 to 165 CC GOR - 2: 175 to 225 CC GOR - 3: 200 to 300 CC			
		(g) Loss of oil & Surge test			GOR - 1: 70 to 130 CC GOR - 2: 75 to 140 CC GOR - 3: 90 to 160 CC			
12.	Bimetallic Terminal Connector	**Routine test**	100%	IS 5561		P	W	V
		(a) Dimensional			As per approved drawing			
		(b) Visual check			Free form defects			
		(c) Tensile strength			As per type test report			
		(d) Resistance			As per type test report			
		(e) Galvanizing test (if required)			As per type test report			
13.	Marshalling Box/ Cooler Control Cabinet	(a) Dimensional & Visual check (workmanship, clearances, ferruling, labeling, accessories, earthing terminals, mounting/ lifting details, 20% spare TBs etc.)	100%	Approved drawing and specification	As per approved drawing	P	P/W	W/V
		(b) Verification of paint shade, thickness & adhesion			As per approved drawing			
		(c) All Functional Check at max & min rated operating voltage, electrical control operations, alarms, interlocks and sequential operations			As per approved drawing			
		(d) BOM check for Component type, make & rating			As per approved drawing			
		(e) DOP check by thin paper insertion method			As per technical specification			

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						Sub-Vendor	Manufacturer	Customer
		(f) Degree of Protection (IP Class) verification			As per type test report / approved drawing			
		(g) Check for sealing gasket (EPDM rubber for outdoor/ neoprene rubber for indoor)			Free form defects			
		Routine test						
		a. HV test at 2kV (for 1 min) for auxiliary winding			1 min withstand			
		b. Verification of wiring and its routing			Firm and aesthetic			
		c. IR test at 500 V for 1 min			1 min withstand			
14.	Remote Tap Changer Control Panel (if applicable)	(a) Dimension & Visual Check	100%	Approved drawing and specification	As per approved drawing	P	P/W	W/V
		(b) 2kV test for Auxiliary wiring			1 min withstand			
		(c) Paint shade & Thickness			As per approved drawing			
		(d) Wiring routing check			Firm and aesthetic			
		(e) Functional Check			As per approved drawing			
		(f) Verification of BOQ			As per approved drawing			
15.	Air cell (Flexi Air Separator)	Make, Visual check of surface finish of complete air cell & Dimensions	100%	IS 3400	No surface defects. As per approved drawing	P	W	V
		Routine test						
		(a) Pressure test at 0.105 Kg /cm² (10Kpa) for 24 hrs			No leakage for 24 hours	P	W	V
		(b) 10 times inflation and deflation test at 0.105 Kg /cm²			No deformation	P	W	V
		Type tests on basic fabric i. Oil side coating compound ii. Air side inner/outer coating iii. Rubber coating (inner/outer) iv. Coated fabric	One sample per lot of raw material		Tensile strength & elongation at break: ISO 1421 Tear resistance: ISO 4674-1 Coating adhesion: ISO 2411 Gas permeability: ISO 7229	P	W	V
16.	Roller Assembly	(a) Visual & Dimensions.	One sample per lot	IS 5517 IS 2004 IS 28 IS 2026	Free from surface defect	P	V	--
		(b) Mechanical Properties & Chemical composition of raw material used for shaft & roller forging	One sample per melt/heat treatment batch		For shaft as per MS EN8, BS 970-1 For roller wheel of cast iron IS 210 For roller wheel of Cast steel IS 1030			
17.	Oil & Winding Temperature Indicator	(a) Type & make	100%	--	As per approved drawing	P	P/W	V
		(b) Accuracy			± 1.5% of FSD			

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						Sub-Vendor	Manufacturer	Customer
		(c) HV test at 2kV for 1 min between all terminals & earth			Withstand for 1 min			
		(d) Switch contact operation test			Operation within ± 2.5° C of setting			
		(e) Contact Rating			As per Manufacturer's std.			
18.	Pressure Relief Device	(a) Type & Make	100%	As per specification	As per approved drawing & free from defect	P	P/W	W/V
		(b) Air Pressure Test			Operate at Specified pressure ± 0.07 kg/cm^2			
		(c) Liquid Pressure Test						
		(d) Switch/contact testing			Satisfactory operation at pressure release			
		(e) Leakage test at 75% operating pressure			No leakage for 24 hrs			
		(f) HV test			2 kV withstand for 1 min			
		(g) Functional test/Calibration			As per Manufacturer's std.			
		(h) Contact Rating						
19.	Magnetic Oil Level Gauge (MOG)	(a) Type & make	100%	--	As per approved drawing & free from defect	P	P/W	W/V
		(b) Dial Calibration for level			Check pointer position for Max, Min and center level (within tolerance as per specifications)			
		(c) 2kV HV test for 1 min between all terminal & earth			Withstand for 1 minute			
		(d) Leak test with air for 6 Hours			No leakage at 4 kg/cm^2			
		(e) Switch/contact operation test			Operate at Min level indication			
		(f) Contact Rating			As per Manufacturer's std.			
20.	Valves (Gate, Globe & Butterfly)	(a) Type, make & visual check for material of valve body, gate wedge, spindle and gland	100%	IS 778	As per approved drawing & no visible defect	P	W	V
		(b) Dimension check						
		(c) For Gate & Globe Valve: (i) Body test at 1.5 MPa (2 minutes) (ii) Seat test at 1.0 MPa (2 minutes) (iii) Seepage test at 2 kg/cm^2 for 12 hrs.			No leakage			
		(d) For Butterfly valve: (i) Pressure test through body and spindle (ii) Pressure test for diaphragm (iii) Oil seepage test (oil 105± 5 °C, pressure of 1.5 kg/cm^2 for 24 hrs.)			(i) No leakage at 5 kg/cm^2 for 10 minutes (ii) Max 6 drops/min at 1.5 kg/cm^2 (iii) No leak in body and spindle Max 6 drops/min through disc			
21.	Transformer Oil	Routine Test	100%	IS: 335 IEC 60296	As per technical specification	P	W	W

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
				IS 6855				
22.	Tank, Tank-cover, Turret, Conservator & Accessories	(a) Visual check of welding joints including earthing connection, matching of tank with cover& Dimensional check after final welding	100% One per design	CBIP Manual on Transformer 2013	Free from defect	P	W	V
		(b) Visual Check for a fit up for butt welds on tank walls, base & cover			Check for proper welding			
		(c) DP test on Butt welds after fit up & load bearing welds (lifting logs, bollards, jacking pads)			Check for proper welding			
		(d) Air leakage test on assembled tank with turrets & on conservator			No leakage			
		(e) Visual check of paint shade, paint film thickness (inside & outside) & film adhesion, primer application			Paint thickness Outside: 155 micron Inside: 30 micron No peel-off Or As per approved drawing			
		(f) WPS (Weld procedure specification) approval			Details to be furnished As per Specification/ASME Sec IX			
		(g) PQR (Process Qualification Record)			Details to be furnished As per Specification/ASME Sec IX			
		(h) Welders Qualification			Details to be furnished As per Specification/ASME Sec IX	P	W	V
		(i) UT (Ultrasonic test) of tank MS Plate of thickness >12mm.			Details to be furnished As per Specification/ASME Sec IX			
		(j) RT (Radiography test) of butt weld in bottom plate of tank after fit up (if any)			Details to be furnished As per Specification/ASME Sec IX			
		(k) Verification of PWHT (Post weld heat treatment)			Details to be furnished As per Specification/ASME Sec IX			
		(l) Surface cleaning by Shot/sand blasting			Details to be furnished as per Specification			
		(m) Tank - i. Pressure test (PT) ii. Vacuum test (VT) iii. Adhesion test iv. Visual Inspection inside transformer tank before PT & VT test			i. Withstand-Twice the normal head of oil or normal head+ 35 KN/m^2 whichever is lower, maintained at base of bank for 8 hrs. ii. Withstand- 3.33 KN/m^2 for 1 hr. ii. Details to be furnished as per manufacturer's standard. iv. Inputs required as per specification	P	W	V

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						Sub-Vendor	Manufacturer	Customer
		(n) Chemical composition & mechanical property of steel (for tank, tank-cover, conservator, turrets and accessories)		IS 2062 BS 4360	As per relevant standards	P	W	V
23.	Radiators	(a) Chemical composition & mechanical property of raw material	100%	BS EN 50216-1 IS513 Manufcaturer's drawing	As per relevant standards	P	W	W/V
		(b) DP test on lifting lugs welds			No welding defect			
		(c) Surface cleaning of header support and bracing details by sand/shot blasting			Free from surface defect			
		(d) Air pressure test on elements			As per relevant standards /CBIP			
		(e) Dimensional check after final welding			As per approved drawing			
		(f) Air pressure test on radiator assembly by water dipping method			2 kg /cm^2 for 30 minutes - no leakage			
		(g) Visual check of paint shade, paint film thickness & film adhesion			As per tech spec, coating thickness more than 70 micron			
		(h) WPS (Weld Procedure Specification) approval			Details to be furnished, if applicable as per Specification/ASME Sec IX			
		(i) PQR (Process Qualification Record)			Details to be furnished, if applicable as per Specification/ASME Sec IX			
		(j) Welders Qualification			As applicable As per Specification/ ASME Sec IX			
24.	OLTC / OCTC (as applicable)	(a) HV test on Auxiliary circuit (2kV for 1min).	100%	IS 8468 IEC 60214	To Withstand for 1 min	P	P/W	V
		(b) Operational test of complete OLTC including functional check of driving mechanism			Satisfactory operation			
		(c) Pressure test on diverter switch oil compartment			No leakage at 10 Psi for 1 hour			
		(d) Mechanical Operation test of diverter switch (endurance test)			No defect after 5000 operations			
		(e) Mechanical test of tap selector motor drive			500 satisfactory operations between extreme taps			
		(f) Sequence test			Switching time within permissible limit			
		(g) Visual & Dimensional check			Free from defects, dimensions as per drawing			
		(h) Operational test on Surge relay			Satisfactory working of trip & reset			
		(i) Milli volt drop/contact resistance measurement after Mechanical test.			As per standard			
		(j) Condition of Silver plating on contacts			Good condition			
		(k) Measurement of Tan delta			To be provided (value to be used for benchmark) as per manufacturer's standard			

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						Sub-Vendor	Manufacturer	Customer
		(l) Helium Test (barrier board leakage test)- For externally mounted OLTC			To be provided as per manufacturer's standard			
25.	Digital RTCC Relay/ Automatic Voltage Regulating Relay (AVR) (if applicable)	(a) Check of Binary input and output signal along with HMI display nomenclature	100%		as per specification/manufacturer's standard			
		(b) Check availability of spare binary input and output terminal						
		(c) Check communication interface						
		(d) Test for complete function include tap position indication, raise and lower command execution						
26.	Cooling Fans & motor	(a) Type, Make & visual check	100%	IS 2312	As per approved drawing, no visual damage/ defect	P	W	V
		(b) Power consumption, rating test			As per approved drawing			
		(c) HV test (3kV Power frequency withstand test for 1 min)			Should withstand			
		(d) Insulation resistance value			2 MΩ (minimum) with 500 V DC megger			
27.	Nitrile Rubber Gasket	(a) Visual check	1 sample/ Lot	ISO 7619-1 ISO 815 ISO 37 ISO 3865 IS 11149	Free from cracks and pin holes	P	W	V
		(b) Dimensions			Within tolerance			
		(c) Shore Hardness			70 ± 5 IRHD			
		(d) Tensile Strength			12.5 N/mm2 min			
		(e) Compression set test			35% (max) at 70 ± 1° C			
		(f) Elongation at break			250% min			
		(g) Accelerated aging in air (at 100 ± 2° C for 72 hours)			Change in harness: ±15 IRHD Tensile strength change: 20% (max) Elongation change: max +10%/ -25%			
		(h) Accelerated aging in oil (at 100 ± 2° C for 72 hours)			Change in hardness: ±8 IRHD Tensile strength change: 35% (max) Volume change: +20%/ -8%			
		(i) Time period between manufacturing of gasket and its use			To be used within self-life period, not to be used after expiry period			
28.	EPDM Gasket for Marshalling Box	(a) Visual Check	1 sample/ Lot	IS 11149	Free from cracks & pinholes	P	W	V
		(b) Dimensional check (Thickness & Width)			Within tolerance			
		(c) Tensile Strength			As per IS 11149			
		(d) Elongation at break			As per IS 11149			
		(e) Shore Hardness check as per DIN-53505			As per IS 11149			
		(f) Compression test (in air) as per DIN, ISO 815			As per IS 11149			

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29.	Bushing CT	Dimensions (Visual check for ID/OD, thickness)	100%	IS 16227 IEC 61869-2	As per approved drawing			
		Routine test						
		(a) Verification of terminal marking & polarity			As per IS 16227/ IEC 61869-2			
		(b) Overvoltage inter-turn test			Rated current withstand for 1 min			
		(c) Determination of error			As per IS 16227/ IEC 61869-2			
		(d) HV Test (Dry power frequency withstand test on secondary winding)			3 kV AC for 1 min withstand			
		(e) Accuracy Ratio			As per IS 16227/ IEC 61869-2			
		(f) Secondary winding resistance for PS/PX class			As per IS 16227/ IEC 61869-2			
		(g) Knee point voltage & excitation current for PS/PX class						
30.	Oil circulating pump (as applicable)	(a) Visual check	100%	IS 9137	no visual damage/ defect	P	P/W	V
		(b) No load running test (rpm, input power and current) (c)			Satisfactory performance & no load losses within limit			
		(d) HV test (2kV power frequency withstand voltage test for 1 min)			Should withstand			
		(e) Oil pressure test on pumps at 5kg/cm^2 for 30 min			No leakage			
		(f) Locked rotor test			Satisfactory operation of protection			
31.	Oil flow Indicator (as applicable)	(a) Type, Make & Visual check (b) Dial & Calibration (c) Contact Rating (d) Dielectric Test between terminals and earth (e) Leak test at 7 kg/cm2 for 2 min (f) Alarm & trip operation check (g) Full flow check	100%	--	(a) As per standard document, no visual damage/defect (b) As per standard document (c) As per standard document (d) Shall withstand 2 kV for 1 min (e) No leak	P	P/W	V
32.	Power/Control Cable	Review of Supplier's TC for physical & electrical tests as per specification/drawing.	Random	--	As per standard document	P	P	V
33.	Silica Gel Breather	(a) Dimension, Type and model check (b) Check of healthiness & colour of Silica gel (c) Pressure test by blanking oil cup end	100%	-	(a) Within tolerance, Type and model as per drg (b) No visible defect, Gel colour is blue/Orange (c) No leak at 0.35 kg/cm^2 (for 30 Min)	P	W	-

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* Category of Responsibility: P - Actual Test Performance V - Verify and Accept W - Witness Actual testing, verify and accept

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
34.	Drum for insulating oil	(a) Visual check of inside cleanliness and outside coat (b) Dimensional check (thickness, height & diameter) (c) Leakage test on drum (d) Drop test (e) Hydraulic test	100%	IS 1783 –1	As per specifications/ IS 1783-1			

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
B	**IN-PROCESS INSPECTION**						
I	**CRGO Lamination for core**						
	1. Visual check, check length & slitting dimension	One sample of each lot of CRGO	IS 3024	Prime CRGO and Free from defect	--	P	V
	2. Dimensional check			As per design Drawings	--	P	V
	3. Check for burr			Less than 20 micron	--	P	V
	4. Check for Edge bow			As per IS 3024 L< 250mm, H<= 2mm L>= 250 mm, H<= 3mm	--	P	V
II	**Core Building**						
	1. Visual check (frame assembly, arrangement of insulation, bonding of polyester tape)	100%	--	Free from defect	--	P	W
	2. Measurement of Total stack height		As per design drawings	within specified tolerance of design	--	P	W
	3. Core Diameter			within specified tolerance of design	--	P	W
	4. Check window width, window height and diagonal of frame			within specified tolerance of design	--	P	W
	5. Assembly of limb Insulation & plates			As per design	--	P	V
	6. Rectangularity of Core Assembly			As per design	--	P	V
	7. Check for Overlaps & air gap at joints			As per design	--	P	V
	8. Check leaning/ inclination of Core			No leaning	--	P	V
	9. Earthing of Core (check of insulation resistance between CC-CL, CC-Yoke bolt, CL-Yoke Bolt by 2kV megger)			Proper connection	--	P	V
	10. Limb Clamping & Binding			As per design drawings	--	P	V
	11. Insulation test between core & core clamp / frame		As per specification	shall withstand 2.5 kV DC for 1 min.	--	P	W
	12. Yoke Bolt Tightness		Design drawing	As per design		P	V
	13. Loss measurement on built up core assembly OR validation by software		As per specification / GTP	Within limit as per GTP	--	P	W
	14. Built-up core sample collection for watt loss verification	1 sample per design	To be furnished	As per declared/offered value of Watt loss value	--	P	V
III	**Winding/coil**						
	1. Nos. of discs	100%	As per approved drawings / Factory drawing	As per Factory drawing	--	P	V

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	2. No of turns / disc	100%	As per approved drawings / Factory drawing	As per Factory drawing	--	P	V
	3. Dimensional checks i) Outer diameter ii) Inner diameter iii) Unshrunk height iv) Radial thickness	100%	As per approved drawings / Factory drawing	As per Factory drawing	--	P	V
	4. Brazing procedure and brazer's qualification	--	Customer approval	As per approval	-	P	V
	5. Visual inspection of brazed joints	100%	As per brazing procedure	As per approval	-	P	V
	6. Visual check for transposition	100%	As per design drawings	As per design	-	P	V
	7. Visual check for terminal marking & length	100%	As per design drawings	As per design	-	P	V
	8. Insulation arrangement including end insulation	100%	As per design drawings	As per design	-	P	V
	9. Lead & coil identification & marking	100%	As per design drawings	As per design	-	P	V
	10. Continuity test (testing of winding continuity/ brazing test)	100%	--	No breaking of continuity	-	P	V
	11. Coil clamping for shrinking & shrunk coil height and clamping force	100%	As per design drawings	As per design		P	V
	12. Check arrangement of fiber optic sensor (FOS) (if applicable)	100%	As per design drawings	As per design		P	V
	13. Inter-turn Insulation	100%	As per design drawings	As per design	-	P	V
IV	**Core Coil Assembly**						
	1. Visual Check of level of bottom yoke (bearing beam)	100%	--	As per design	-	P	W
	2. Visual Check assembly of the magnetic shields (if applicable)		--	As per design	-	P	W
	3. Visual Check strip barrier assembly on all limbs		--	As per design	-	P	W
	4. Visual Check position of lead take out of HV		--	As per design	-	P	W
	5. Visual Check clamping of upper yoke		--	As per design	-	P	W
	6. Visual Check torque/ pressure of tensile bolt		--	As per design	-	P	W
	7. Visual Check insulation resistance between cooling duct by 500 V megger		--	As per design	-	P	W
	8. Check IR between core and frame at 2 kV by Megger.		--	As per design	-	P	W

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	Check of insulation resistance between CC-CL, CC-Yoke Bolt, CL-Yoke Bolt-2kV Megger						
	9. Visual check for inter-coil insulation		--	As per design	-	P	W
	10. Lead & coil identification & marking		--	As per design	-	P	W
	11. Brazing / Crimping of Joints		--	Shall be smooth and no sharped age	-	P	W
	12. Visual check for completeness, cleanliness, clearance of live parts, absence of sharp edges, placement of lead support assembly		--	Complete assembly shall be free from dust / particles	-	P	V
	13. Ratio test (Not applicable for Reactors)		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	14. Magnetic balance test (Not applicable for Reactors)		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	15. Magnetizing current test, polarity & vector group (Not applicable for Reactors)		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	16. Alignment of Spacers/Blocks		--	Aligned	-	P	V
	17. HV test		Manufacturer's standard	10kV for 1 min withstand	-	P	W
	Core and Coil Assembly (including core cheese assembly) (For reactor only) 1. Check for alignment of core. 2. Verification of placement of first core cheese assembly of core cheese 3. Vertically of limbs and limb Height 4. Visual Physical Verification		As per design drawings	As per plant standard			
V	**DRYING OF ACTIVE PART: Vapor Phase Drying (VPD) Validation**						
	1. Check of temp of Evaporator 2. Check temp of Main heating 3. Check temp of Sprayed Kerosene 4. Check Vacuum Pressure (mbar) of VPD 5. Check Vacuum Pressure (mbar) of Fine vacuum 6. Check Water Extraction (g / Hr / Ton of Insulation) / Process Termination parameters 7. Check total process time (Hrs.)	100%	Manufacturer's standards/drawings /checklist	Manufacturer's standards/drawings/ checklist Graph of Vacuum Vs Time and Temperature Vs time to be submitted for review	-	P	V
	8. Check Oil characteristics before impregnation a. Electric strength b. Water content c. Tan delta at 90^{0}C d. Resistivity at 90^{0}C(For Information)			As per Annexure-L of the document			

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	e. IFT at room temperature						
VI	**Connections and checks before tanking**						
	1. OLTC / OCTC fitting & connections (Not applicable for Reactors)	100%	Manufacturer standard	Manufacturer standard	--	P	---
	2. Check for cable sizes	100%	As per design drawings	As per design	--	P	V
	3. Check for clearance from tank walls	100%	As per design drawings	As per design	--	P	V
	4. Visual checks for crimped joint	100%	--	Shall be smooth and no sharped age	--	P	V
	5. Visual checks for bushing CT assembly tightness	100%	--	Assembly tightness	--	P	V
	6. Ratio test (Not applicable for Reactors)	100%	As per IS 2026 / IEC 60076	Tolerance as per standards	--	P	V
VII	**Tank**						
	1. Thickness of walls	100%	As per approved drawings	As per approved drawings	--	P	V
	2. Dimensions	100%	As per approved drawings	As per approved drawings	--	P	V
	3. Visual internal Inspection	100%	As per approved drawings	As per approved drawings		P	V
	4. Pressure test	100%	As per specification	To withstand, permanent deflection shall not exceed as per specification	--	P	W
	5. Vacuum test	100%	As per specification	To withstand, permanent deflection shall not exceed as per specification	--	P	W
VIII	**Opening, Tanking and Oil filling**						
	1. Drying	100%	Manufacturer standard	Low voltage tan delta and PI values shall be checked periodically and after achieving the satisfactory values the process will be declared complete	--	P	
	2. Checks for complete tightness before taking (a) Tightness of all joints / screws (b) Application of thread locking adhesive (c) Padding of top yoke (d) Pressing of active parts (e) Fitting of wall shunts & packing (f) Electrical clearance of core/coil assembly after completion of terminal gear connections.	100%	Manufacturer standard	As per design	--	P	

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Sr. No.	Item / Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub- Vendor	Manufacturer	Customer
	3. Cleanliness of tank before tanking	100%	Manufacturer standard	Shall be clean.	--	P	---
	4. Tanking of active parts and check for clearance including clearance of the leads from tank walls & Core/frame earthing.	100%	As per design drawings	As per design	--	P	V
	5. 2kV HV test between (a) Core & end frame (b) Core & yoke bolts (c) End frame and yoke bolts	100%	As per specification	To withstand 2kV for 1 min	--	P	V
	6. Check for oil quality before impregnation	100%	As per specification	As per specification	--	P	V
	7. Proper scarfing of insulation during tapping of terminal gear joints, position of leads.	100%	Manufacturer standard	Manufacturer standard		P	V
	8. Oil filling & Air release	100%	Manufacturer standard	Manufacturer standard	--	P	---
	9. Impregnation process	100%	Manufacturer standard	Sufficient impregnation time shall be given before conducting the electrical test on the transformer	--	P	---

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Sr. No.		Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
A.		**Acceptance Tests** **For Transformers:**	100%	Specification IS: 2026 IEC 60076 other applicable standard			
	1.	Appearance, construction and dimension check as assembled for testing			As per approved drawings	P	W
	2.	Check validity of calibration of all test equipment and measuring instruments (e.g. HV test equipment, Loss measurement kit, Partial Discharge kit, impulse units etc.)			As per Specification/ IS: 2026/ IEC 60076/ other applicable standard	-	V
	3.	Measurement of winding resistance at all taps				P	W
	4.	Measurement of voltage ratio at all taps				P	W
	5.	Check of phase displacement and vector group				P	W
	6.	Measurement of no-load loss and current measurement at 90%, 100% & 110% of rated voltage and rated frequency				P	W
	7.	Magnetic balance test (for three phase Transformer only) and measurement of magnetizing current				P	W
	8.	Short Circuit Impedance and load loss measurement at principal tap and extreme taps				P	W
	9.	Measurement of insulation resistance (IR) & Polarization Index (PI)				P	W
	10.	Measurement of insulation power factor and capacitance between winding to earth and between windings				P	W
	11.	Measurement of insulation power factor and capacitance of bushings				P	W
	12.	Tan delta of bushing at variable frequency (Dielectric frequency response)				P	W
	13.	Full wave lightning impulse test for the line terminals (LI) (for 72.5kV< Um≤170 kV)				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility* Manufacturer	Customer
	14.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformers with Um>170 kV)				P	W
	15.	Switching impulse test for the line terminal (SI) (for transformers with Um>170 kV)				P	W
	16.	Applied voltage test (AV)				P	W
	17.	Line Terminal AC withstand voltage test (LTAC) (for transformer with 72.5 kV< Um ≤170 kV)				P	W
	18.	Induced voltage withstand test (IVW) (for transformers with Um ≤170 kV)				P	W
	19.	Induced voltage test with PD measurement (IVPD)				P	W
	20.	Test on On-load tap changer (Ten complete cycle before LV test) and other tests such as One complete operating cycle at 85 % of auxiliary supply voltage ,one complete operating cycle with Transformer energized at rated voltage and frequency at no load .Ten tap change operation with +/- 2 steps of principal tap with as far as possible the rated current of Transformer with one winding short circuited etc. as per IS 2026				P	W
	21.	Measurement of dissolved gasses in dielectric liquid from each separate oil compartment except diverter switch compartment.				P	W
	22.	Check of core and frame insulation				P	W
	23.	Leak testing with pressure for liquid immersed transformers (tightness test)				P	W
	24.	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.				P	W
	25.	Frequency Response analysis after completion of test for max, min &				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
		normal tap (Soft copy of test report to be submitted to site along with test reports)					
	26.	High voltage withstand test on auxiliary equipment and wiring after assembly				P	W
	27.	Tank vacuum test (at tank supplier premises during tank manufacturing)				P	W
	28.	Tank pressure test (at tank supplier premises during tank manufacturing)				P	W
	29.	Check of the ratio and polarity of built-in current transformers				P	W
	30.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)				P	W
	31.						
B.	**Type Tests/Special test**		One from Lot	Specification/ IS:2026 / IEC 60076/other applicable standard	Specification/ IS:2026 / IEC 60076/other applicable standard		
	For Transformers:						
	1.	Measurement of transferred surge on Tertiary due to HV lightning impulse				P	W
	2.	Measurement of transferred surge on Tertiary due to HV switching impulse				P	W
	3.	Full wave lightning impulse test for the line terminals (LI) (for Um<= 72.5kV)				P	W
	4.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformer with Um≤170 kV)				P	W
	5.	Lightning impulse test for the neutral terminals (LIN)					
	6.	Switching impulse test for the line terminal (SI) (applicable for Um>72.5 kV & ≤170 kV)				P	W
	7.	Temperature rise test				P	W
	8.	Measurement of Zero seq. reactance (for three phase Transformer only)				P	W

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Sr. No.	**Test**		**Sampling rate**	**Reference / Standard**	**Acceptable Value**	**Category of Responsibility***	
						Manufacturer	**Customer**
	9.	Measurement of harmonic level in no load current				P	W
	10.	Determination of sound level				P	W
	11.						
	12.	Short circuit withstand capability test (Dynamic)				P	W

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Typical example for calculation of flux density, core quantity, no-load loss and weight of copper

Calculation of flux density, core quantity, no-load loss and weight of copper for a specific transformer has been given below. Similar calculations for any rating of transformer can be carried out and relevant data may be obtained from the manufacturer.
Example: 75 MVA, 220/11, YNd11, 3 Phase, Power transformer,
Tap Range: -2.5% to +7.5% , Off-circuit Switch (Linear) connection

Measured data of core step width and thickness:

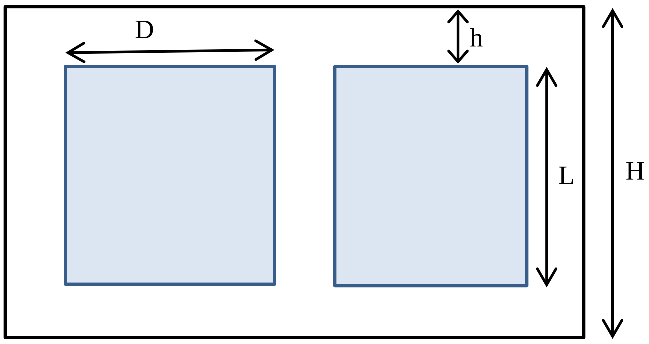
STEP NO.	**WIDTH**	**THICKNESS**	**THICKNESS**	**AREA OF STEP**	**AREA OF STEP**	**SUM OF STEP AREA**
	(mm)	**(mm)**	**(mm)**	**(mm^2)**	**(mm^2)**	**(mm^2)**
1	260	8.25	8.25	2145.00	2145.00	4290.00
2	300	8.41	8.41	2523.00	2523.00	5046.00
3	320	8.17	8.17	2614.40	2614.40	5228.80
4	360	8.48	8.48	3052.80	3052.80	6105.60
5	380	8.52	8.52	3237.60	3237.60	6475.20
6	400	8.45	8.45	3380.00	3380.00	6760.00
7	440	8.42	8.42	3704.80	3704.80	7409.60
8	460	14.4	14.4	6624.00	6624.00	13248.00
9	500	10.05	10.05	5025.00	5025.00	10050.00
10	520	19.06	19.06	9911.20	9911.20	19822.40
11	560	25.43	25.43	14240.80	14240.80	28481.60
12	600	14.5	14.5	8700.00	8700.00	17400.00
13	620	15.5	15.5	9610.00	9610.00	19220.00
14	640	15.79	15.79	10105.60	10105.60	20211.20
15	660	19.1	19.1	12606.00	12606.00	25212.00
16	680	23.2	23.2	15776.00	15776.00	31552.00
17	700	23.07	23.07	16149.00	16149.00	32298.00
18	720	40.05	40.05	28836.00	28836.00	57672.00
19	740	71.67	71.67	53035.80	53035.80	106071.60
				GROSS AREA (mm^2):		**422554.00**
Stacking Factor = 0.96 to 0.97						
NET CORE AREA (A)=Gross Area x Stacking factor= 422554 x 0.96 mm^2 = 4056.52 cm^2						

CALCULATION OF FLUX DENSITY:

Phase voltage = 4.44 f x B_{max} x A x N x 10^{-4}
Where,
Phase voltage = 11 kV
Frequency (f) =50 Hz
A= 4056.52 cm^2
N= No. of turns on 11 kV side =72

Maximum flux density, B_{max} = (11000)/(4.44*50*4056.52*72*10^{-4}) = 1.696 T

CALCULATION OF WEIGHT OF CORE:



Net core area (A) = 4056.52 cm^2
Window height (L) = 2000 mm
Yoke height (h) =740 mm
Core Height (H) = L+ 2 x h= 2000 + (2 x 740)=3480 mm
Window width (D) =810 mm
Limb Pitch = D+h = 810+740 = 1550 mm

There are 3 core heights and 4 window widths

Hence, total periphery of the core = 3H+4D = (3x3480) +(4x810)
= 13680 mm =1368 cm

Weight of the core
= Total periphery of the core x Cross-section area of core x Density of CRGO steel
=1368.0 x 4056.52 x 7.65 x 10^{-3}
= **42452.3 kg**

Guaranteed weight as per GTP= 42000 kg

Average Core Lamination Thickness =0.23 mm
Cooling duct thickness measured =4.24 mm

CALCULATION OF NO LOAD LOSS FROM SUPPLIER'S LOSS CURVES:

Weight of core lamination = **42452.3 kg**

Flux density at normal tap at 100% rated voltage=1.696 T

Referring to supplier's curves for core losses against working flux density
The value of watts/kg at 1.7 Tesla. = 0.78 approx

No load loss = Core weight x Watts/kg at 1.7 Tesla x Building Factor x 10^{-3} kW
= 42452.3 x 0.78 x 1.11x 10^{-3}= 36.755 kW
(Where the value of building factor taken is 1.11)

Guaranteed No Load Loss = 39.0kW

Calculated No load loss < (Guaranteed loss figure)

<u>Estimation of copper quantity during stage Inspection</u>

A. Weight of bare copper by ID/OD METHOD

	Periphery (P) (mm)	Outer Dia (OD) =P/3.14 (mm)	Radial depth (RD) (mm)	Mean Dia (OD-RD) (mm)
LV Winding	**3035**	966.1	**77.60**	888.5
HV Winding	**4585**	1459.5	**169.50**	1290.0
Regulating (Tap) Winding	**4585**	1459.5	**169.50**	1290.0

No. of Turns:
LV Winding: 72 HV Winding: 811 Tap Winding : 84

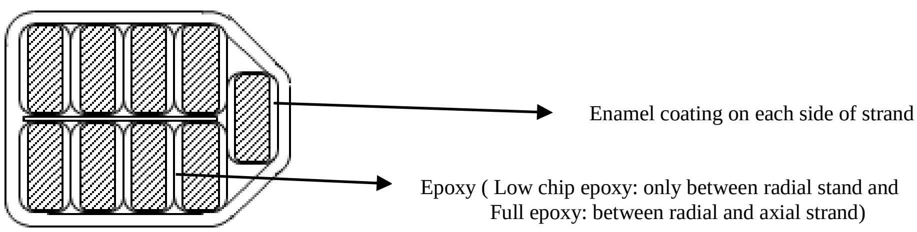
Type of Conductor in LV winding – Continuously Transposed Cable (CTC)
No. of Coils in LV Winding =1
No. of Cables parallel in LV Winding =2
No. of strands per cable in LV Winding = 77

Type of Conductor in HV winding – Twin Paper Insulated Copper Conductor (TPICC)
No. of Coils parallel in HV Winding =2
No. of Cables per turn in HV Winding=2
No. of strands per cable in HV Winding=2

Type of Conductor in Tap winding – Paper Insulated Copper Conductor (PICC)
No. of Coils parallel in Tap Winding=2
No. of Cables per turn in Tap Winding=3
No. of strands per cable in Tap Winding=1

No. of phases = 3

Measured Strand dimension
Size of LV strand **=** 5.067 x 1.929 mm (with 0.1 mm enamel and 0.04 mm epoxy)
So bare size of LV strand = (5.067-0.1) x (1.929 -0.14*) mm (* Low chip epoxy used)
= 4.967 x 1.789 mm



Bare Size of HV strand = 9.880 x 1.792 mm
Bare Size of Tap strand = 7.845x 3.012 mm
Area of each LV Cable = Strand area x No of strands/Cable

= [(4.967x1.789)-0.363)] x 77 = 656.27 mm^2
Area of each HV Cable = Strand area x No of strands/Cable
= [(9.88x1.792)-0.363)] x 2 = 34.68 mm^2
Area of each Tap Cable = Strand area x No of strands/Cable
= [(7.845x3.012)-0.55] x 1 = 23.08 mm^2

Bare Cu Weight of LV winding
= 3 x π x Mean Diameter x No. of Turns x Area of cable x No. of cables per turn x Cu Density
= 3 x 3.142 x 888.5 x 72 x 656.27 x 2 x 8.89x 10^{-6} = 7036 kg

Bare Cu Weight of HV winding
= 3 x π x Mean Diameter x No. of Turns x Area of cable x No. of cables per turn x Cu Density x No. of parallel Coils
= 3 x 3.142 x 1290 x 811 x 34.68 x 2 x 8.89x 10^{-6}x 2= 12161 kg

Bare Cu Weight of Tap winding
= 3 x π x Mean Diameter x No. of Turns x Area of cable x No. of cables per turn x Cu Density x No. of parallel Coils
= 3 x 3.142 x 1290 x 84 x 23.08 x 3 x 8.89x 10^{-6}x 2= 1258 kg

Total Bare Copper weight = 7036+12161+1258 = 20455 kg

B. WEIGHT OF BARE COPPER BY PER UNIT LENGTH METHOD

Measured bare cable Cu weight of LV winding per 650 mm = 3718 gm
bare cable Cu weight of LV winding per unit length = 5720 gm/meter

Measured bare cable Cu weight of HV winding per 595 mm = 184 gm
bare cable Cu weight of HV winding per unit length = 309.3 gm/meter

Measured bare cable Cu weight of Tap winding per 745 mm = 160 gm
bare cable Cu weight of Tap winding per unit length = 214.8 gm/meter

Bare Cu Weight of LV winding
= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length
= 3x 3.142x888.5x72x 2 x5720 x 10^{-6} = 6898 kg

Bare Cu Weight of HV winding
= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length x No. of parallel Coils
= 3x3.142x1290x811x2x309.3x2x 10^{-6} = 12200 kg

Bare Cu Weight of Tap winding
= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length x No. of parallel Coils
= 3 x3.142 x 1290x 84 x 3 x 214.8 x2x 10^{-6} = 1316 kg

Total Bare Copper weight = 6898+12200+1316 = 20414 kg

C. WEIGHT OF BARE COPPER BY RESISTANCE METHOD

Measured Ambient temperature = 31 ^{o}C
Measured Resistance of each strand of LV = 0.42760 ohm
Measured Resistance of each LV cable = 0.42760/77
= 0.005553ohm
Measured Resistance per strand of each HV coil (46 disc from HV center)
= 3.121 ohm

Measured Resistance per strand of each HV coil (Last 4 disc of HV bottom)
= 0.26834 ohm

So Total Measured Resistance per Stand of each HV coil (50 disc from HV centre)
= 3.121 + 0.26834
=3.38934 ohm
So Total Measured Resistance per Cable of each HV coil (50 disc from HV centre)
= 3.38934/2 = 1.69467 ohm
Measured Resistance per cable of each Tap coil (2 disc of Tap coil) = 0.067465 ohm
So, Total Measured Resistance per cable of each Tap coil (8 disc of Tap coil)
= 0.067465 x 8/2 =0.26986

Resistivity (ρ) of Copper (at 20 ^{o}C) = 0.017241 ohms- mm^2/meter

Resistance Conversion factor at 20 ^{o}C = (235+20)/(235+31)= 0.95865
Resistance of LV Winding at 20 ^{o}C = Resistance of LV Winding x Resistance Conversion factor
= 0.005553 x 0.95865 = 0.005324 ohm
Resistance per cable of each HV coil at 20 ^{o}C = Resistance of HV cable x Resistance Conversion factor
=1.69467 x 0.95865 =1.6246 ohm
Resistance per cable of each Tap coil at 20 ^{o}C = Resistance of Tap cable x Resistance Conversion factor
= 0.26986 x 0.95865
= 0.2587 ohm
R = ρ (L/A)

ρ : Resistivity, L : Length in Meters, A : Area of conductors in mm^2

Length of each LV cable = (R x A)/ ρ **=** 0.005324x 656.27/ 0.017241
= 202.27 x10^3 mm
Length of each HV cable = 1.6246 x 34.68/ 0.017241
= 3267.86 x10^3 mm
Length of each Tap cable = 0.2587 x 23.08/ 0.017241
= 346.31 x10^3 mm
Bare Cu Weight of LV winding
= 3 x length of per cable x area of each cable x no. of parallel cables x Cu density
= 3 x 202.27 x10^3 x 656.27 x 2 x 8.89x 10^{-6}
= 7081 kg

Bare Cu Weight of HV winding
= 3 x length of per cable x area of all parallel conductors x Cu density x No. of parallel Coils
= 3 x 3267.86 x10^3 x 34.68 x 2 x 8.89x 10^{-6} x 2
= 12090 kg

Bare Cu Weight of Tap winding

= 3 x length of per cable x area of all parallel conductors x Cu density x No. of parallel Coils

= $3 \times 346.31 \times 10^{3} \times 23.08 \times 3 \times 8.89 \times 10^{-6} \times 2$

= 1279 kg

Total Bare Copper weight = 7081+12090+1279= 20450 kg

D. CURRENT DENSITY CALCULATION:

LV winding:

Current = 2272.73 A; Conductor area = 656.27x2= 1312.54 mm^2

Current density = 2272.73 / 1312.54 = 1.73 A/mm^2

HV winding: (Minimum Tap)

Current = 201.88 A; Conductor area = 34.68 x2x2= 138.72 mm^2

Current density = 201.88 / 138.92 = 1.46 A/mm^2

Tap Winding: (Minimum Tap)

Current = 201.88 A; Conductor area = 23.08 x3x2= 138.48 mm^2

Current density = 201.88 / 138.92 = 1.46 A/mm^2

BASIC MANUFACTURING FACILITY & MANUFACTURING ENVIRONMENT

Customer/Purchaser always desires that transformer manufactured and delivered is of good quality and must perform trouble free service for its "Specified Design Life". The consistency in quality of material used & manufacturing process are main cause for variation in quality of transformer. It is also equally very important that transformer is manufactured in a clean dust free and humidity controlled environment. Any compromise on this aspect will have adverse effect in expected design life of transformer, however good is the quality of material used. A broad list of facilities the transformer manufacturers should have are given below:

Basic manufacturing facility

Following manufacturing facility should be available for use with transformer manufacturer:

1. EOT Crane for main manufacturing bay and other shops (With Load Cell).
2. Vapor Phase Drying Oven (adequately sized to accommodate offered transformer and have facility to record temperature, vacuum, moisture etc.)
3. Air Casters for material handling
4. Core cutting line (if applicable)
5. Vacuum auto claves
6. Air oven
7. Adjustable Horizontal and vertical winding machine
8. Winding Mandrels
9. Hydraulic Press
10. Brazing equipment
11. Mechanical platform
12. Tools and fixtures
13. Mechanical power press
14. Welding machines
15. Crimping tools
16. Faraday's cage
17. Motor Generator Set/ Static Power System Set

18. Testing transformer
19. Capacitor bank
20. Impulse voltage generator
21. Capacitance & Tan delta bridge
22. Power Analyser
23. Current & Voltage transformer
24. Partial Discharge (PD) measuring kit (for all manufacturers) & PD Diagnostic Kit (for 400 kV & above voltage class Transformer manufacturer)
25. Temperature data logger
26. Noise measurement kit
27. Thermo vision camera
28. Loss measurement kit
29. Insulation tester
30. Winding resistance meter
31. Turn ratio meter
32. Transformer oil test lab
33. Dissolved Gas Analysis (DGA) test kit
34. Sweep Frequency Response Analyser (SFRA) kit
35. Frequency Domain Spectroscopy (FDS) kit
36. **NABL Accredited laboratory for testing**
37. Oil Storage tanks
38. Oil filter plant with requisite level of vacuum and filter
39. Tensometer for Oil Surface tension
40. Particle Count Kit (for 400 kV & above Transformer)
41. Multimeters

Manufacturing environment (Clean, dust free and humidity controlled environment)

A. Transformer must be manufactured in a bay having positive pressure w.r.t. external environment. Winding shall be manufactured in an clean, dust free and humidity controlled environment. The dust particle shall be monitored regularly in the manufacturing areas. Further, there shall be positive atmospheric pressure, clean, dust free and humidity controlled environment for following:

1. Insulation storage
2. Core storage
3. Glue stacking area
4. Core cutting line
5. Winding manufacturing bay
6. Core building area
7. Core coil assembly area
8. Testing lab
9. Packing & dispatch area

B. Following accessories to be kept in clean and covered location:

1. Piping
2. Radiator
3. Tank
4. Bushing (as per manufacturer's guideline)
5. Marshalling box
6. Turret
7. Conservator
8. Insulating oil

Annexure- H

List of drawings/documents to be submitted by the manufacturer

1.0 Each drawing shall be identified by a drawing number and each subsequent resubmission/revision or addition to the drawing shall be identified by a revision number. All drawings shall be thoroughly checked for accuracy & completeness and signed. Any mistakes or errors in drawings shall not form a basis for seeking extension of delivery period.

2.0 In addition to any other drawings which the manufacturer may like to supply, the following drawings/ calculations/ documents/ catalogues shall be submitted in hard and soft copy:

(a) Guaranteed Technical Particulars (GTPs) and other Technical particulars
(b) Rating and Diagram Plate giving details of terminal marking and connection diagram
(c) General Arrangement (GA) drawing (as built drawing) of transformer showing Plan, Elevation, End view (left side & right side view looking from HV side) and 3D view identifying various fittings & accessories, dimensions, weight, clearances, quantity of insulating oil, centre of gravity etc.
(d) View showing maximum lifting height of core-coil assembly and maximum clearance over tank top required for taking out the bushing.
(e) List of all accessories, description, make, weight and quantity
(f) Bill of Materials (BoM) with description, make & quantity
(g) Foundation Plan showing Rail gauge, fixing details of foundation bolts, clamping arrangement to restrict movement during earthquake & location of jacking pads and loading details
(h) Bushing Drawing showing dimensions, electrical & mechanical characteristics, mounting details and test tap details (as applicable)
   i) HV Bushing
   ii) LV (or LV1/LV2)Bushing
   iii) Tertiary Bushing
   iv) Neutral Bushing
(i) Transport Dimension Drawing indicating transport weight, transport condition (oil filled/ gas filled), lifting bollards,

jacking pads, pulling eyes, quantity and location of impact recorder etc.

(j) General Arrangement Drawing of Cooler Control Cabinet, Marshalling box

(k) General Arrangement Drawing of RTCC panel (if applicable)

(l) GA drawing for Junction Box (if applicable)

(m) GA drawing for Cable Box (if applicable)

(n) Cooler Control Scheme: Schematic wiring diagram of cooling arrangement along with write up on scheme

(o) Tap Changer Control Scheme (if applicable): Schematic wiring diagram of OLTC along with write up on scheme

(p) Mounting Arrangement and wiring diagram of remote WTI along with write up.

(q) Alarm/Trip Indication Scheme

(r) Valve Schedule Plate drawing showing all valves, air vents, drain plugs etc. with type, size, material and quantity of valves

(s) Technical literature of all fittings and accessories

(t) Calculation in support of thermal withstand capability of transformer due to short circuit

(u) Calculation of hot spot temperature

(v) Value of air core reactance with a typical write-up of calculation

(w) Magnetisation Characteristics of bushing CTs and neutral CTs

(x) Hysteresis Characteristics of iron core

(y) Over fluxing withstand duration curve

(z) Typical heating and cooling curves

(aa) Drawing showing winding arrangement & geometrical sequence w.r.t core with winding ID/OD, height & separation distance between windings etc.

(bb) Twin bi-directional roller assembly drawing

(cc) Oil Flow Diagram

(dd) List of spares

(ee) Connection diagram of all protective devices to marshalling box showing physical location

(ff) Insulating oil storage tank drawing

(gg) Oil sampling Bottle details

(hh) Customer inspection schedule

(ii) Test procedure of transformer/reactor

(jj) Manufacturer Quality Program (MQP) and Field Quality Plan (FQP) (kk) Field Welding Schedule for field welding activities (if applicable)

(ll) Type test reports

(mm) O&M manual (hard copy and soft copy) of transformer/reactor inter-alia including instructions for Aircell, Oil filling, Bushing removal and Core Coil Assembly un-tanking etc.

Annexure – I

SCOPE OF DESIGN REVIEW

Sr. No.	Description
1.	Core and Magnetic Design
2.	Over-fluxing characteristics up to 1.7 U_m (for transformer) and Linear characteristics (for reactor)
3.	
4.	Inrush-current characteristics while charging
5.	Winding and winding clamping arrangements
6.	Characteristics of insulation paper
7.	Typical data and parameters mentioned in GTP
8.	Short-circuit withstand capability including thermal stress / withstand capability for 2 seconds .
9.	Thermal design including review of localized potentially hot area
10.	Structural design
11.	Overvoltage withstand capability of reactor
12.	Cooling design
13.	Overload capability
14.	Calculations of losses, flux density, core quantity etc.
15.	Calculations of hot spot temperature
16.	Eddy current losses
17.	Seismic design, as applicable
18.	Insulation co-ordination
19.	Tank and accessories
20.	Bushings
21.	Mechanical layout design including lead routing and bushing termination
22.	Tapping design (as applicable)
23.	Protective devices
24.	Number, locations and operating pressure of PRD)
25.	Location, Operating features and size of Sudden Pressure Relay/ Rapid Pressure Rise Relay
26.	Radiators and Fans

27.	Sensors and protective devices– its location, fitment, securing and level of redundancy
28.	Oil and oil preservation system
29.	Corrosion protection
30.	Electrical and physical Interfaces with substation
31.	Earthing (Internal & External)
32.	Processing and assembly
33.	Testing capabilities
34.	Inspection and test plan
35.	Transport and storage
36.	Sensitivity of design to specified parameters
37.	Acoustic Noise
38.	Spares, inter-changeability and standardization
39.	Maintainability
40.	Conservator capacity calculation
41.	Winding Clamping arrangement details with provisions for taking it "in or out of tank"
42.	Conductor insulation paper details
43.	Location and numbers of Optical temperature sensors (if provided)
44.	The design of all current connections
45.	Location & size of the Valves
46.	Manufacturing facilities and manufacturing environment (clean, dust free, humidity controlled environment) as per Annexure G

Annexure-J

CRITERIA FOR SELECTION OF SIMILAR REFERENCE TRANSFORMER FOR DYNAMIC SHORT CIRCUIT WITHSTAND TEST

A transformer is considered similar to another transformer taken as a reference if it has the following characteristics in common with the latter:

- Same type of operation, for example generator step-up unit, distribution, interconnection transformer;
- Same conceptual design, for example dry type, oil-immersed type, core type with concentric windings, sandwich type, shell type, circular coils, non-circular coils;
- Same arrangement and geometrical sequence of the main windings;
- Same type of winding conductors, for example aluminium, aluminium alloy, annealed or work-hardened copper, metal foil, wire, flat conductor, continuously transposed conductors and epoxy bonding, if used;
- Same type of main windings, for example helical-, disc-, layer-type, pancake coils;
- **Absorbed power at short circuit (rated power/per unit short-circuit impedance) between 70% and 130% of that relating to the reference transformer;**
- Axial forces and winding stresses occurring at short circuit not exceeding 120 % of those relating to the reference transformer;
- Same manufacturing processes;
- Same clamping and winding support arrangement.

(**Note:-**A format for comparison of characteristics as given above of successfully type tested reference transformer and of transformer short circuit strength of which shall be evaluated (offered transformer) has been provided below. Data of a typical sample reference transformer has been filled for reference and guidance of utility to compare a Short Circuit tested transformer with the offered transformer in order to verify the similarity criteria.)

DATE :	Format for determining similar reference transformer for short Circuit withstand Strength	Manufacturer NAME
DOC No.:		
Page: -- of --		

		Details of offered transformer short circuit strength of which is being evaluated	Details of SC tested transformer	Is characteristic similar ?	Reference document /Remarks if any
General Information					
	Customer and Purchase Order No.:				
	Project Name:				
	Transformer General Rating Description (MVA, Voltage Ratio, tested short circuit current):		**315MVA, 400/220/33KV AUTOTRANSFORMER, 3 phases, --kA**		

	Unit number/ Serial no:				
	Short circuit test laboratory detail:	-NA-	KEMA, Netherland		
	Short circuit test report reference No. & Date:	-NA-			
Characteristics as per IEC 60076-5 :2006					
1	**Type of Transformer based on operation:** *e.g. Generator Step up unit; Distribution; Interconnecting; Auto; Station auxiliary etc.*		**AUTO transformer**	**Yes/No**	Reference: 1. *Rating & Diagram plate 2. Approved GTP
2	**Factory of production, material used (Material of conductor, cellulose insulating material, oil, grade of CRGO material), and as built Drawing**				Reference: Short circuit test report
3	**Tested Short Circuit Current and duration of Dynamic short circuit current (250ms / 500ms)**				Reference: Short circuit test report along with as built drawing

<table>
<tr>
<td>4</td>
<td>Conceptual design

e.g. Dry / oil-immersed type ; Core type with concentric windings / sandwich type, shell type, Circular coils / non-circular coils</td>
<td></td>
<td>OIL-IMMERSED, CORE TYPE, CONCENTRIC WINDINGS, CIRCULAR COILS</td>
<td>Yes/No</td>
<td>Reference:
1. Rating & Diagram plate
2. Approved GTP</td>
</tr>
<tr>
<td>5</td>
<td>Arrangement and geometrical sequence of main windings

e.g.; Core-LV-HV-T</td>
<td></td>
<td>CORE - LV (TER) – REG – IV - HV</td>
<td>Yes/No</td>
<td>Reference:
1. Winding assembly drawing in Short circuit test report if available
2. *Or Representative Coil assembly drawing reference</td>
</tr>
<tr>
<td>6</td>
<td>Type of conductors for each winding

e.g aluminium / aluminium alloy, annealed or work-hardened Copper; metal foil / wire / flat conductor / Continuously Transposed conductor; Epoxy bonding (Yes/No); work hardened Proof stress (min) N/mm^2</td>
<td></td>
<td><table>
<tr><td></td><td>LV</td><td>Tap</td><td>IV</td><td>HV</td></tr>
<tr><td>Conductor</td><td>COPPER</td><td>COPPER</td><td>COPPER</td><td>COPPER</td></tr>
<tr><td>Type</td><td>CTC</td><td>CTC</td><td>CTC</td><td>CTC</td></tr>
<tr><td>Epoxy coated</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Proof stress N/mm (min)</td><td></td><td></td><td></td><td></td></tr>
</table></td>
<td>Yes/No</td>
<td>Reference:
1. *Test Certificates submitted by the conductor Vendor for each winding
2. Approved GTP</td>
</tr>
<tr>
<td>7</td>
<td>Type of each windings</td>
<td></td>
<td><table>
<tr><td>Winding</td><td>LV</td><td>Tap</td><td>IV</td><td>HV</td></tr>
</table></td>
<td>Yes/No</td>
<td>Reference:
1. In case Short ckt. test report is inclusive of detail on</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td><table><tr><td>5a</td><td>e.g. Helical- /Layer- / Disc- type / pancake coils</td></tr><tr><td>5b</td><td>e.g. Line lead entry (top, bottom , Center, Edge)</td></tr></table></td>
<td></td>
<td><table><tr><td>Type</td><td>Layer /Disc</td><td>Multi-start Layer</td><td>Disc</td><td>Disc</td></tr><tr><td>Line Lead entry</td><td>Top/Bottom</td><td>Top/Bottom</td><td>Top/Bottom</td><td>Center entry</td></tr></table></td>
<td></td>
<td>Winding type
Lead entry detail
2. Representative Coil assembly drawing reference</td>
</tr>
<tr>
<td>8</td>
<td>Absorbed power at Short Circuit
(= Rated Power/per unit short circuit impedance)
[The ratio shall be between 70 % to 130% of that rating of the reference transformer]</td>
<td></td>
<td><table><tr><td>Sc. Tested Transformer</td><td>Max Voltage Tap</td><td>Min Voltage Tap</td><td>Nor Voltage Tap</td></tr><tr><td>Rated MVA</td><td>315</td><td>315</td><td>315</td></tr><tr><td>Impedance measured after sc. test</td><td>10.4%</td><td>12.5%</td><td>15.4%</td></tr><tr><td>Absorbed power (MVA)</td><td>3028.85</td><td>2520.00</td><td>2045.45</td></tr></table></td>
<td>Yes/No</td>
<td>Reference:
1. Short ckt test report inclusive of Routine test Impedance values</td>
</tr>
</table>

9	**Axial force and winding stresses occurring at short circuit as per IS table** *(Simulated as in Same Declared Program or same Calculation method used)* *[The axial forces and winding stresses occurring at SC shall not exceed 120% of that of reference transformer]*		As per Table given in IS 2026-5/IEC 60076-5. **(A typical example with data of forces and stresses has been provided at the end of this Annexure-J.)**	**Yes/No**	Reference: 1. As per calculation made / results of the simulation software used (Name of software used :…….)
10	**Same manufacturing process**		**General Process reference to be provided** Manufacturing process as per Standard common practice & QAP plan for the subject rating & type	**Yes/No**	Reference: 1. *Standard QAP plan submitted 2. Standard document for Manufacturing Practice (On site availability)

11	**Same clamping and winding support arrangement** [Core Clamping principle, winding radial & axial support system, **cleats & lead support arrangement**]		**General conceptual description to be provided** 1. Core clamping drawing with support arrangement and calculation of SC force withstand by clamping structure. 2. Winding drawing with axial and radial support details, lead exit details	**Yes/No**	Reference: 1. Clamping arrangement: Provide basic details 2. Winding bottom support structure and cleat & lead arrangement: Adequacy has been validated by the simulation software.....

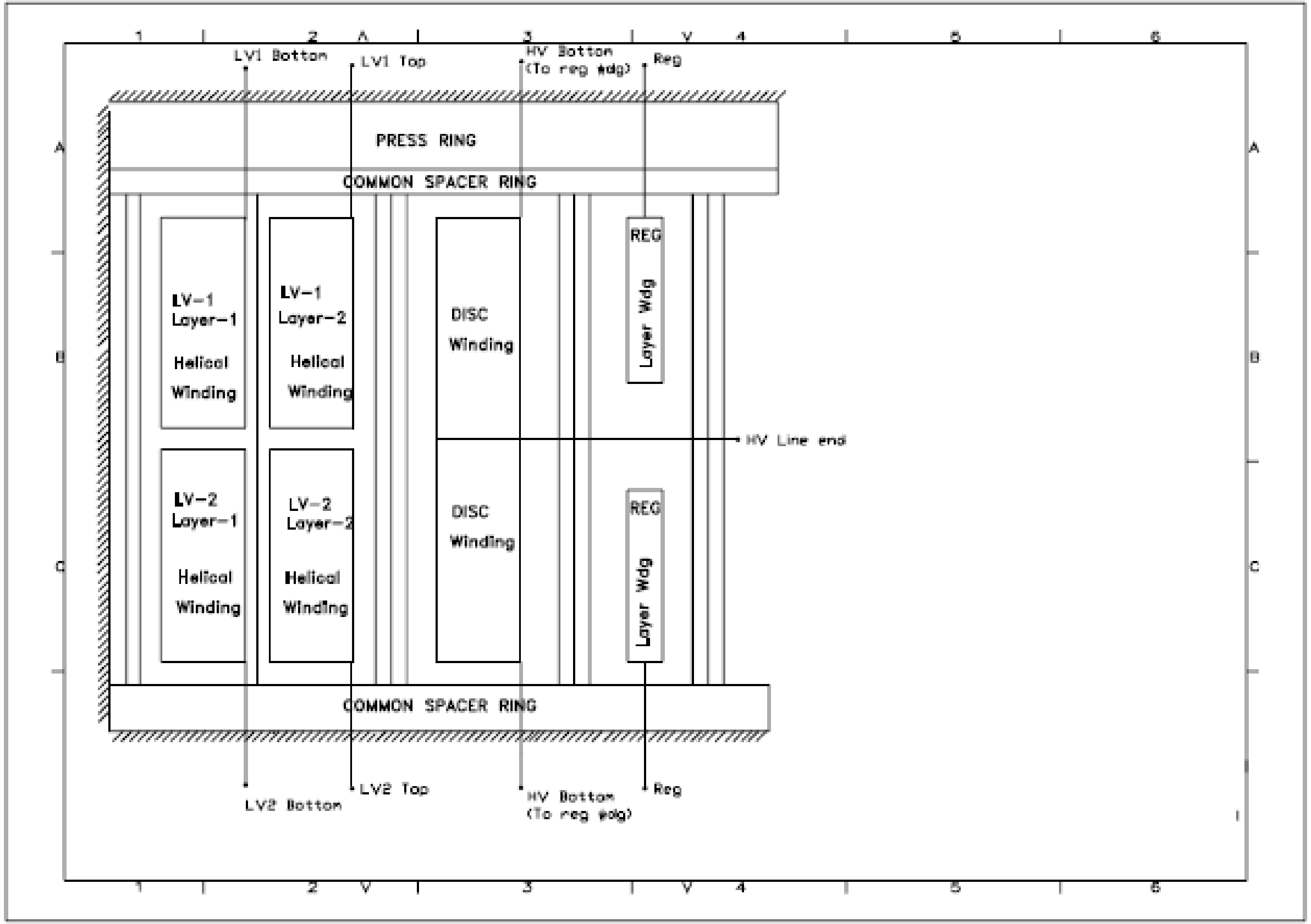
*To be made part of short circuit test report document

(For design to be similar every criteria specified above should match)

<u>Result</u>: The reference transformer was found/not found to be similar to the offered transformer. Design review of offered transformer can be carried out by comparison with reference transformer as per the process given in IEC 60076-5.

Manufacturer Signature Purchaser's Signature

Representative Coil assembly reference Winding Arrangement



The detail comparison of technical parameters of typical offered & reference short circuit tested transformer is given below. The data is for reference and guidance purpose only.

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
1.00	Contract Ref.	………	………
1.01	Package & Substation	………	………
2.00	**Rating**		
2.01	HV / LV	315 MVA	500 MVA
2.02	TV	105 MVA	167 MVA
2.03	Cooling	ONAN/ONAF/ODAF	ONAN/ONAF/ODAF
2.04	Rating at Different cooling	189/252/315MVA (60%/80%/100%)	300/400/500MVA (60%/80%/100%)
2.05	Voltage ratio	400/220/33 kV	400/220/33 kV
2.06	Voltage / Turn	200	280
2.07	Frequency	50 Hz	50 Hz
2.08	Phases	3	3
2.09	Max. Partial discharge at 1.58 Um/√3	<100 pC	<100 pC
2.10	Design of Power Frequency Level	570 kVrms	570 kVrms
2.11	Noise Level	80 dB	80 dB

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
2.12	Neutral (Solidly Earthed)	Solidly Earthed	Solidly Earthed
2.13	Service	Outdoor	Outdoor
2.14	Duty	Continuous	Continuous
2.15	Overload capacity	As per IEC 60076-7	As per IEC 60076-7
3.00	**Impedance with Tolerance**		
3.01	HV - LV		
3.02	Normal tap	Designed/Guaranteed/Measured	Designed/Guaranteed
3.03	Max Voltage tap	12.10%/12.5% ± IEC Tol/12.4%	12.4%/12.5% ± IEC Tol
3.04	Min Voltage tap	9.8%/-/10.12%	9.8%/10.3% ± IEC Tol
3.05	HV - TV	16.8%/-/16.29%	16.1%/15.4% ± IEC Tol
3.06	Normal tap		
3.07	Max Voltage tap	67%/60% Min/69.36%	64%/60% Min
3.08	Min Voltage tap	59%/-/60.81%	56%
3.09	LV-TV	79%/-/80.94%	75%
4.00	Temp. rise over an ambient of 50 Deg C		
4.01	Top Oil	35 Deg C	45 Deg C

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
4.02	Winding	40 Deg C	50 Deg C
4.03	Winding hot spot rise	66 Deg C	61 Deg C
4.04	Core hot spot rise	61 Deg C	55 Deg C
5.00	Guaranteed losses at Principle tap, rated voltage & frequency (Mentioned measured values in DSC tested unit)	Guaranteed/Measured/Designed	Designed/Guaranteed
5.01	Load Loss, kW	444.5/425.78/429.39	495/500
5.02	No Load loss, kW	104.5/84.27/84.18	88.4/90
5.03	Aux Loss, kW	8.5/6.76/8.28	15/15
6.00	**System Fault Level (HV / IV / LV)**		
6.01	If System fault level is higher than SC tested T/F please submit calculation of short circuit impedance variation.	50/40/-kA	63/50/-kA
7.00	Winding connection (HV/IV/LV)	Auto Star/Delta	Auto Star/Delta
8.00	Insulation (HV/IV/LV)	Graded/Graded/Uniform	Graded/Graded/Uniform
8.01	HV (LI/LIC/SI/PF/AC)	1300kVp/1430kVp/1050kVp/570kVrms /38kVrms	1300kVp/1430kVp/1050kVp/570kVrms /38kVrms
8.02	IV (LI/LIC/SI/PF/AC)	950kVp/1045kVp/750kVp/395kVrms/38kVrms	950kVp/1045kVp/750kVp/395kVrms/38kVrms

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
8.03	LV (LI/LIC/AC)	250kVp/275kVp/95kVrms	250kVp/275kVp/95kVrms
8.04	N (LI/AC)	170kVp/38kVrms	170kVp/38kVrms
9.00	**Bushing Ratings**		
9.01	HV	420kV/2000A, OIP Condenser	420kV/1250A, RIP Condenser
9.02	LV	245kV/1250A, OIP Condenser	245kV/2000A, RIP Condenser
9.03	TV	72.5kV/3150A, OIP Condenser	52kV/3150A, RIP Condenser
9.04	Neutral	36kV/2000A, Oil Communicating	36kV/2000A, Oil Communicating
9.05	Impulse level (HV/IV/LV/N)	1425kVp/1050kVp/250kVp/170kVp	1425kVp/1050kVp/250kVp/170kVp
9.06	Switching impulse level (HV/IV)	1050kVp/850kVp	1050kVp/850kVp
9.07	Power Frequency (Dry) (HV/IV/LV/N)	695kVrms/505kVrms/105kVrms/77 kVrns	695kVrms/505kVrms/105kVrms/77 kVrns
10.00	**CORE**		
10.01	Flux Density at Rated Voltage	1.722 T	1.72 T
10.02	Core Construction [main limb / return limb]	3 Main Limbs / 2 Return Limbs	3 Main Limbs / 2 Return Limbs
10.03	Cross-section ratio - Main & Return limb Main limb & Yoke	100% & 53% 100% & 53%	100% & 53% 100% & 53%

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
10.04	Core Diameter	815	1015
10.05	Window Height (top of Bottom yoke to bottom of top yoke)	2500	2400
10.06	Phase center /Phase - Return limb	2315 / 1420	2610/1650
10.07	Grade	HP Grade	HP Grade
10.08	Building factor	1.17	1.18
10.09	Weight	67500 kgs Approx.	108500 kgs Approx.
11.00	**Winding**		
11.01	Winding arrangement sequence (Core - LV - Reg. - Common - Series)	Core - LV - Reg. - Common - Series	Core - LV - Reg. - Common - Series
11.02	Winding Type & Material		
11.03	LV	Helical, Electrolytic Copper	Helical, Electrolytic Copper
11.04	REG	Multi Helical, Electrolytic Copper (Tap)	Multi Helical, Electrolytic Copper (Tap)

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
11.05	IV	Disc, Electrolytic Copper	Disc, Electrolytic Copper
11.06	HV	Shielded disc, Electrolytic Copper	Shielded disc, Electrolytic Copper
12.00	**Conductor Type / dimension / Insulation**		
12.01	LV	Epoxy Bonded CTC, 1.5 x 7.8//23, 0.5 PI	Epoxy Bonded CTC, 2|| (1.3 x 5.4//31), 0.5 PI
12.02	REG	Epoxy Bonded CTC, 1.25 x 4.8//25, 1.5 PI (ZNO elements used)	Epoxy Bonded CTC, 1.36 x 6.5//27, 1.5 PI (ZNO elements used)
12.03	IV	Epoxy Bonded CTC, 1.4x 6.45//23, 1.1 PI	Epoxy Bonded CTC, 2|| (1.1 x 6.4//25), 1.1 PI
12.04	HV	Epoxy Bonded CTC, 2 X (1.4 x 5.5//17), 1.5 PI	Epoxy Bonded CTC, 2 X (1.1 x 5.7//35), 1.5 PI
13.00	**Proof Stress Value in Mpa**		
13.01	LV	180	200
13.02	REG	160	200
13.03	IV	200	200

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
13.04	HV	160	200
13.00	**ID / OD / Height**		
13.01	LV	875/955/1900	1075/1160/1780
13.02	REG	1115/1155/1780	1320/1365/1700
13.03	IV	1305/1575/1950	1515/1845/1790
13.04	HV	1755/2100/1950	2069/2430/1790
14.00	**No of Turns (Max / Nor / Min) Voltage Tap**		
14.01	LV	165	115
14.02	REG	112/0/112	80/0/80
14.03	IV	635	450
14.04	HV	520	368

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
15.00	**Winding weight**	Bare Copper	Bare Copper
15.01	LV	3440 kg	4300 kg
15.02	REG	2100 kg	2300 kg
15.03	IV	16450 kg	20700 kg
15.04	HV	22400 kg	27500 kg
16.00	**Current Density (Max / Nor / Min) Voltage Tap (A/mm²)**		
16.01	LV	4.02	3.99
16.02	REG	2.85/3.14/3.49	2.81/3.1/3.44
16.03	IV	2.03/1.83/1.58	1.92/1.73/1.49
16.04	HV	1.62/1.78/1.98	1.54/1.7/1.89
17.00	**Loss at Max / Nor / Min Voltage Tap (kW)**		

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
17.01	I^2R	385 / 344 / 415	441 / 394 / 471
17.02	Stray	39/ 45 / 56	47 / 54 / 117
17.03	Eddy	30/ 37 / 55	37 / 47 / 67
17.04	Stray+Eddy	69 / 82 / 111	84 / 101 / 184
17.05	Total Load Loss	454 / 426 / 526	525 / 495 / 655
17.06	% (Stray+Eddy) of Load loss	15.2 / 19.3 / 21	16 / 20.5 / 28
17.07	Core loss	84.5	88.4
18.00	**GAP (mm)**		
18.01	CORE - LV or CORE-TV	30	30
18.02	LV - REG	80	80
18.03	REG - IV	75	75
18.04	IV-HV	90	112

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
18.05	PH - PH	175	177
18.06	PH - RETURN LIMB	160	166
19.00	**Spacers / Circle (Nos. x Width)**		
19.01	LV	24 x 35W	36 X 30W
19.02	REG	24 x 45W	36 X 40W
19.03	IV	36 X 40W	36 X 45W
19.04	HV	36 X 50W	36 X 60W
20.00	**Supporting Area ((No of spacer x width) *100/Mean dia)**		
20.01	LV	29.20%	31.0%
20.02	REG	30.3%	34.1%
20.03	IV	32.0%	31.0%
20.04	HV	30.0%	30.5%

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
21.00	**Top Ring Thickness & Material**	100 mm & Laminated Press Board	130 mm & Laminated Press Board
22.00	**Bottom Ring Thickness & Material**	80 mm & Laminated Press Board	90 mm & Laminated Press Board
23.00	**Oil Quantity during first filling**	100 kL	115 kL
24.00	**Tank Thickness**		
24.01	**Side**	12 mm	12 mm
24.02	**Top**	25 mm	25 mm
24.03	**Bottom**	20 mm + Box Stiffener	20 mm + Box Stiffener
25.00	Change of Solid Insulation & Oil duct for above GAP (Sr. No – 18.0) YES / NO	-	Similar/No change w.r.t short circuit tested unit.
26.00	Active Part arrangement (Core & Coil Assembly) Change YES / NO	-	Similar/No change w.r.t short circuit tested unit.

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
27.00	Internal clearance in oil (Active part - Tank) Change (Yes / No)	-	Similar/No change w.r.t short circuit tested unit.
28.00	Cooling System (Radiator, Fans, Pumps) Change (Yes / No), If yes, submit detailed design calculation for supporting documents)	-	Same / Fans & pumps are suitably considered to dissipate total losses

Comparison Table - Forces & Electric Field Stress Summary			DOC No : ______________ REV : _________________
Sr. No	**Technical Parameters**	**315MVA, 400/220/33 kV Short Circuit Tested**	**500MVA, 400/220/33 kV Offered Transformer**
1.0	NOA Ref No.	-----	-----
1.1	Package & Substation	-----	-----
2.0	Radial Forces (Actual / Permissible) (N/mm^2 or Mpa)		
2.1	LV	57.05/180 Mpa	47.5/200 Mpa
2.2	Regulating	56.06/160 MPa	75.16/200 Mpa
2.3	IV	61.93/200 Mpa	69.56/200 Mpa
2.4	HV	86.14/160 Mpa	100.25/200 Mpa
3.0	Axial Tilting Forces (Actual / Permissible) (kN)		
3.1	LV	3954/37207 kN	485/105686 kN
3.2	Regulating	296/6764 kN	398/3164 kN

3.3	IV	1436/129384 kN	1819/111123 kN
3.4	HV	1105/56222 kN	2405/349302 kN
4.0	Axial Yoke Clamp Force in Winding (kN)	1912 kN	1723 kN
5.0	Compressive Force in Winding (Actual / Permissible) (kN)		
5.1	LV	3954/9845 kN	485/1421 kN
5.2	Regulating	296/432 kN	398/796 kN
5.3	IV	1436/2585 kN	1819/4075 kN
5.3	HV	1105/3591 kN	2405/4642 kN
6.0	Tengential (Spiralling) Force in LV Winding (Actual / Permissible) (kN)	310.36/979.24	18.29/61.6
7.0	Dielectric Stresses (Actual / Permissible) (kV_{rms}/mm)		
7.1	Oil Stress (Core - LV)	< 6.5 kV_{rms}/mm	
7.2	Oil Stress (LV - Regulating)	< 6.5 kV_{rms}/mm	
7.3	Oil Stress (Regulating- IV)	< 6.5 kV_{rms}/mm	

7.4	Oil Stress (IV- HV)	< 6.5 kV_{rms}/mm
7.5	Max Oil Stress Location & Value	IV - HV winding < 6.5 kV_{rms}/mm
7.6	Creep Stress in LV Winding	< 3 kV_{rms}/mm
7.7	Creep Stress in Regulating Winding	< 3 kV_{rms}/mm
7.8	Creep Stress in IV Winding	< 3 kV_{rms}/mm
7.9	Creep Stress in HV Winding	< 3 kV_{rms}/mm
7.10	Paper Stress	< 16 kV_{rms}/mm
7.11	Stress at Normal Service condition	Less than half of above values

Comparison of forces and stresses of 500MVA,400/220/33kV,3-Phase Auto Transformer with SC tested 315MVA,400/220/33kV, 3-Phase Auto Transformer as per IEC-60076-5

Doc. No: ________________; Rev_________

Type of force/ Stress	Tertiary Winding				Tap Winding				Common Winding				Series Winding			
	Actual	Reference	Allowable	Critical	Actual	Reference	Allowable	Critical	Actual	Reference	Allowable	Critical	Actual	Reference	Allowable	Critical
Mean hoop tensile stress on disc-, helical-, and layer type windings (Mpa)	Not Applicable				16.41	10.99	160	-	21.95	14.18	200	-	100.25	86.14	200	-
Mean hoop compressive stress on disc, helical, single layer type windings (Mpa)	47.5	57.05	160	-	75.16	56.06	160		69.56	61.93	200		Not Applicable			
Equivalent mean hoop compressive stress on multi layer type windings (Mpa)	Not applicable															

Stress due to radial bending of conductors between axial sticks and spacers (Mpa)	70.5	642	211.5	-	69.6	14.63	123.8	-	201.9	22.66	278.6	-				-
Stress due to axial bending of conductors between radial spacers (Mpa)	305.44	1375	1460	-	177.8	134.8	1146.8	-	2574.08	1114	8597.4	-	2336.2	5160	11120.4	-
Thrust force acting on the low voltage winding lead exists (kN)	18.29	310.36	61.6	-	Not Applicable				Not Applicable				Not Applicable			
Maximum axial compression force on each physical winding (kN)	485	3954	1421	-	398	296	796	-	1819	1436	4075	-	2405	1105	4642	-

Maximum axial compression force on winding compared to crit. Force for tilting (kN)	485	3954	-	105686	398	296	-	3164	1819	1436	-	111123	2405	1105	-	349302
Maximum end thrust force on physical winding : - UP (kN) - DOWN (kN)	201/ 165	2429/ 3316	-	-	101/ 97	82/59	-	-	572/ 744	531/ 508	-	-	785/ 877	732/ 750	-	-
Compressive stress on conductor paper Insulation and radial spacers (Mpa)	11.25	20.1	80	-	17.66	16.77	80	-	8.78	12.56	80	-	10.55	5.78	80	-
Compressive stress on end stack insulation structures and end ring (Mpa)	4.66	12.35	80	-	4.48	4.64	80	-	2.76	4.63	80	-	3.44	3.83	80	-

	Actual	Reference	Allowable	Critical
Compressive stress on common press rings (Mpa)	59.21	60.27	80	-
Tensile stress on tie rods (Mpa)	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Clamping force per limb (kN)	1723	1912	-	

Annexure-K

PAINTING PROCEDURE

PAINTING	Surface preparation	Primer coat	Intermediate undercoat	Finish coat	Total Dry Film Thick-ness (DFT)	Colour shade
Main tank, pipes, conservator tank, oil storage tank & Driving Mechanism (DM) Box etc. (external surfaces)	Shot Blast cleaning Sa 2 ½*	Epoxy base Zinc primer (30-40μm)	Epoxy high build Micaceous iron oxide (HB MIO) (75μm)	Aliphatic polyurethane (PU) (Minimum 50μm)	Minimum 155μm	RAL 7035
Main tank, pipes (above 80 NB), conservator tank, oil storage tank & DM Box etc. (Internal surfaces)	Shot Blast cleaning Sa 2 ½*	Hot oil resistant, non-corrosive paint, low viscosity varnish or epoxy	--	--	Minimum 30μm	Glossy white for paint
Radiator (external surfaces)	Chemical / Shot Blast cleaning Sa 2 ½*	Epoxy base Zinc primer (30-40μm)	Epoxy base Zinc primer (30-40μm)	PU paint (Minimum 50μm)	Minimum 100μm	Matching shade of tank/ different shade aesthetically matching to tank

	Manufacturer may also offer Radiators with hot dip galvanised (in place of painting) with minimum thickness of 40μm (min)					
Radiator and pipes up to 80 NB (Internal surfaces)	Chemical cleaning, if required	Hot oil proof, low viscosity varnish or Hot oil resistant, non-corrosive Paint	--	--	--	--
Digital 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	Minimum 80μm / for powder coated minimum 100μm	RAL 7035 shade for exterior and Glossy white for interior
Control cabinet / Marshalling Box - No painting is required.						

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

Annexure–L

I. UNUSED INHIBITED HIGH GRADE INSULATING OIL PARAMETERS

Sl. No.	Property	Test Method	Limits
A	**Function**		
1a.	Kinematic Viscosity at 40 °C	IS 1448 Part 25 or ISO 3104 or ASTM D7042	12 mm^2/s (Max.)
1b.	Kinematic Viscosity at -30 °C		1800 mm^2/s (Max.)
2.	Appearance	A representative sample of the oil shall be examined in a 100 mm thick layer, at ambient temperature	The oil shall be clear and bright, transparent and free from suspended matter or sediment
3.	Pour point	IS 1448 Part 10/Sec 2 or ISO 3016	-40 °C (Max.)
4.	Water content a) for bulk supply b) for delivery in drums	IEC 60814	 30 mg/kg (Max.) 40 mg/kg (Max.)
5.	Electric strength (breakdown voltage)	IS 6792 or IEC 60156	Minimum 30 kV (new unfiltered oil) / 70 kV (after treatment)
6.	Density at 20 °C	IS 1448 Part 16 or ISO 12185 or ISO 3675 or ASTM D7042	895 kg/m^3 (Max.)
7.	Dielectric dissipation factor (tan delta) at 90 °C	IS 16086 or IEC 60247 or IEC 61620	0.0025 (Max.)
8.	Negative impulse testing KVp @ 25 °C	ASTM D3300	145 (Min.)
9.	Carbon type composition (% of Aromatic, Paraffins and Naphthenic compounds)	IEC 60590 and IS 13155 or ASTM D2140	Maximum Aromatic : 4 to12 % Paraffins : <50% & balance shall be Naphthenic compounds.
B	**Refining/Stability**		
1.	Colour	ISO 2049	L0.5 (less than 0.5)

2.	Appearance	–	Clear, free from sediment and suspended matter
3.	Neutralization Value (Total Acidity)	IEC 62021-1 or IEC 62021-2	0.01 mg KOH/g (Max.)
4.	Interfacial tension at 27°C	IEC 62961 or ASTM D971	0.043 N/m (Min.)
5.	Total sulphur content	ISO 14596 or ISO 8754	0.05 % (Max.) (before oxidation test)
6.	Corrosive sulphur	DIN 51353	Not Corrosive
7.	Potentially corrosive sulphur	IEC 62535	Not Corrosive
8.	Presence of oxidation inhibitor	IS 13631 or IEC 60666	0.08% (Min.) to 0.4% (Max.)
9.	DBDS	IEC 62697-1	Not detectable (<5 mg/kg)
10.	Metal passivator additives	IEC 60666	Not detectable (<5 mg/kg)
11.	2-Furfural and related compound content	IS 15668 or IEC 61198	Not detectable (<0.05 mg/kg) for each individual compound
12.	Stray gassing under thermo-oxidative stress	Procedure in Clause A.4 of IEC 60296-2020 (oil saturated with air) in the presence of copper	Non stray gassing: < 50 µl/l of hydrogen (H_2) and < 50 µl/l methane (CH_4) and < 50 µl/l ethane (C_2H_6)
C	**Performance**		
1.	Oxidation stability	IEC 61125 (method c) Test duration: 500 hours	
	-Total acidity*	4.8.4 of IEC 61125:2018	0.3 mg KOH/g (Max.)
	-Sludge*	4.8.1 of IEC 61125:2018	0.05 % (Max.)
	-Dielectric Dissipation Factor* (tan delta) at 90 °C	4.8.5 of IEC 61125:2018	0.05 (Max.)
	*values at the end of oxidation stability test		
D	**Health, safety and environment (HSE)**		

1.	Flash point	IS 1448 Part 21 or ISO 2719	135 °C(Min.)
2.	Poly Cyclic Aromatic (PCA) content	IP 346	<3%
3.	Poly Chlorinated Biphenyl (PCB) content	IS 16082 or IEC 61619	Not detectable (< 2 mg/kg)

Note: Supplier shall declare the chemical family and function of all additives and the concentrations in the cases of inhibitors, antioxidants and passivators.

II. UNUSED UNINHIBITED INSULATING OIL PARAMETERS

Sl. No.	Property	Test Method	Limits
A	**Function**		
1a.	Kinematic Viscosity at 40 °C	IS 1448 Part 25 or ISO 3104 or ASTM D7042	12 mm²/s (Max.)
1b.	Kinematic Viscosity at -30 °C		1800 mm²/s (Max.)
2.	Appearance	A representative sample of the oil shall be examined in a 100 mm thick layer, at ambient temperature	The oil shall be clear and bright, transparent and free from suspended matter or sediment
3.	Pour point	IS 1448 Part 10/Sec 2 or ISO 3016	-40 °C (Max.)
4.	Water content a) for bulk supply b) for delivery in drums	IEC 60814	 30 mg/kg (Max.) 40 mg/kg (Max.)
5.	Electric strength (breakdown voltage)	IS 6792 or IEC 60156	Minimum 30 kV (new unfiltered oil) / 70 kV (after treatment)
6.	Density at 20 °C	IS 1448 Part 16 or ISO 12185 or ISO 3675 or ASTM D7042	895 kg/m³ (Max.)
7.	Dielectric dissipation factor (tan delta) at 90 °C	IS 16086 or IEC 60247 or IEC 61620	0.0025 (Max.)

8.	Negative impulse testing KVp @ 25 °C	ASTM D3300	145 (Min.)
B	**Refining/Stability**		
1.	Colour	ISO 2049	Max. 1.5
2.	Appearance	–	Clear, free from sediment and suspended matter
3.	Neutralization Value (Total Acidity)	IEC 62021-1 or IEC 62021-2	0.01 mg KOH/g (Max.)
4.	Interfacial tension at 27°C	IEC 62961 or ASTM D971	0.04 N/m (Min.)
5.	Corrosive sulphur	DIN 51353	Non-Corrosive on copper and paper
6.	Potentially corrosive sulphur	IEC 62535	Non-Corrosive
7.	Presence of oxidation inhibitor	IS 13631 or IEC 60666	Not detectable (<0.01%)
8.	DBDS	IEC 62697-1	Not detectable (<5 mg/kg)
9.	Metal passivator additives	IEC 60666	Not detectable (<5 mg/kg)
10.	2-Furfural and related compound content	IS 15668 or IEC 61198	Not detectable (<0.05 mg/kg) for each individual compound
C	**Performance**		
1.	Oxidation stability	IEC 61125 (method c) Test duration: 164 hours	
	-Total acidity*	4.8.4 of IEC 61125:2018	1.2 mg KOH/g (Max.)
	-Sludge*	4.8.1 of IEC 61125:2018	0.8 % (Max.)
	-Dielectric Dissipation Factor* (tan delta) at 90 °C	4.8.5 of IEC 61125:2018	0.5 (Max.)
	*values at the end of oxidation stability test		
D	**Health, safety and environment (HSE)**		

1.	Flash point	IS 1448 Part 21 or ISO 2719	135 °C(Min.)
2.	Poly Cyclic Aromatic (PCA) content	IP 346	<3%
3.	Poly Chlorinated Biphenyl (PCB) content	IS 16082 or IEC 61619	Not detectable (< 2 mg/kg)

Note: Supplier shall declare the chemical family and function of all additives and the concentrations in the cases of inhibitors, antioxidants and passivators.

III. Oil used for first filling, testing and impregnation of active parts at manufacturer's works shall meet parameters as mentioned below

1	Break Down voltage (BDV)	-	70kV (Min.)
2	Moisture content	-	5 ppm (Max.)
3	Tan-delta at 90°C	-	0.005 (Max.)
4	Interfacial tension	-	0.04 N/m (Min.)

IV. Each lot of the oil shall be tested prior to filling in main tank at site for the following:

1	Break Down voltage (BDV)	-	70 kV (Min.)
2	Moisture content	-	5 ppm (Max.)
3	Tan-delta at 90°C	-	0.0025 (Max.)
4	Interfacial tension	-	0.04 N/m (Min.)

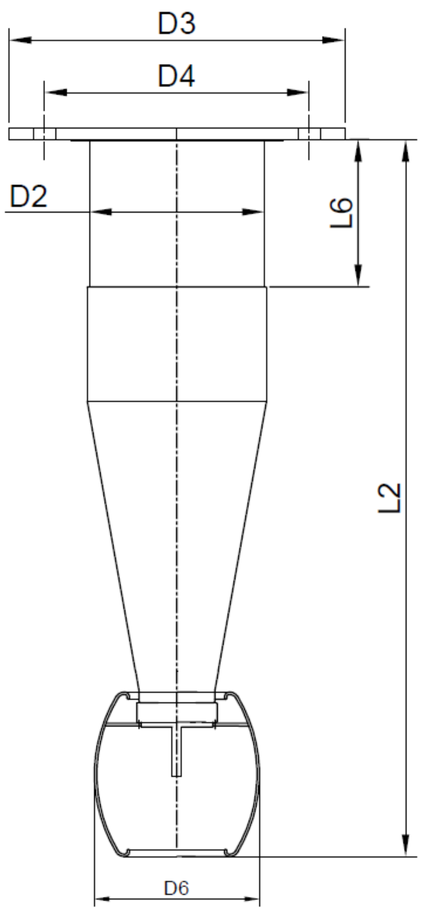
V. After filtration & settling and prior to energization at site oil shall be tested for following:

1	Break Down voltage (BDV)	-	70 kV (Min.)
2	Moisture content at hot condition	-	5 ppm (Max.)
3	Tan-delta at 90°C	-	0.005 (Max.)
4	Interfacial tension	-	0.04 N/m (Min.)
5	*Oxidation Stability	-	
	a) Acidity		0.3 (mg KOH /g) (Max.)-For Inhibited Oil 1.2 mg KOH/g (Max.)-For Uninhibited Oil
	b) Sludge	-	0.05 % (Max.) - For Inhibited Oil 0.8 % (Max.) - For Uninhibited Oil

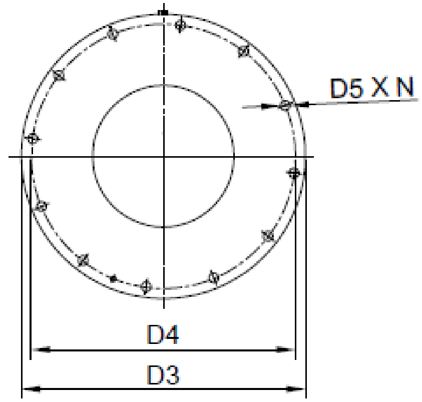
	c) Tan delta at 90 °C	-	0.05 (Max.) - For Inhibited Oil 0.5 (Max.) - For Uninhibited Oil
6	Total PCB content*		Not detectable (< 2 mg/kg)
	* Separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of the utility		

STANDARD DIMENSIONS FOR CONDENSER BUSHINGS

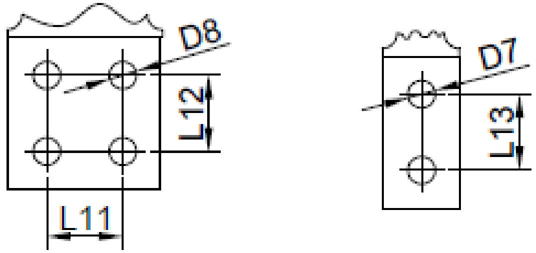
(For 420 kV and below voltage class Bushings)



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 kVp	1425	1050		650		325		250
Creepage Distance (mm)	13020	7595		4495		2248		1612
Current Rating (A)	**1250**	**1250**	**2000**	**1250**	**2000**	**800**	**2000**	**1250**
Type of lead	Solid Stem (SS)	SS	SS	SS	SS	SS		SS
L2 ±5	1640	1130	1230	800	1030	695		450
L6 (min.)	400	300		300	300	300		100
D2 (max.)	350	270		165	180	115	165	115
D3±2	720	450		335	335	225	335	225
D4±1 (PCD)	660	400		290	290	185	290	185
D5xN	24x12	20x12		15x12	15 x12	15x6	15x12	15x6
D6 (max.)	350	270		180		115		115
L11	-	-	45	-	45	-	55	-
L12	-	-	40	-	40	-	40	-
L13	40	40	-	40	-	40	-	40
D7	Φ14	Φ14		Φ14	Φ14	Φ14	Φ14	Φ14
D8	-	-	Φ 14	-	-	-	-	-
Length & Diameter of Air End Terminal	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60

Notes:

1. All dimensions are in mm.
2. No positive tolerance where maximum dimension specified and no negative tolerance where minimum dimension is specified.
3. For other details of oil end terminal for 2000 A (145 kV/245 kV) solid stem type bushing, refer Fig 4 of IS 12676.
4. For other details of oil end terminal for 2000 A, 72.5 kV solid stem type bushing, refer Fig 3B of IS 12676.
5. For other details of oil end terminal for 800 A and 1250 A (52kV/72.5 kV/145 kV/245 kV/420 kV) solid stem type bushing, refer Fig 3A of IS 12676.

PHYSICAL INTERCHANGEABILITY OF TRANSFORMERS OF DIFFERENT MAKE

1.0 One of the objectives of standardization is to achieve physical interchangeability of transformers of different makes, procured by utility (ies), by standardizing the minimum foundation loading to be considered for civil foundation design of transformers. In case of failure of any transformer, outage time to replace a failed unit by a spare unit/new unit of different make would be minimized as it can be accommodated in the same space without/minor modification in existing foundation.

2.0 In general, the foundation layout & design of transformer depends on weight of the transformer (with oil and all fittings & accessories), design of soak pit (with or without remote oil collecting pit) with trans rack/grating & gravels and free space to be kept below the transformer to accommodate oil and water in case of fire. The number of rails, number & location of jacking pads of transformers are also equally important.

3.0 The foundation design should take into account the following points:

The foundations of transformer should be of block type foundation. Minimum reinforcement should be governed by IS: 456.

a) Transformer can be placed on foundation either directly or on roller assembly (with suitable locking arrangement) along with suitable anti Earthquake Clamping Device as specified in Chapter-2.

b) The plinth height of transformer foundation may be kept from 300 mm to 500 mm above finished ground level of the substation/switchyard depending upon the size of the transformer. Pulling blocks should be provided for shifting of transformer for maintenance purposes.

c) The pedestal support should be provided for supporting the cooler bank, firefighting system etc. The RCC Rail-cum-road system integrated with the transformer foundation may be provided to enable installation and the replacement of any failed unit. The transfer track system should be suitable to permit the movement of any failed unit fully assembled (including OLTC, bushings) with oil. This system should enable the removal of any failed unit from its foundation to the nearest road. If trench/drain crossings are required, then suitable

R.C.C. culverts should be provided in accordance with I.R.C. standard/relevant IS.

d) Foundation of each transformer including oil conservator tank and cooler banks etc. should be placed in a self-sufficient pit surrounded by RCC retaining walls (Pit walls). The retaining wall of the pit from the transformer should be such that no part of transformer/reactor is outside the periphery of retaining wall.

e) An oil soak pit of adequate capacity should be provided below each oil filled transformer to accommodate at least 150% of full quantity of oil contained in the transformer and minimum 300 mm thick layer of gravels/pebbles of approximately 40 mm size (spread over a steel iron grating/trans rack) providing free space below the grating. Alternatively, an oil soak pit should be provided below each transformer/reactor to accommodate 1/3rd of total quantity of oil contained in the transformer and minimum 300 mm thick layer of gravels/pebbles of approximately 40 mm size (spread over a steel iron grating/trans rack) providing free space below the grating provided a common remote oil collecting pit of capacity at least equal to oil quantity in the largest size transformer/reactor is provided for a group of transformers. Bottom of the soak pit below the transformer/reactor should be connected to the common oil collecting pit with drain pipe (two or more Hume/concrete pipes) of minimum 150 mm diameter with a slope not less than 1/96 for fast draining of oil and water through gravity from soak pit to the burnt oil collecting pit, which is generally located away from transformers/reactors.

f) Every soak pit below a transformer should be suitably designed to contain oil dropping from any part of the transformer.

g) The common remote oil collecting pit and soak pit (when remote oil collecting pit is not provided) should be provided with suitable automatic pumping facility, to always keep the pit empty and available for an emergency.

h) The disposal of transformer oil should be carried out in an environmental friendly manner.

i) The minimum height of the retaining walls of pit should be 150mm to 200mm above the finished ground level to avoid outside water pouring inside the pit. The bottom of the pit is generally made of PCC M15 grade and should have a uniform slope towards the sump pit. While designing the oil collection pit, the movement of the transformer must be taken into account.

j) The grating shall be made of MS flat of size 30 mm x 5 mm at spacing of 30 mm and MS bar of 6 mm dia at spacing of 150 mm at right angle to each other. Maximum length & width of grating should be 2000 mm & 500 mm respectively. The gratings, supported on ISMB 150 mm, should be placed at the formation level and will be covered with 300 mm thick layer of stone aggregate having size 40 mm (approximate). All steel work used for grating and supports should be painted with epoxy based zinc phosphate primer (two packs) confirming to IS: 13238-1991, thereafter with two or more coat of bituminous paint of approved quality should be applied.

k) In case of transformers with separately mounted cooler / radiator bank, the position of the cooler / radiator bank has been recommended on the left side of the transformer when viewing from HV side. However, transformer shall be designed in such a way that cooler / radiator bank can be positioned on either side of the main tank. Similarly the conservator shall be on the left side of the tank while viewing from HV side.

l) The separation wall(s) or fire barrier wall(s) of four hours fire withstand rating shall be provided between the transformers and reactors or between the transformer(s) & the adjacent wall of a building if wall of the building do not have the capability to withstand fire for a duration of four (4) hours as per Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations.

m) Other requirement related to civil construction of foundation may be specified by the utility in line with relevant BIS standards and best practices.

4.0 It is a fact that maximum weight of transformer (with oil and all fittings & accessories) and outline dimension do not vary much from manufacturer to manufacturer for same rating. Hence a common foundation layout plan with soak pit (with oil and all fittings & accessories) with loading details would facilitate the interchangeability of transformers/reactors of different make of similar/same ratings. The utilities shall strive to standardize the foundation plan for different rating of transformers so that transformers of different makes could be accommodated in the same space with minor modification / without any modification in the existing foundation resulting in reduction in the outage time of replacement of old transformer or reactor.

5.0 The rail track gauge shall be 1676 mm. All voltage class transformers shall have two (2) rails..

6.0 The manufacturers have different arrangement of jacking and different spacing between jacking pads. Hence, it is difficult to standardize the civil foundation drawing based on jacking pad locations / arrangement. Design of block foundation based on weight of transformer for a particular MVA rating along with no. of rails as mentioned above and provision of suitable size of portable metal plate for jacking [(400 mm x 400 mm x 32 mm thick) / (300 mm x 300 mm x 30 mm thick)] would facilitate the physical interchangeability of transformers/reactors of different make on same foundation block. One set of metal plates for jacking of Transformer shall be provided by OEM / contractor. Minimum size of metal plates for jacking and minimum weight of transformer to be considered for design of foundation block shall be as follows:

Rating of Transformer (MVA, Voltage ratio, no. of Phases)	Weight of transformer (in metric Tons)	Minimum size of removable metal plates for Jacking of transformer
315MVA, 400/33kV, 3-Phase Transformer with two LV winding	**To be indicated by manufacturer / utility**	400 mm x 400 mm x 32 mm thick
250MVA, 400/33kV, 3-Phase Transformer with two LV winding	**-do-**	400 mm x 400 mm x 32 mm thick
160MVA, 400/33kV, 3-Phase Transformer with two LV winding	**-do-**	400 mm x 400 mm x 32 mm thick
125MVA, 400/33kV, 3-Phase Transformer with two LV winding	**-do-**	400 mm x 400 mm x 32 mm thick
160MVA, 220 (or 230)/33kV, 3-Phase Power Transformer	**-do-**	400 mm x 400 mm x

		32 mm thick
125MVA, 220 (or 230)/33kV, 3-Phase Power Transformer	**-do-**	400 mm x 400 mm x 32 mm thick
100MVA, 220 (or 230)/33kV, 3-Phase Power Transformer	**-do-**	400 mm x 400 mm x 32 mm thick
100MVA/75MVA, 132 (or 110)/33kV, 3-Phase Power Transformer	**-do-**	400 mm x 400 mm x 32 mm thick
50MVA / 31.5MVA, 132(or 110)/33kV, 3-Phase Power Transformer	**-do-**	300 mm x 300 mm x 30 mm thick

1100 V GRADE POWER & CONTROL CABLES

1.1 Separate cables shall be used for AC & DC.

1.2 Separate cables shall be used for DC1 & DC2.

1.3 At least one (1) core shall be kept as spare in each copper control cable of 4C, 5C or 7C size whereas minimum no. of spare cores shall be two (2) for control cables of 10 core or higher size.

1.4 The Aluminium/Copper conductors used for manufacturing the cables shall be true circular in shape before stranding; shall be of good quality, free from defects and shall conform to IS 8130.

1.5 The fillers and inner sheath shall be of non-hygroscopic, fire retardant material, shall be softer than insulation and outer sheath shall be suitable for the operating temperature of the cable.

1.6 Progressive sequential marking of the length of cable in metres at every one metre shall be provided on the outer sheath of all cables.

1.7 Strip wire armouring method (a) mentioned in Table 5, Page-6 of IS: 1554 (Part 1) – 1988 shall not be accepted for any of the cables. For control cables only round wire armouring shall be used.

1.8 The cables shall have outer sheath of a material with an oxygen index of not less than 29 and a temperature index of not less than 250°C.

1.9 All the cables shall conform to fire resistance test as per IS: 1554 (Part - I).

1.10 The normal current rating of all PVC insulated cables shall be as per IS: 3961.

1.11 Repaired cables shall not be accepted.

1.12 Allowable tolerance on the overall diameter of the cables shall be ± 2 mm.

1.13 PVC Power Cables

1.13.1 The PVC insulated 1100V grade power cables shall be of Fire Retardant Low Smoke Halogen (FRLSH) type, C2 category, conforming to IS: 1554

(Part-I) and its amendments read along with this specification and shall be suitable for a steady conductor temperature of 85°C. The conductor shall be stranded aluminium of H2 grade conforming to IS 8130. The insulation shall be extruded PVC of type-C of IS: 5831. A distinct inner sheath shall be provided in all multi core cables. For multi core armoured cables, the inner sheath shall be of extruded PVC. The outer sheath shall be extruded PVC of Type ST-2 of IS: 5831 for all cables. The copper cable of required size can also be used.

1.14 **PVC Control Cables**

1.14.1 The 1100V grade control cables shall be of FRLSH type, C2 category conforming to IS: 1554 (Part-1) and its amendments, read along with this specification. The conductor shall be stranded copper. The insulation shall be extruded PVC of type A of IS: 5831. A distinct inner sheath shall be provided in all cables whether armoured or not. The outer sheath shall be extruded PVC of type ST-1 of IS: 5831 and shall be grey in colour except where specifically advised by the purchaser to be black.

1.14.2 Cores shall be identified as per IS: 1554 (Part-1) for the cables up to five (5) cores and for cables with more than five (5) cores the identification of cores shall be done by printing legible Hindu Arabic Numerals on all cores as per clause 10.3 of IS : 1554 (Part - 1).

ANNEXURE – P

LIST OF CODES/STANDARDS/REGULATIONS/PUBLICATIONS

A list of Codes/Standards/Regulations/Publications which shall be used for design review, manufacturing, testing, erection, transportation etc. has been given below. In case of revision/amendment of these, revised/amended versions shall be followed.

IS 2026: Part 1 : 2011 (Reaffirmed Year : 2016)	-	Power transformers: Part 1 General
IS 2026: Part 2 : 2010 (Reaffirmed Year : 2020)	-	Power transformers Part 2 Temperature-rise
IS 2026: Part 3 : 2018	-	Power Transformers Part 3 Insulation Levels, Dielectric Tests and External Clearances in Air (Fourth Revision)
IS 2026: Part 4 : 1977 (Reaffirmed Year : 2016)	-	Power transformers: Part 4 Terminal marking, tappings and connections
IS 2026 : Part 5 : 2011 (Reaffirmed Year : 2016)	-	Power Transformers Part 5 Ability to Withstand Short Circuit
IS 2026 : Part 6 : 2017	-	Power Transformers Part 6 Reactors
IS 2026 : PART 7 : 2009 (Reaffirmed Year : 2019)	-	Power Transformers Part 7 Loading Guide for Oil-Immersed Power Transformers
IS 2026 : Part 8 : 2009 (Reaffirmed Year : 2019)	-	Power Transformers : Part 8 Applications guide
IS 2026 : Part 10 : 2009 (Reaffirmed Year : 2019)	-	Power Transformers : Part 10 Determination of sound levels
IS 2026 : Part 10 : Sec 1 : 2018	-	Power Transformers part 10 Determination of Sound Levels Section 1 Application guide
IS 2026 : Part 14 : 2018	-	Power Transformers Part 14 Liquid-Immersed Power Transformers Using High-Temperature Insulation Materials
IS 2026 : Part 18 : 2018	-	Power Transformers Part 18 Measurement of Frequency Response

IS 3024 : 2015	-	Grain Oriented Electrical Steel Sheet and Strip (Third Revision)
IEC / IEEE 60214-2:2019		Tap-changers - Part 2: Application guidelines
IS 649 : 1997 (Reaffirmed Year : 2018)	-	Methods for testing steel sheets for magnetic circuits of power electrical apparatus
IS-10028 (Part 1, 2 & 3)	-	Code of practice for selection, installation & maintenance of transformer
IS 3639 : 1966 (Reaffirmed Year : 2016)	-	Fittings and Accessories for Power Transformers
IS 3637 : 1966 (Reaffirmed Year : 2016)	-	Gas Operated Relays
IS 335 : 2018	-	New Insulating Oils — Specification (Fifth Revision)
IEC 60296-2020	-	Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment
IEC 60422 : 2013	-	Mineral insulating oils in electrical equipment - Supervision and maintenance guidance
IS 6792 : 2017	-	Insulating Liquids - Determination of the Breakdown Voltage at Power Frequency - Test Method (Second Revision)
IS 8468 : Part 1 : 2018 IEC 60214-1 : 2014	-	Tap - Changers Part 1 Performance Requirements and Test Methods (First Revision)
IS 8478 : 1977 (Reaffirmed Year : 2016)	-	Application guide for on-load tap changers
IS/IEC 60137 : 2017	-	Bushings for alternating voltages above 1000 Volts
IS 12676 : 1989 (Reaffirmed Year : 2016)	-	Oil Impregnated Paper Insulated Condenser Bushings - Dimensions and Requirements

IS 4257 : Part 1 : 1981 (Reaffirmed Year : 2019)	-	Dimensions for Clamping Arrangements for Porcelain Transformer Bushings - Part I : For 12 kV to 36 kV Bushings
IS 4257 : Part 2 : 1986 (Reaffirmed Year : 2019)	-	Dimensions for clamping arrangements for porcelain transformer bushings: Part 2 For 72.5 kV and 123 kV bushings
IS 8603 : 2008 (Reaffirmed Year : 2019)	-	Dimensions for porcelain transformers bushings for use in heavily polluted atmospheres 12/17.5kV, 24kV and 36kV
IS 8603 : Part 4 : 2003 (Reaffirmed Year : 2019)	-	Dimensions for Porcelain Transformer Bushings for Use in Heavily Polluted Atmospheres - Part 4 : 52 kV Bushings
ANSI-C57.12.80	-	General requirements for Distribution, Power and Regulating Transformers
ANSI-C57.12.90	-	Test Code for Distribution, Power and Regulation Transformers
NEMA-TR-1	-	Transformers, Step Voltage Regulators and Reactors
IS 1747 : 1972 (Reaffirmed Year : 2016)	-	Nitrogen
IS-5: 2007	-	Colours for Ready Mixed Paints and Enamels
IS 3043 : 2018	-	Code of Practice for Earthing
IS 8263 : 2018	-	Radio Interference Test on High -Voltage Insulators (First Revision)
IS 8269 : 1976 (Reaffirmed Year : 2014)	-	Methods for switching impulse tests on high voltage insulators
IS 2071 : Part 1 : 2016	-	High-voltage Test Techniques Part 1 General Definitions and Test Requirements (Third Revision)
IS 16803 : 2018	-	High Voltage Test Techniques - Measurement of Partial Discharges by Electromagnetic and Acoustic Methods

IS/IEC 60270 : 2000 (Reaffirmed Year : 2016)	-	High — Voltage Test Techniques — Partial Discharge Measurements
IS 13235 : Part 1 : 2019	-	Short-Circuit Currents — Calculation of Effects Part 1 Definitions and Calculation Methods (First Revision)
IS 13235 : Part 2 : 2019	-	Short-Circuit Currents — Calculation of Effects Part 2 Examples of Calculation (First Revision)
IS 16227 : Part 1 : 2016 IEC 61869-2 : 2007	-	Instrument Transformers: Part 1 General requirements
IS 16227 : Part 2 : 2016 IEC 61869-2 : 2012	-	Instrument Transformers Part 2 Additional Requirements for Current Transformers
IS 16227 : Part 100 : 2018	-	Instrument Transformers Part 100 Guidance for Application of Current Transformers in Power System Protection
IS/IEC 60529 : 2001 (Reaffirmed Year : 2019)	-	Degrees of protection provided by enclosures (IP CODE)
IS/IEC-60947	-	Low voltage switchgear and control gear
IS 2062 : 2011 (Reaffirmed Year : 2016)	-	Hot Rolled Medium and High Tensile Structural Steel
IS 9595 : 1996 (Reaffirmed Year : 2019)	-	Metal arc welding of carbon and carbon manganese steels - Recommendations
IS 10801 : 1984 (Reaffirmed Year : 2016)	-	Recommended procedure for heat treatment of welded fabrications
IS 4253 : Part 1 & 2 : 2008 (Reaffirmed Year : 2019)	-	Cork Composition Sheets
IS 11149 : 1984	-	Rubber Gaskets

(Reaffirmed Year : 2019)		
IS 12444 : 1988 (Reaffirmed Year : 2015)	-	Continuously cast and rolled electrolytic copper wire rods for electrical conductors
IS 513 : 2016	-	Cold Reduced Carbon Steel Sheet and Strip
IS 12615 : 2018	-	Line Operated Three Phase A.C. Motors (IE CODE) "Efficiency Classes and Performance Specification" (Third Revision)
IS/IEC 60034 : PART 5 : 2000 (Reaffirmed Year : 2018)	-	Rotating electrical machines : Part 5 Degrees of protection provided by the integral design of rotating electrical machines (IP CODE) - Classification
IS 5561 : 2018	-	Electric Power Connectors- Specification
IS 2932 : Part 1 : 2013 (Reaffirmed Year : 2018)	-	Enamel, Synthetic, Exterior : (a) Undercoating (b) Finishing - Specification : Part 1 for Domestic and Decorative Applications
IS 2074 : Part 1 : 2015	-	Ready Mixed Paint, Air Drying, Red Oxide - Zinc Chrome, Priming - Specification
IS 3400	-	Methods of Test for Vulcanized Rubber
IS 456 : 2000 (Reaffirmed Year : 2016)	-	Plain and Reinforced Concrete - Code of Practice (Including Amendment 1, 2, 3,& 4)
IS 13238 : 1991 (Reaffirmed Year : 2017)	-	Epoxy Based Zinc Phosphate Primer (two Pack)
IS 2848 : 1986 (Reaffirmed Year : 2016)	-	Industrial Platinum Resistance Thermometer Sensors
IS/IEC 61850	-	Communication Networks and Systems for Power Utility Automation
IS 16683 : Part 1, 2 & 3 : 2018	-	Selection and Dimensioning of High Voltage Insulators Intended for Use in Polluted Conditions
IEEE 1538-2000		Guide for determination of maximum winding temperature rise in liquid filled

		transformers
IEEE Standard C57.156-2016		Guide for tank rupture mitigation of oil immersed transformers
IEEE Standard C57.150-2012		Guide for Transformer Transportation
IEEE Standard C57.149-2012		Guide for the application and interpretation of Frequency Response Analysis of oil immersed transformers
IEEE Standard C57.104-2019		Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers
IEC 60599-2015		Mineral oil-filled electrical equipment in service - Guidance on the interpretation of dissolved and free gases analysis
IEEE Std. C57.12.10 - 2017		Standard requirements for liquid immersed power transformers
IEEE Std. 57.104-2019		Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers
IEC 60599		Mineral oil-filled electrical equipment in service – Guidance on the interpretation of dissolved and free gases analysis
IEEE Std. 62-1995		Guide for Diagnostic Field Testing of Electric Power Apparatus - Part 1: Oil Filled Power Transformers, Regulators, and Reactors
CIGRE Technical Brochure No. 529 -2013		Guide lines for conducting design reviews for Power Transformers
CIGRE Technical Brochure No. 673-2016		Guide on Transformer Transportation
CIGRE Technical Brochure No. 530-2013		Guide for conducting factory capability assessment for Power Transformers
CIGRE TB 209		Short Circuit Performance of Power Transformers
CIGRE TB 436		Experiences in service with new insulating liquids
Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations		

Central Electricity Authority (Technical Standard for Construction of Electrical Plants and Electric Lines) Regulations
Central Electricity Authority (Installation and Operation of Meters) Regulations
CBIP Manual on Transformers (Publication No. 317)
ISO 9001: Quality System – Model for Quality Assurance in Design/Development.
ISO-14001 (Environmental Management System)
OHSAS 18001 (Occupational Health and Safety Management System)