

**TECHNICAL SPECIFICATION FOR
160MVA, 220/132 KV AUTO TRANSFORMER**

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2. GENERAL TECHNICAL REQUIREMENTS FOR SUPPLY OF POWER TRANSFORMERS

SCOPE

This section provides for design, manufacture, assembly, inspection and testing at manufactures works before dispatch, packing, supply and delivery of power Transformers at destination substation / store complete with all fittings, accessories and associated equipment for efficient and trouble free operation as specified hereinafter, unloading at site/destination, placing on plinth, erection, testing and commissioning.

It is not the intent to specify completely herein all details of the design and manufacture of the equipment. However, the equipment shall conform in all respect to the standards of engineering, design & workmanship listed in this specification and shall be capable of performing continuous commercial operation in a manner acceptable to the purchaser who shall have power to reject the material which in his judgment is not in accordance therewith.

The equipment offered shall be complete will all components in all respects. All such components shall be deemed to be within the scope of supply irrespective of whether those are specifically mentioned in this specification and/or the commercial order or not.

The scope of work shall also include erection, testing and commissioning of the equipment to be supplied against this tender.

In case of parallel operation with the existing transformer,

- i. The impedance, vector group, OLTC connection & range etc. of the transformer is to be matched with that of the existing transformer.
- ii. Necessary provision is to be kept in the transformer control scheme for parallel operation with the existing OLTC control scheme having provision of Master/Follower/Independent /Off operation.
- iii. Matching of physical orientation, mounting rail gauge etc. to facilitate inter-changeability with the existing single phase transformer.

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
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

IEC 60076 All parts	-	Power Transformers
IS 3024 : 2015	-	Grain Oriented Electrical Steel Sheet and Strip (Third Revision)
IS 8468 : Part 1 : 2018 IEC 60214-1 : 2014	-	Tap-Changers Part 1 Performance Requirements and Test Methods (First Revision)
IEC / IEEE 60214-2:2019		Tap-changers- Part 2: Application guidelines
IS 8478 : 1977 (Reaffirmed Year : 2016)	-	Application guide for on-load tap changers

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/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 Regulator
IS 1747 : 1972 (Reaffirmed Year : 2016)	-	Nitrogen
IS-5: 2007	-	Colors 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 (Reaffirmed Year : 2019)	-	Rubber Gaskets
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 (twoPack)
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, Regulator
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 Technical Brochure No. 761 (WGA2.49)	Condition assessment of 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)	

In case of difference in provision between IEC and ISS, the stringent one shall be followed.

DRAWINGS

LIST OF DRAWINGS/DOCUMENTS TO BE SUBMITTED BY THE MANUFACTURER

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.

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 Bushing
- iii) 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/Digital RTCC panel
- (l) GA drawing for Junction Box
- (m) GA drawing for Cable Box
- (n) Cooler Control Scheme: Schematic wiring diagram of cooling arrangement along with write up on scheme
- (o) Tap Changer Control Scheme :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) Magnetization 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) Customer inspection schedule
- (gg) Test procedure of transformer
- (hh) Manufacturer Quality Program (MQP) and Field Quality Plan (FQP)
- (ii) Type test reports
- (jj) O&M manual (hard copy and soft copy) of transformer inter-alia including instructions for Aircell, Oil filling, Bushing removal and Core Coil Assembly un-tanking etc.

SCOPE OF DESIGN REVIEW

Description
1. Core and Magnetic Design
2. Over-fluxing characteristics up to 1.7 U _m (for transformer)
3. Inrush-current characteristics while charging
4. Winding and winding clamping arrangements
5. Characteristics of insulation paper
6. Typical data and parameters mentioned in GTP
7. Short-circuit withstand capability including thermal stress / withstand capability for 2 seconds

8. Thermal design including review of localized potentially hot area
9. Structural design
10. Cooling design
11. Overload capability
12. Calculations of losses, flux density, core quantity etc.
13. Calculations of hot spot temperature
14. Eddy current losses
15. Seismic design, as applicable
16. Insulation co-ordination
17. Tank and accessories
18. Bushings
19. Mechanical layout design including lead routing and bushing termination
20. Tapping design
21. Protective devices
22. Number, locations and operating pressure of PRD
23. Location, Operating features and size of Sudden Pressure Relay/ Rapid Pressure Rise Relay
24. Radiators ,Fans and Pumps
25. Sensors and protective devices– its location, fitment, securing and level of redundancy
26. Oil and oil preservation system (if applicable)
27. Corrosion protection
28. Electrical and physical Interfaces with substation
29. Earthing (Internal & External)
30. Processing and assembly
31. Testing capabilities
32. Inspection and test plan
33. Transport and storage
34. Sensitivity of design to specified parameters
35. Acoustic Noise
36. Spares, inter-changeability and standardization
37. Maintainability
38. Conservator capacity calculation
39. Winding Clamping arrangement details with provisions for taking it “in or out of tank”
40. Conductor insulation paper details
41. Location and numbers of Optical temperature sensors (if provided)

42. The design of all current connections
43. Location & size of the Valves
44. Manufacturing facilities and manufacturing environment (clean, dust free, humidity controlled environment)

All drawings should be in ink and suitable for microfilming. The drawings shall include the following information.

- a) Dimensions and Tolerance on dimensions.
- b) Material designation used for different components with reference to standards.
- c) Fabrication details such as welds, finishes and coatings.
- d) Catalogue or part number for each component and the total assembly with bill of materials.
- e) Identification Marking
- f) Weight of individual components and total assembled weight.
- g) All dimensions and date shall be in S.I Units.

The successful tenderers within 30 (thirty) days after placement of the order, shall furnish six sets of the following drawings for the approval of the purchaser. The drawing in auto-cad should also be submitted.

The purchaser shall communicate his approval/ comment on the drawings to the supplier within reasonable period. **The supplier will depute his engineer for having discussion and design review. In case any modification is required according to the purchaser's comments, the supplier shall modify the drawings and resubmit six copies of the modified drawings for purchaser's approval within one weeks from the date of communication of comments on the drawings.**

The manufacturing of the equipment shall be strictly in accordance with the approved drawings and no deviations shall be permitted without written approval of the purchaser. All manufacturing & fabrication prior to the approval of the drawing shall be at the supplier's risk.

INSTRUCTION MANUALS

The supplier shall furnish 06 (six) copies of operation, maintenance and erection manual per unit of transformer to the office of the Chief Engineer (Planning & Engineering), Bihar State Power Transmission Co. Ltd. The manuals shall be bound volumes and shall contain the following documents/information.

- i Instructions regarding erection, commissioning operation and maintenance of the equipment.
- ii All relevant information and drawings pertaining to the main equipment as well as auxiliary devices.
- iii Marked erection drawing identifying the component parts of the equipment as shipped to enable the purchaser to carry out the erection of the equipment with his own personnel.
- iv Detailed dimensions, assembly and description of all the components.

- v. Apart from the above, each manual shall also contain one set of all the approved drawings, type test reports as well as acceptance/inspection test reports and routing test reports of the corresponding consignment dispatched.

Note :- These manual shall be invariably furnished to the office of the Chief Engineer (Planning & Engineering), BSPTCL, Patna before dispatch of the transformers.

DESIGN AND CONSTRUCTION DETAILS

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

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.

Components having identical rating shall be interchangeable.

CLIMATE AND ISOCRERAUNIC CONDITION:

The climate and Iscreraunic conditions at site are given below:

(i)	Maximum ambient temperature in shade	-	50° C
(ii)	Minimum ambient temperature in shade	-	40 ° C
(iii)	Maximum daily average ambient temperature	-	35°C
(iv)	Maximum yearly average ambient temperature	-	30° C
(v)	Maximum relative humidity	-	100%
(vi)	Average number of thunder storm days	-	80 P/U
(vii)	Average rainfall per annum	-	125 cm.
(viii)	Maximum wind pressure	-	150 Kg. /M2
(ix)	Height above sea level	-	Not
	exceeding 1000 m		
(x)	Earthquake acceleration	-	0.05x2g.

3. Design Review

SPECIFIC TECHNICAL REQUIREMENTS

The technical parameters of the Transformer are detailed in Annexure-A: Specific Technical Requirements.

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: (format of GTP) 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.

PERFORMANCE

The power transformers shall be **used for bi-directional flow of rated power.**

Transformers shall be capable of operating under natural cooled condition (ONAN) 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 up to specified load. **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 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 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.

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.

The transformers shall be capable of **operating continuously** at the rated MVA without danger, **at any tapping with voltage variation of $\pm 10\%$**

corresponding to the voltage of that tapping.

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.

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.

The **maximum flux density** in any part of the core and yoke **at the rated MVA, voltage and frequency** shall be such that **under 10 % continuous over-voltage condition it does not exceed 1.9 Tesla at all tap positions.**

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 duration of 2 seconds** and the same shall be verified during design review.

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

220 kV system	-40 kA for 1 sec (sym, rms, 3 phase fault)
132kV system	- 31.50 kA for 1 sec (sym, rms, 3 phase fault)
33kV system	- 25 kA for 1 sec (sym, rms, 3 phase fault)

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

Transformer shall be capable of withstanding thermal and mechanical stresses due to symmetrical and asymmetrical faults on any terminals.

Mechanical strength of the transformer shall be such that it can withstand 3-phase and 1- phase through fault with rated voltage applied to HV and LV terminals of transformer. The short circuit shall alternatively be considered to be applied to each of the HV and LV transformer terminals.

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 winding hot spots shall be calculated considering the maximum localized losses, insulation thickness at the maximum loss and the oilflow

patterns in the winding. The oil temperature rise in the windings shall be used to determine hot spots rather than the bulk top oil temperature. The hot spot for all leads shall be calculated and it shall not exceed the calculated hot spot of the windings.

Tank hotspot temperature under over voltage condition specified above shall **not exceed 110 deg C** considering maximum ambient temperature as 50 deg C.

Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or non-metal material shall not exceed the safe operating temperature of that material. Adequate temperature margins shall be provided to maintain long life expectancy of these materials.

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.

MAXIMUM LOSSES

The maximum permissible losses (No load loss, I^2R 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.**

<u>S. No</u>	Differential of specified losses vs Measured losses	RATE (in INR per KW)
1	No load Loss	Rs. 10,00,000/KW
2	I^2R Losses/Load Losses (Differential of whichever loss is higher shall be considered for penalty)	Rs. 8,00,000/KW
3	Auxiliary Losses	Rs. 8,00,000/KW

Note: For a fraction of a kW, the penalty shall be applied on pro rata basis.

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.

DYNAMIC SHORT CIRCUIT TEST REQUIREMENT

The transformer, the design of which is similar to the offered transformer, should have been successfully tested for short circuit withstand capability as per IS 2026 Part-5 within last 5 years. The criteria for similar transformer are specified in Annexure-J of CEA guidelines (File No.CEA-PS-14-169/2/2019-PSETD Division) of transformer. 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.

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.

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.

4. Construction Details

TANK

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.**

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

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

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

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.

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.

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.

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.

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.

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.

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.

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.

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.

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 relays safely.

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.

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.

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.

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.

The tank shall be provided with suitable valves as specified below. Location of valves shall be finalized during design review.

Sr. No.	Description of Valve	Type
1	Drain Valve	Gate
2	Filter valve	Gate
3	Sampling Valve	Globe
4	Radiator isolation valve	Butterfly
5	Buchholz relay isolation valve	Gate
6	Sudden pressure relay	Gate
7	OLTC- tank equalizing valve	Gate / Needle
8	OLTC Drain cum filling valve	Gate
9	Valve for vacuum application on Tank	Gate
10	Conservator Drain valve	Gate
11	Aircell equalizing valve	Gate/Globe/Ball
12	Valve for Conservator vacuum (top)	Gate
13	Filter valve for Cooler Bank (Header)	Gate
14	Cooler Bank isolation valve	Butterfly
15	Pump Isolation valve	Butterfly

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.

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.

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 account the slopes of the plinth (if any) on which the transformer is being mounted.

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 is 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.

Foundation, Roller Assembly and Anti Earthquake Clamping Device.

Foundation, Roller Assembly and Anti Earthquake Clamping Device.

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

For transformer to be placed directly on foundation, one set of rollers shall be provided for movement within the yard. The rollers for transformer are to be provided with flanged bi-directional wheels and axles. This set of wheels and axles shall be suitable for fixing to the under carriage of transformer to facilitate its movement on rail track. Suitable locking arrangement along with foundation bolts shall be provided for the wheels to prevent accidental movement of transformer.

The rail track gauge shall be 1676 mm.

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

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.

For support of cooler pipes, Buchholz pipe (if required), Pre-fabricated metallic support from pit shall be provided which shall be further encased with concrete to prevent rusting.

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.

Conservator

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.**

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

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.

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.

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

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.

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 stenciled 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”**.

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.

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

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.

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.

Conservator Protection Relay (CPR)/Air cell puncture detection relay (if required) 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.

Piping works for conservator

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

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.

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

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.

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

BREATHER:-

The main transformer tank/conservator and OLTC tank/ OLTC conservator both shall have breather whose technical specification is mentioned below:-

Technical specification of maintenance free breather for transformers

Objective and Principle of Working of the Breather:

Dehydrating breathers work according to the following principle. When the oil conservator sucks in air (e.g., due to the reduced load), the air flows through a

filter made of high-grade steel wire mesh to the inside of the device. This filter and the dust cap filter dust, sand and other dirt particles from the air. The filtered air flows through the desiccant chamber filled with colorless, moisture adsorbing pellets and are dehydrated. The dehydrated air rises further via the pipe in the oil conservator. The dehydrating breather is mounted on the pipe to the oil conservator. A suitable counter-flange must be installed on the pipe to mount the dehydrating breather. The desiccant contained in the drying assembly is dehydrated using sensor controlled by the built-in heating unit, thus obviating the need for periodic desiccant replacement.

By providing the Maintenance Free Type of Breather the objective is to achieve reduced site inspections, Cost reduction by obviating the complete process of ordering, storage and replacement of the desiccant. It also leads to no pollution and disposal problem of the used up desiccant (which is associated with the conventional pigmented silica gel) is eliminated.

Specification:

1. The main Transformer tank conservator shall be fitted with a silica gel Breather of the Maintenance-Free type, in a convenient floor height at eye level.
2. Each Silica gel breather shall be equipped with a humidity sensor, a condition based microprocessor control unit to ensure that the regeneration of the silica gel is activated only when the transformer is exhaling.
3. A stainless steel filter at the bottom shall protect the silica gel chamber against external environment influences.
4. Insect Protection for the High Grade Filter is also to be provided.
5. This condition controlled application should be environmental friendly.
6. Material of External Construction of the Breather: All external parts must be suitable for mounting for outdoor use, resistant against transformer oil and ultraviolet rays. **Salt water resistance should be made available on request.** No plastic parts shall be used in the construction of the breather.
7. Ambient Temperature: The equipment must be suitable for ambient: 0 to + 80 Deg C.
8. Degree of Protection: Minimum IP55. If the Breather need to be installed in a location where there could be sub-zero temperatures, a filter heater must be provided.
9. The control unit on the breather must be equipped with suitable heater to prevent moisture condensation.
10. The breather should be provided with status LEDs for local display. Also suitable contacts must be provided to take the signal to a remote control room.
11. The moisture and temperature measurement system (sensor) installed should be modular making it easy to replace the same if at all the same is necessary during the

- service of breather. A self-diagnostic system must be provided with LED indication and remote signal through a relay should be provided.
12. To protect against overvoltage, a micro fuse and an additional built in line filter must be provided to avoid failures caused by high-frequency interference.
 13. The control unit in the breather must provide analogue output signal of 4-20mA and also should be equipped with a USB Port for data logging.
 14. Suitable Data Logger should be also provided in the control unit.
 15. The Breather should be equipped with an optional integrated test button. This should allow to carry out a self-test at any time and to check the functions, like the relay circuits, the heating or the signal transmission in the control room.
 16. Rated Insulation Voltage:
500VAC 50 Hz, 1min., voltage supply voltage: against ground;
500VAC 50 Hz, 1min., analog output against ground; 2.5kVAC 50/60Hz, 1 min., relay contact against ground
 17. **Necessary List of Type Test Conducted and Routine Test Certificate issued by the manufacturer of the maintenance free Breather used must be provided for each supply.**

The arrangement and placement of maintenance free breather shall be such that retrofitting with conventional type breather as described above for OLTC is possible with ease. The quantity of silica gel in maintenance free breather shall depend upon the size of transformer and volume of oil contained therein. The bidders are required to indicate this in their offer.

PRESSURE RELIEF DEVICE :

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

PRD shall be provided with special shroud to direct the hot oil in case of fault condition. It shall be provided with an outlet pipe which shall be taken right up to the soak pit of the transformer. The size (Diameter) of shroud shall be such that it should not restrict rapid release of any pressure that may be generated in the tank, which may result in damage to equipment. Oil shroud should be kept away from control cubicle and

clear of any operating position to avoid injury to personnel in the event of PRD operation.

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

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

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

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. Pressurized water ingress test for Terminal Box (routine tests) shall be conducted on Buchholz relay.

TEMPERATURE INDICATOR :

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 wirings 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 degrees 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.

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]. 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 weatherproof and epoxy coating at all sides. Instruments should meet degree of protection of IP55 as per IEC60529. 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 contact 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.

Fiber Optic System

The transformer shall be fitted with optical fiber temperature system for direct/real time temperature monitoring and control. The technical specification for such system is mentioned below:

TECHNICAL SPECIFICATION OF FIBER OPTIC SYSTEM Fiber

Optic Temperature Sensors:

The transformer shall be equipped with fiber optic temperature sensors for monitoring direct hotspots into transformer windings, core, and oil temperature. 13 fiber optic sensors shall be installed for the following measurement points:

- One sensor each on the lateral winding of Primary and Secondary phases
- Two sensors each on the central windings of Primary and Secondary phases
- Two sensors for Top and bottom oil temperatures, preferably where the oil enters and exits center phase winding assembly
- Three sensors positioned to measure the hottest temperatures in the core, between the core and core clamping structure, and of the core clamping structure.

The locations of fiber optic sensors shall be proposed by the Manufacturer and locations finalized by agreement of the Purchaser.

Fiber Optic temperature Sensors shall be based on the proven zero-drift wavelength-shift Gallium Arsenide (GaAs) technology, suitable for all oil types, 200 µm all silica, Torlon disk, with a protection layer in radiant green colored PTFE Teflon protective spiral-wrap for improved visibility and mechanical strength. Sensors shall withstand exposure to hot kerosene vapor during the transformer insulation drying process.

Fiber Optic temperature sensor tips and tip/disk assemblies shall meet the following:

- i The temperature measurement range should be between -80 °C to +250 °C, with a total system accuracy of ± 1 °C.
- ii No greater than 3pC (pico-Coulomb) partial discharge in mineral oil under 60 Hz AC stress per ASTM D149, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies and negative lightning impulse conditions per ASTM D3426, Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Material using Impulse Waves
- iii Fiber optics sensors to withstand pull test of forces exceeding 60 N (~6 kg-F); 1 kg-f (kilogram-force) is about 10 N (Newton)
- iv End interface ST connectors made of Zirconia for optimal light energy transfer

FO System Accessories:

The optical signal shall be brought out of the tank using a solder-glass optical feedthrough (without use of O-rings or seals), withstanding pressure in excess of 200 PSI. A 316L Stainless steel-based tank wall plate accommodating thirteen optical feedthroughs shall be installed on the tank.

The optical feedthroughs shall be assembled on the Tank Wall Plate and assembly shall be pressure-tested for the expected pressure inside transformer.

A protective 316L stainless steel-based interface box (I-Box) cover designed to mate with the wall plate shall be supplied. The box must be leak proof (IP66 rated), so that all optical feedthroughs and extension cables are protected from moisture and dust ingress.

EARTHING TERMINALS :-

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.**

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 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.

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.

CORE

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

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 rightangles 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.

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.

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.

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

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

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.

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

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

Single point core earthing should be ensured to avoid circulating current. Core earth should be brought separately on the top of the tank to facilitate testing after installation on all transformers. The removable links shall have adequate section to carry ground fault current. Separate identification name plate/labels shall be provided for the 'Core' and 'Core clamp'. Cross section of Core earthing connection shall be of minimum size 80 sq.mm copper with exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 sq. mm tinned copper where they are clamped between the laminations.

In case core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the lamination, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.

Insulation of core to clamp/frame shall be tested at 2.5 kV DC for 1 minute without breakdown after the transformer is filled with liquid and insulation resistance should be at least 500 Mega ohm for new transformer.

WINDINGS

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.**

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.

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.

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.

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.

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.

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

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.

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.

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.

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.

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.

Winding paper moisture shall be less than 0.5%.

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

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.

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.

Winding terminations into bushings

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.

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.

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.

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.

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.

GAS AND OIL-ACTUATED RELAYS

GAS AND OIL-ACTUATED RELAYS

Each transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts, which close on collection of gas or low oil level, and tripping contacts which close following oil surge conditions. Separate relays shall be provided for on load tap changer.

Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

Each relay shall be fitted with a calibrated glass window for indication of gas volume.

To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point, approximately 1400 mm above ground level,. Where it shall be terminated by a cock, which shall have provision for locking to prevent unauthorized operation.

The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal-operation of the relay will not take place under normal service conditions, including starting or stopping of oil circulating pumps whether by manual or automatic control under all operating temperatures.

The pipe work shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, nor is to be tied into or connected through the pressure relief vent. Sharp bends in the pipe work shall be avoided. For this reason, bushing turrets, if fitted shall have vent pipes, which will route any gas collection through the relay.

A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay.

A straight run of pipe work shall be provided for a length of five times the internal diameter of the pipe on the conservator side of the gas and oil- actuated relay.

The surge float contacts shall close at a rate of steady oil flow between the following limits. As far as possible, the limits shall also be met when the relay is subjected to oil surge conditions, produced by rapid opening of a lever operated gate valve.

The relays shall be so located as to be easily accessible from the top of the tank. Oil Pipe Connection I.D. (mm) Operational Limits for Relay.

[Rising angles of 1° to 9°.]

700-1300

750 – 1400

900-1600

The gas collection contacts shall operate within the angle limits, specified for test:

when a transformer is provided with two conservators, the gas and oil -actuated relays shall be arranged as follows:

- (i) If the two conservators are connected to the transformer by a common oil pipe, one relay shall be installed in the common pipe.
- (ii) If the two conservators are piped separately to the transformer, two relays shall be installed, one in each pipe connection.

4.16.12 The clearance between oil pipe work and live metal shall be not less than the minimum clearances as per standard practice.

INSULATING OIL :-

The insulating oil shall be unused inhibited (Type A, High Grade) 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 10% 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.

TAP CHANGING MECHANISM :

Main OLTC Gear Mechanism

Three phase 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 side), location (physical and electrical) of tap winding (end of common/ series winding or at neutral end), range of voltage variation, no. of steps etc. shall be as given in **Annexure-A**.

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 shall be designed so as to ensure that its operation

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

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.

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.

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.

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

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.

Local OLTC Control Cabinet (Drive Mechanism Box)

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.

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 than 1800mm). 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.

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.

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/contactors 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.

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.

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.

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.

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 input to digital RTCC/relevant BCU (as applicable)/SCADA system. The tap position indicator shall also be provided in control room.

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

For 3-phase transformer, 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

The following minimum contacts shall be available in DM Box. For three phase unit, 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

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.

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

Remote Control & Monitoring of OLTC (through Bay Control Unit/ Digital RTCC Relay, as applicable)

Requirement of digital RTCC relays may be specified by the utility for existing conventional substations as per its practice. For substations/ power plants having Substation Automation System, Control & monitoring of OLTC shall be carried out through Substation Automation System. All the 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. Wherever, digital RTCC relay is required following specification may be followed.

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

Each digital RTCC relay shall be used to control 1 bank of transformers(i.e. 3 Nos. 1-Phase units or 1 No. 3-Phase unit). No. of relays including spare relay, if any, shall be specified by the utility as per requirement.

All digital relays can be housed in a single digital RTCC panel in control room or in the BCU panel in kiosks located in the switchyard.

~~For existing substations, the requirement of digital RTCC panel and relays shall be specified by the utility. However, availability of existing RTCC schemes /Digital RTCC relays need to be specified to finalise matching digital RTCC relays. The Digital RTCC relays envisaged for existing transformers shall be integrated for parallel operations. All required cables for the same shall be deemed to be included in the scope.~~

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.

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.

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.

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.

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

Raise/Lower control: The remote OLTC scheme offered shall have provision to raise or lower taps 3-Phase Transformer.

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.

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.

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.

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.

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.

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.

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.

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

- (a) INCOMPLETE STEP alarm
- (b) OLTC motor overload protection alarm
- (c) Supply to DM Motor fail alarm
- (d) OLTC IN PROGRESS alarm
- (e) Local/ Remote Selector switch positions in DM Box
- (f) OLTC upper/lower limits reached alarm
- (g) OLTC Tap position indications for transformer units
- (h) Independent-combined-remote selector switch positions of CMB (in case of single phase transformer)
- (i) 415V, AC Main Supply Fail.
- (j) 415V, AC Standby Supply Fail

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

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

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

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

The Cooler Control Cabinet (CCC)/Individual Marshalling Box (IMB), Common Marshalling Box (CMB), 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 1.6mm. Digital RTCC panel shall be made of CRCA sheet of minimum thickness of 2.0 mm and shall be painted suitably as mentioned in this specification.

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

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.

All the contacts of various protective devices mounted on the transformer and all the secondary terminals of the bushing CT shall also be wired up to the terminal board in the Marshalling Box. All the CT secondary terminals in the Marshalling Box shall have provision for shorting to avoid CT open circuit while it is not in use. All the necessary terminations for remote connection to Purchaser's panel shall be wired up to the Common Marshalling Box.

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.

AUXILIARY POWER SUPPLY FOR OLTC, COOLER CONTROL AND POWER CIRCUIT

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.

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.

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).

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%.

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/Common Marshalling Box for failure of normal source and for transfer to standby source and also for failure to transfer.
- d) Automatic re-transfer to normal source without any intentional time delay following re-energization of the normal source.
- e) Both the transfer and the re-transfers shall be dead transfers and AC feeders shall not be paralleled at any time.

For spare unit which is not connected through isolator switching arrangement, 415 volt, three phase four (4) wire AC supply shall be provided for heater,.

TRANSFORMER BUSHINGS :-

4.21.1 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 for 400 kV and below voltage class transformers	RIP/RIS
Bushings of 36 kV and below	Solid porcelain
Bushings of other rating	OIP/RIP/RIS

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

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.

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

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

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.

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.

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

Bushings of **identical rating of different makes shall be interchangeable** to optimise the requirement of spares.

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.

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

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

Clamps and fittings shall be of hot dip galvanised/stainless steel except for Aluminium Clamps and connectors.

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

No arcing horns shall be provided on the bushings.

Corona shield (wherever required or not, as per calculation at the time of bid), shall be provided at bushing terminal (air end) to minimize corona.

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.

Oil end portion of RIP/RIS type bushings shall be fitted with metal housing with positive dry air pressure and a suitable pressure monitoring device shall be fitted on the metal housing during storage to avoid direct contact with moisture with epoxy. The pressure of dry air need to be maintained in case of leakage.

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

Tan delta measurement at variable frequency (in the range of 20 Hz to 350 Hz) shall be carried out on each condenser type bushing(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.

Tan δ value of 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.

COOLING :-

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.

The cooler shall be designed using **tank mounted radiators**. Design of cooling system shall satisfy the performance requirements.

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

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.

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

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.

Cooling fans 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 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.

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.

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.

Automatic operation control of fans 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. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.

Suitable manual control facility for cooler fans 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 manually.

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) Common thermal overload trip
- g) Thermal overload trip for each fan
- h) Stand by fan

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.

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.

All the necessary terminations for remote connection to Purchaser's panel shall be wired upto the Marshalling Box (3-Ph unit).

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.

CLEANING AND PAINTING :-

Before painting or filling with oil or compound, all ungalvanised parts shall be completely cleaned and made free from rust, scale and grease and all external rough surfaces in castings, shall be filled by metal deposition. The interior of all transformer tanks and other oil filled chambers and internal structural steel work shall be cleaned of all scale and rust by sand blasting or other approved method. These surfaces shall be painted with an oil resisting varnish or paint Unexposed welds not be painted.

PAINTING PROCEDURE

PAINTING	Surface preparation	Primer coat	Intermediate undercoat	Finish coat	Total Dry Film Thickness (DFT)	Colour shade
<u>External surfaces:</u> Main tank, pipes, conservator tank, oil storage tank & Driving Mechanism (DM) Box etc. ()	Shot Blast cleaning Sa 2 1/2*	Epoxy base Zinc primer (30-40µm)	Epoxy high build Micaceous iron oxide (HB MIO) (75µm)	Aliphatic polyurethane (PU) (Minimum 50µm)	Minimum 155µm	RAL 7035

Internal surfaces: Main tank, pipes (above 80 NB#), conservat or tank, oil storage tank & DM Box etc. ()	Shot Blast cleaning Sa 2 ½*	Hot oil resistant, non-corrosive paint, low viscosity varnish or epoxy	--	--	Minimum 30_ m	Glossy white for paint
Radiator (external surfaces)	Chemical / Shot Blast cleaning Sa 2 ½*	Epoxy base Zinc primer (30-40_ m)	Epoxy base Zinc primer (30-40_ m)	PU paint (Minimum 50_ m)	Minimum 100_ m	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 40_ m (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 80_ m / for powder coated minimum 100_ m	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

5.0 QUALITY ASSURANCE PROGRAMME

INTRODUCTION

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) Organization 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.

GENERAL REQUIREMENTS - QUALITY ASSURANCE

All materials, components and equipment required for transformer 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.

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 Organization, 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.

List of testing equipment available with the manufacturer for stage/final testing of transformer 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.

The transformer 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 authorized 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.

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.

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

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.

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 organization, 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.

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.

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.

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.

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

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.

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.

Transformer 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 authorized agency, during various stages of site activities starting from receipt of materials/equipment at site till commissioning.

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.

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.

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.

QUALITY ASSURANCE DOCUMENTS

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.

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.

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.

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.

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.

Note:- The word 'Inspector' shall mean the authorized representative and to inspect and examine the materials and workmanship of the works during its manufacture or erection.

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

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).

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.

5.04.2 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.

Virtual Stage inspection & Factory Acceptance Test (FAT)

The conventional practice of witnessing Stage inspection and Factory Acceptance Test (FAT) of transformers 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.

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 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.

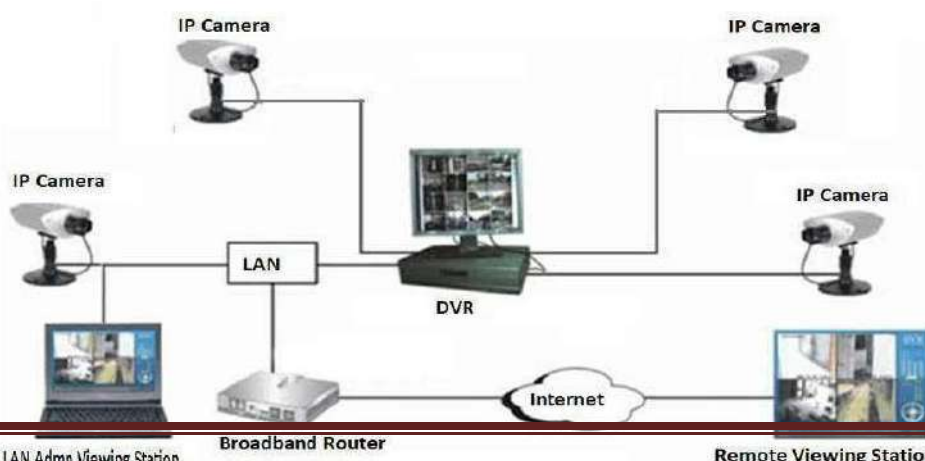
(Note: Issues of screen blinking may be observed during chopped wave lightning impulse due to earthing issues and should be ignored)
- (c) Qualified engineers well-conversant with technology shall be deployed to effectively handle online stage inspection/FAT.
- (d) Online applications like Microsoft 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 visualization 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.

Procedure for virtual inspection / testing:

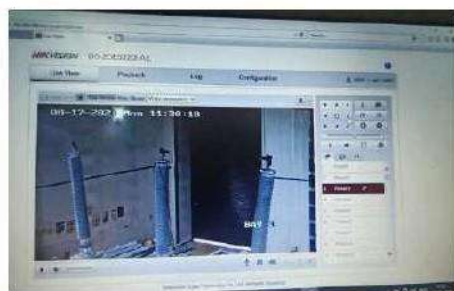
- (a) Manufacturer's QA/QC in-charge will plan, verify the process checklist and ensure that the Stage inspection/Routine/FAT are conducted as per approved quality plan in line with the Technical Specification.
- (b) Manufacturer will submit soft copies of Photographs and Calibration Certificates with proper index sheet duly certified from their end in order to demonstrate readiness of Transformer for inspection/testing.
- (c) The Date and time and arrangement for online stage inspection/FAT shall be finalized 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 utilities'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 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 authorized 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 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 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 may be moved to next stage of manufacturing process and after getting FAT Clearance from utility/purchaser.

- (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.

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.

Deleted

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.

The inspection by the Inspector and issue of **Joint Inspection report 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.**

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.

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.
- d) Calibration certificates for all the testing equipments, test certificates of raw materials etc.

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.

Factory Tests

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.

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.

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

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.

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 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 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

islower, 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.

Stage Inspection

Stage inspection will be carried out by the Inspector **on Core, Winding, core-coil assembly & Tank during the manufacturing stages** of the transformer. 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.

Stage inspection will be carried out on at least one Transformer 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.

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.

1. Invoice of supplier
2. Mills' approved test certificates
3. Packing list
4. Bill of lading
5. Bill of entry certificate by custom.
6. Description of material, electrical analysis, physical inspection, certificate for surface defects, chemical composition certificate, thickness and width of the materials
7. 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 organization of repute and not through any agent.

Typical example for calculation of flux density, core quantity, no-load loss and weight of copper during stage inspection shall be as per "Standard Specifications and technical Parameters for Transformers and Reactors (66 kV & above voltage class)".

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)
- 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)

Pre-shipment Checks at Manufacturer's Works

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

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

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

Ensure following setting of impact recorder at the time of installation with transformer 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.

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

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.

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

7.0 UNLOADING OF TRANSFORMERS INCLUDING HANDLING AND PLACEMENT ON PLINTH, ERECTION, TESTING & COMMISSIONING OF TRANSFORMERS AT SITE:

The supplier shall have to do unloading of transformers including handling and placement on plinth, erection, testing & commissioning of the transformers at site supplied by them. They shall quote charges accordingly in the schedule of price. Such quoted rates shall be considered for tender evaluation.

The charge for deputation of their service engineer on per day basis shall also be quoted in the price bid. This will not be considered for tender evaluation.

Upon the transformer having successfully erected & completed the required site tests and commissioned, the purchaser or it authorized engineer, after satisfying that the equipment is in full and satisfactory working condition, will issue a Job completion certificate which will form basis for payment of their service bills.

8.0 SPARE PARTS & MAINTENANCE BQUIPMENTS:

The tenders shall quote separately for mandatory spares as specified in the schedule. The make and type of such spares offered shall be same as those offered along with the main transformer and inter changeable with the similar items. The prices offered for supply of these spares shall be taken into consideration for the purpose of bid evaluation.

The tenderers shall also indicate in their proposal and quote their rates for any other spares recommended for the trouble free operation of the equipment for five years. The prices of these optional spare not be taken into consideration for the purpose of bid evaluation. The purchaser shall decide the actual quantities of spare parts to be include in the order on the basis of this list and the items wise prices of spare parts.

9.0 ERECTION AND MAINTENANCE TOOLS:

The tenderers shall separately list out in their tender the sets of tools required for initial erection and subsequent maintenance for the power transformer and the associated equipment. The prices quoted for such tools shall not be taken into consideration for the purpose bid evaluation.

10.0

VENDOR SELECTION FOR MOUNTING ACCESSORIES:

S. No.	ItemDescription	Proposed make
1.	Core	Core materials to be procured directly from authorized dealer of CRGO manufacturer as following:
		POSCO, Korea
		NIPPON, Japan
		JFE, Japan
2.	Winding	HINDALCO
		Hindustan Copper
		Sterlite
	CTC Conversion	Asta India, Vadodara
		KSH International, Chakan
		Precision Wires, Silvassa
		Sri Cables & Conductors (P) Ltd., Bhopal
	3.	Transformer Oil
4.	Paper Insulation for Conductor	Weidman Electrical, Switzerland
		Smurift Munksjo, Sweden
5.	Pre-compressed Board	ABB, Sweden
		H Weidman, Switzerland
		Senapathy Whiteley, Bangalore
		Raman Boards, Mysore
6.	Un-impregnated Densified Wood	Permalli Wallace, Bhopal
		Western India Plywood, Cannanore
7.	Bushing CT	Mahindra Electricals, Mumbai
		BHEL, Bhopal
		Pragati Electricals Pvt. Ltd., Thane
		A.U. Electric Machines, Allahabad
8.	Tank	Self manufacturing as well as out sourced
	Sheet	SAIL, RINL, TISCO, IISCO
	Tank fabricator	Satyam Industries, Bhopal
		Allahabad Enterprises, Allahabad
9.	OIP Bushing	Alstom
		CGL, Nasik/Aurangabad

		ABB
10.	Porcelain Bushing Insulator	CJI, Khurja
		W S Industries, Chennai
		Jayashree Insulators, Halol
		BHEL, Banglore
11.	Rubber Gasket	Nu Cork Products, Bhiwadi
		Bombay Oil Seal Mfg Co., Mumbai
12.	Marshalling Box	BHEL, Bhopal
		Pyrotech, Udaipur
		C&S, Noida
		United Industrial Components Co., Navi Mumbai
		Ashoka Electronic, Bhopal
		Own make subject to valid type test report
13.	Terminal Connector	Nootan, Vadodara
		Milind Engineering, Mumbai
14.	Bucholz Relay	EMB,Germany
15.	OTI/WTI	Perfect Control, Chennai
		Precimeasure, Bangalore
16.	OLTC	BHEL, Bhopal
		CTR, Pune
		ABB, Sweden
		Easun MR, Chennai
17.	Radiators	CTR, Pune
		Transpares, Ahmedabad
		Hi Tech Radiators, Mumbai
		Thermal Transfer, Bangalore
		Gururaj Radiators Pvt. Ltd., Naini
18	Silicagel Breather (Maintenance free)	MESSKO
19.	Fibre Optic Sensor	Rugged Monitoring Inc, Canada
20.	Valves	Leader Valves, Jalandhar
		GG Valves Ltd, Udaipur
		Petson Valves, Coimbatore
21.	PRV (Pressure Release Valve)	Sukrut, Pune
		Qualitrol Company, USA
		MESSKO, Germany

22.	Cooling fan	Marathon, Kolkata
		Khaitan, Kolkata
		CGL

ANNEXURE -A GTP for 160 MVA 220/132 kV, 3-Phase Auto Transformer

S. No.	Description	Unit	TECHNICAL PARAMETERS
1.	Voltage ratio (Line-to-Line)	kV	220/132
2.	Rated capacity (HV and LV)	MVA	160
3.	No of phases		3 (Three)
4.	Vector Group		YNa0
5.	Type of transformer		Power Transformer
6.	Applicable Standard		IEC 60076 / IS 2026
7.	Cooling type		ONAN/ONAF/OFAF
8.	Rating at different cooling	%	60 /80/ 100
9.	Cooler Bank Arrangement		2 X 50%
10.	Frequency	Hz	50
11.	Tap changer		
i)	Type		On-load tap changer
ii)	Tapping range and steps		-10% to +10% 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	%	10.3
ii)	Principal tap	%	12.5 (No negative tolerance)
iii)	Min. Voltage tap	%	15.4
13.	Tolerance on Impedance	%	As per IEC with no negative tolerance
14.	Service		Outdoor
15.	Duty		Continuous
16.	Overload Capacity		IEC 60076-7
17.	Temperature rise over 50°C ambient temp.		

i)	Top oil measured by thermometer	°C	45
ii)	Average winding measured by resistance method	°C	50
18.	Winding hot spot rise over yearly weighted temperature of 32 °C	°C	61
19.	Tank hot spot temperature	°C	110
20.	Maximum design ambient temperature	°C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV _p	950
	LV	kV _p	650
	Neutral	kV _p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV _p	1045
	LV	kV _p	715
iii)	Switching Impulse withstand Voltage		
	HV	kV _p	750
	LV	kV _p	540
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV _{rms}	395
	LV	kV _{rms}	275
	Neutral	kV _p	38
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	245
	LV	kV	145
	Neutral		36
ii)	Rated current (Min.)		
	HV	A	1250
	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV _p	1050
	LV	kV _p	650
	Neutral	kV _p	170
iv)	Switching Impulse withstand voltage on HV	kV _p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV _{rms}	505
	LV	kV _{rms}	305
	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		7595
	LV	mm	4495
	Neutral	mm	1116
vii)	Maximum Partial discharge level at U _m on HV & LV	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	75
25.	Maximum Permissible Losses of Transformers		
i)	Max. No Load Loss at rated voltage and frequency	kW	30
ii)	Max. Load Loss at rated current and frequency and at 75°C at principal tap for HV & LV	kW	200

iii)	Max. I^2R Loss at rated current and frequency and at 75°C at principal tap for HV & LV	kW	145
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	6

ANNEXURE –B DETAILS OF BUSHING CT AND NEUTRAL CT for 160 MVA Transformer

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

Note:

- i) **Parameters of WTI CT for each winding shall be provided by the contractor and finalized at the time of approval.**
- ii) **For estimation of spares, one set of CTs shall mean one CT of each type used in transformer.**
- iii) The CT used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
- iv) Class (for the relevant protection & duties) as per IEC 185.

ANNEXURE-C GUARANTEED AND OTHER TECHNICAL PARTICULARS FOR POWER TRANSFORMER

(To be filled in by the manufacturer)

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
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/Auto iii) GT/Step-down/ICT/Station Start-up/ Auxiliary/ Rail Trackside Supply iv) Bi directional			
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 Capacity / Full load rating (HV/LV)	MVA		
9.	3-Phase/Bank of Three Single Phase (A,B,C)			
10.	Rated No Load Voltages (HV /LV)	kV		
11.	Currents at normal tap (HV /LV)	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 10% extra oil	kg		
	ix) Weight of core	Kg		
	x) Weight of copper (HV/LV/ Regulating)	kg		

	xi) Insulating Oil volume (excluding 10% extra oil)	Ltrs		
	xii) Quantity of oil in OLTC	Ltrs		
15.	Transport limitation			
16.	LV Winding i) Stabilizing tertiary (Yes/No) ii) Loaded (Yes/No)			
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 : <ul style="list-style-type: none"> • 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 ² R Loss at rated current & frequency (at 75°C) at principal tap	kW		
	Tolerance (to be considered for loss evaluation)	%		
	iii) Eddy current and stray loss at rated current & frequency (at 75°C) at principal tap	kW		

	iv) Load Loss(I^2R +Eddy and Stray) at rated current & frequency (at 75°C) at principal tap	kW		
	v) Guaranteed Auxiliary loss at rated voltage and frequency	kW		
	Tolerance (to be considered for loss evaluation)	%		
	vi) Calculated Fan Loss	kW		
	vii) Calculated Pump Loss	kW		
	viii) Air core reactance of HV winding	%		
	ix) Guaranteed Impedance (at Highest MVA base)	%		
	(a) HV-LV(at Principle tap)			
	Tolerance			
	x) Impedance at extreme tappings at Highest MVA base [for HV-LV for two winding transformer]	%		
	a) Max. Voltage tap			
	b) Min. Voltage tap			
	Tolerance	%		
	xi) Zero sequence impedance at principal tap (for 3-phase transformers)			
19.	Capacitance to earth for HV/LV	pF		
20.	Regulation at full load at 75 °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	kA		

	current)			
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% 140% 150% 170%	msec		
29.	Free space required above the tank top for removal of core			
30.	Maximum Partial discharge level at $1.58 U_r/\sqrt{3}$	pC		

A. MAGNETIC SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufa-cturer
1.	Core Type: i) 3 Phase 3 Limb (3 wound limbs) ii) 3 Phase 5 Limb (3 wound limbs) iii) 1 Phase 2 Limb (2 wound limbs) iv) 1 Phase 3 Limb (1 wound limb) v) 1 Phase 4 Limb (2 wound limbs) vi) 1 Phase 5 Limb (3 wound Limbs)			
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	
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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	oC		

B. 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) LV	A/mm ² & sq. mm				
5.	Maximum current density under short circuit: i) HV ii) LV	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 °C	ohm				
8.	Number of Turns/Phase					
9.	Insulating material used for HV/LV winding					
10.	Insulating material used between : i) HV and LV winding ii) Regulating winding and adjacent winding/core					
11.	Details of special arrangement					

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				

C. COOLING SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	Type of Cooling [ONAN (or) ONAN/ONAF (or) ONAN / ONAF / OFAF(or) ONAN / ONAF/ ODAF (or) ONAN / ONAF1 / ONAF2 etc.]			
2.	Percentage Rating Corresponding to Cooling Stages (HV/LV)			
3.	No. of Cooler banks (2x50% / 2x100% / 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 temperature when supply to fans and / or pumps 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	°C		
7.	Type of Cooler: i) Radiator Bank ii) Oil to Air Heat Exchanger (Unit Cooler) iii) Oil to Water Cooler (Single Tube) iv) Oil to Water Cooler (Double Tube) v) Tank Mounted vi) Header Mounted vii) Separately Mounted viii) Degree of Protection of terminal box			

8.	<p>Cooling Fans:</p> <ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> • natural cooling • forced air cooling vii) Degree of Protection of terminal box 			
9.	<p>Oil Pumps:</p> <ul style="list-style-type: none"> 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.	<p>Coolers (Oil to Air):</p> <ul style="list-style-type: none"> i) Quantity (Running + Standby) ii) Type and Rating 			
11.	<p>Coolers (Oil to Water):</p> <ul style="list-style-type: none"> 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.	<p>Radiators:</p> <ul style="list-style-type: none"> i) Width of elements (mm) ii) Thickness (mm) iii) Length (mm) iv) Numbers 			
13.	Cooler loss at rated output, normal ratio, rated voltage, rated frequency at ambient temperature of 50°C	kW		

D. DIELECTRIC SYSTEM

Sl. No.	Description	Unit	Offered by manufacturer				
1.	Geometric Arrangement of winding with respect to core e.g: Core-LVHV-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	IV	LV	HV-N	IV-N
	i) Lightning Impulse withstand voltage (1.2/50 μ s)	kV _p					
	ii) Chopped wave Lightning Impulse withstand voltage	kV _p					
	iii) Switching Impulse withstand voltage (250/2500 μ s)	kV _p					
	iv) Power frequency withstand voltage	kV _{rms}					

	(one minute / 5 minutes)						
6.	Tan delta of windings at ambient temperature	%					

E. 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	oC					
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					
	viii) One minute Power frequency withstand voltage (dry & wet)	kV _{rms}					
	ix) Minimum Creepage Distance	mm					
	x) Quantity of oil in bushing and specification of oil used						
	xi) Make and Model						
	xii) Tan delta of bushings	%					
	xiii) Max Partial discharge level at U _m	pC					
	xiv) Terminal Pad details						
	xv) Weight of assembled bushings	kg					
	xvi) Whether terminal connector for all bushings included in the scope of supply						

4.	Minimum clearances between bushings (for HV, IV and LV) (a) Phase to phase (b) Phase to ground			
5.	Indicator / Relay			
	i) Winding temperature thermometer/ indicator: Range Accuracy			
	iii) Oil temperature thermometer/ indicator: Range Accuracy			
	iii) Temperature sensors by fiber optic			
	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 valve Provided	Y/N		

13.	Tap Changer protective device			
14.	Type and material of gaskets used at gasketed joints			
15.	<p>Bushing CTs: (HV side and LV side)</p> <p>i) Voltage class</p> <p>ii) No. of cores</p> <p>iii) Ratio</p> <p>iv) Accuracy class</p> <p>v) Burden</p> <p>vi) Accuracy limit factor</p> <p>vii) Maximum resistance of secondary winding</p> <p>viii) Knee point voltage</p> <p>ix) Current rating of secondaries</p>	<p>kV</p> <p>VA</p> <p>Ω</p> <p>V</p> <p>A</p>		
16.	<p>Neutral CTs:</p> <p>i) Voltage class</p> <p>ii) No. of cores</p> <p>iii) Ratio</p> <p>iv) Accuracy class</p> <p>v) Burden</p> <p>vi) Accuracy limit factor</p> <p>vii) Maximum resistance of secondary winding</p> <p>viii) Knee point voltage</p> <p>ix) Current rating of secondaries</p>	<p>kV</p> <p>VA</p> <p>Ω</p> <p>V</p> <p>A</p>		
17.	<p>Transformer Oil</p> <p>i) IS 335 / IEC60296 / as per specification</p> <p>ii) Inhibited/ un-inhibited</p> <p>iii) Mineral / Natural Ester / Synthetic Ester</p> <p>iv) Spare oil as percentage of first filling</p> <p>v) Manufacturer</p> <p>vi) Quantity of oil (before filling and before commissioning)</p> <p>vii)Moisture content (mg/L or ppm)</p> <p>viii) Tan delta (Dielectric Dissipation Factor) at 90°C</p> <p>ix) Resistivity (Ω-cm))</p>			

	<p>x) Breakdown Voltage (before and after treatment) (kV)</p> <p>xi) Interfacial tension at 20 °C (N/m)</p> <p>xi) Pour point (°C) xii) Flash point(°C)</p> <p>xiii) Acidity (mg KOH/gm)</p> <p>xiv) Inhibitors (for inhibited oil) (%)</p> <p>xv) Oxidation Stability</p>			
18.	<p>Press Board:</p> <p>i) Make</p> <p>ii) type</p>			
19.	<p>Conductor Insulating Paper</p> <p>i) Kraft paper</p> <p>ii) Thermally upgraded Kraft paper</p> <p>iii) Nomex</p>			
20.	<p>Provision for fire protection system (as per spec), if yes, provide details</p>	Y/N		
21.	<p>Insulation of core bolts, washers, end plates etc.</p>			
22.	<p>Weights and Dimensions:</p> <p>i) Weights:</p> <p>a. Core</p> <p>b. Windings</p> <p>c. Tank</p> <p>d. Fittings</p> <p>e. Oil</p> <p>f. Total weights of complete transformers with oil and fittings</p> <p>ii) Dimensions;</p> <p>a. Overall Height above track</p> <p>b. Overall length</p>			

	<p>c. Overall breadth</p> <p>iii) Minimum bay width required for installation of the transformer</p> <p>iv) Weight of the heaviest package of the transformer arranged for transportation</p>			
23.	<p>Lifting Jacks</p> <p>i) Number of jacks included</p> <p>ii) Type and Make</p> <p>iii) Capacity iv) Pitch</p> <p>v) Lift</p> <p>vi) Height in close position</p>			
24.	<p>Rail Track gauges</p> <p>i) 2 Rails or 3 rails or 4 rails</p> <p>ii) Distance between adjacent rails on shorter axis</p> <p>iii) Distance between adjacent rails on longer axis</p>			

ANNEXURE-D TEST PLAN AND PROCEDURES

Tests for Transformers

No.	Test	Um ≤ 170kV	Um > 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.	Tan delta of bushing at variable frequency (Frequency Domain Spectroscopy)	Routine	Routine
11.	Full wave lightning impulse test for the line terminals (LI)	Type (for Um≤72.5kV) Routine (for 72.5kV< Um≤170 kV)	-
12.	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
13.	Lightning impulse test for the neutral terminals (LIN)	Type	Type
14.	Switching impulse test for the line terminal (SI) (Not applicable for Um≤72.5 kV)	Type	Routine
15.	Applied voltage test (AV)	Routine	Routine
16.	Line terminal AC withstand voltage test (LTAC) (Not applicable for Um≤72.5 kV)	Routine	Type
17.	Induced voltage withstand test (IVW)	Routine	-
18.	Induced voltage test with PD measurement (IVPD)	Routine*	Routine
19.	Measurement of transferred surge on Tertiary due to HV lightning impulse and LV lightning impulse	-	Type

20.	Measurement of transferred surge on Tertiary due to HV Switching impulse and LV Switching impulse	-	Type
21.	Test on On-load tap changer (Tap changer fully assembled on the transformer)	Routine	Routine
22.	Measurement of dissolved gasses in dielectric liquid	Routine	Routine
23.	Check of core and frame insulation	Routine	Routine
24.	Leak testing with pressure for liquid immersed transformers (tightness test)	Routine	Routine
25.	Appearance, construction and dimension check	Routine	Routine
26.	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.	Routine	Routine
27.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine	Routine
28.	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine	Routine
29.	Tank vacuum test	Routine	Routine
30.	Tank pressure test	Routine	Routine
31.	Check of the ratio and polarity of built-in current transformers	Routine	Routine
32.	Temperature rise test	Type	Type
33.	Overload testing in short-circuit method (applicable for 765 kV transformer only)	-	Type
34.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)	Routine	Routine
35.	Over excitation test (applicable for 765 kV transformer only)	-	Routine
36.	Measurement of Zero seq. reactance (for three phase Transformer only)	Type	Type
37.	Measurement of harmonic level in no load current	Type	Type
38.	Determination of acoustic sound level	Type	Type
39.	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)	Type	Type
40.	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 G Ω 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 whichever applicable (HV-IV, HV-LV, IV-LV or otherwise 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.

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 (as applicable)

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) + IV (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 result in highest temperature rise for the test.

The Temperature rise type test results shall serve as a “fingerprint” 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 or ONAF1 and 24 hours for ODAF or OFAF or ONAF2 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, steadyperiod 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)

ANNEXURE-E MANUFACTURING QUALITY PLAN

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

TC --- Test PD- Perpendicular CD- Cross MD- Machine PICC-Paper Insulated

Sr. No.	Item/ Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub- Vendor	Manufact urer	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 \pm 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	P	V	W/V
					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 Tolerance (%) Thickness (mm) 0.25 to 0.5 - 10 Over 0.5 to 1.3 - 7.5 Over 1.3 - 5			

		(b) Resistivity at 20 deg.C		IS 13730	For annealed conductor: 0.01727 ohm/mm ² /m (max)	P	V	W/V
					For half hard conductor: 0.01777 ohm-mm ² /m (max)			
		(c) Insulation test for bunched conductor between strands of CTC (if applicable)		IS 13730	Maximum Charging current	P	V	W/V
		(d) Elongation test for annealed conductors (if applicable)		IS 7404 IS 13730	Thickness Elongation (mm)% 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	-

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) Up to 1.0 - 1.01 to 1.60 - 1.61 to 2.24 - 2.25 to 3.55 - 3.56 to 5.60 - (Tolerance $\pm 25\%$)	Corner Radius (mm) 0.50 x nominal thickness 0.50 0.65 0.80 1.00	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	Paper to be smooth, unglazed surface, free from dust particles and no surface defect Thickness tolerance within specified value $\pm 10\%$		P	V	--
		(b) Density			Nominal value ± 0.05 gm/cm ³				
		(c) Substance (grammage)		f Test	Thickness(μ m) Sub(g/m ²) 50 40 65 52 75 60 90 72 Tolerance: For material ≤ 45 g/m ² $\pm 10\%$ For material > 45 g/m ² $\pm 5\%$				
		(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 μ m/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 (Klemm Method)			10 %				

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 160o bend without fracture			
		(d) Surface insulation resistivity check			Average value: 10 Ω cm ² (min.) Individual value: 05 Ω 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	IS 3024	As per table no. 2 of IS 3024	--	P	V
		(h)Magnetic Polarisation	from	IS 3024	As per appropriate tables of IS 3024	--	P	V
		(i) Grade of CRGO	offered lot	Approved drawing/ Document	Approved Drawing/Document/ Manufacturer standard	P	V	V
		(j) Permeability at 800 A/m				P	V	V

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/cm ³)	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 (Crev) (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						

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer

					> 3-3.6 mm - 30 kV / mm > 6-8 mm TK - kV/mm			
--	--	--	--	--	--	--	--	--

		(l) Ash Content (%)			1 % maximum																		
		(m) Elongation (MD, CD)			<table border="1"> <thead> <tr> <th></th> <th>MD</th> <th>CD</th> </tr> </thead> <tbody> <tr> <td>Up to 1.6</td> <td>- 3 %</td> <td>4 %</td> </tr> <tr> <td>>1.6-3 mm</td> <td>- 3 %</td> <td>4 %</td> </tr> <tr> <td>>3-3.6 mm</td> <td>- 3 %</td> <td>4 %</td> </tr> <tr> <td>>6-8 mm TK</td> <td>- 3 %</td> <td>4 %</td> </tr> </tbody> </table>		MD	CD	Up to 1.6	- 3 %	4 %	>1.6-3 mm	- 3 %	4 %	>3-3.6 mm	- 3 %	4 %	>6-8 mm TK	- 3 %	4 %			
	MD	CD																					
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) <ul style="list-style-type: none"> 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) <ul style="list-style-type: none"> 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 size each 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 /cm2																		
		(g) Compressive strength test			Min for LD - 1400 KV /cm2																		
		(h) Shear strength age-wise			Min for LD - 450 KV /cm2																		
		(i) Thickness			<table border="1"> <thead> <tr> <th>Thickness (mm)</th> <th>Tolerance (±mm)</th> </tr> </thead> <tbody> <tr> <td>10 to 25</td> <td>1.4</td> </tr> <tr> <td>26 to 50</td> <td>2.0</td> </tr> <tr> <td>51 to 150</td> <td>-</td> </tr> </tbody> </table>				Thickness (mm)	Tolerance (±mm)	10 to 25	1.4	26 to 50	2.0	51 to 150	-							
Thickness (mm)	Tolerance (±mm)																						
10 to 25	1.4																						
26 to 50	2.0																						
51 to 150	-																						
		(j) Shrinkage (MD, CD)	IEC 61061/Plant standard																				
		(k) pH Value																					

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(l) Breakdown voltage, parallel to the laminations						
7.	Porcelain Bushings (Hollow)	(a) Visual & dimensional check.	10% Sample per lot	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/ IEC		As per IS 3347/IS 8603/ IEC 60137			
8.	Polyester Impregnated Glass Resin 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			<ul style="list-style-type: none"> • 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 ($\pm 3\%$)			
		(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) Lightning 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			

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(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) <ul style="list-style-type: none"> • BDV • Water content • Tan delta at 90°C • IFT at 27°C 			<ul style="list-style-type: none"> • BDV: Min 70 kV • Water content: Max 5 ppm • Tan Delta at 90°C Max:0.0025 • IFT at 27°C: Min 0.04 N/m 	P	W	V
		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			As per approved drawing			

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		operations, alarms, interlocks and sequential operations						
		(d)BOM check for Component type, make & rating			As per approved drawing			
		(e) DOP check by thin paper insertion method			As per technical specification			
		(f) Degree of Protection (IP Class) verification			As per type test report / approved drawing			
		(g) Check for sealing gasket (EPDMrubber 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 /cm ² (10Kpa) for 24 hrs			No leakage for 24 hours	P	W	V
		(b) 10 times inflation and deflation test at 0.105 Kg /cm ²			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	Free from surface defect	P	V	--

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(b) Mechanical Properties & Chemical composition of raw material used for shaft & roller forging	One sample per melt/heat treatment batch	IS 28 IS 2026	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 (b) Accuracy (c) HV test at 2kV for 1 min between all terminals & earth (d) Switch contact operation test (e) Contact Rating	100%	--	As per approved drawing ± 1.5% of FSD Withstand for 1 min Operation within ± 2.5° C of setting As per Manufacturer's std.	P	P/W	V
18.	Pressure Relief Device	(a) Type & Make (b) Air Pressure Test (c) Liquid Pressure Test (d) Switch/contact testing (e) Leakage test at 75% operating pressure (f) HV test (g) Functional test/Calibration (h) Contact Rating	100%	As per specification	As per approved drawing & free from defect Operate at Specified pressure ± 0.07 kg/cm ² Satisfactory operation at pressure release No leakage for 24 hrs 2 kV withstand for 1 min As per Manufacturer's std.	P	P/W	W/V
19.	Magnetic Oil Level Gauge (MOG)	(a) Type & make (b) Dial Calibration for level (c) 2kV HV test for 1 min between all terminal & earth (d) Leak test with air for 6 Hours (e) Switch/contact operation test (f) Contact Rating	100%	--	As per approved drawing & free from defect Check pointer position for Max, Min and center level (within tolerance as per specifications) Withstand for 1 minute No leakage at 4 kg /cm ² Operate at Min level indication As per Manufacturer's std.	P	P/W	W/V
20.	Valves (Gate, Globe & Butterfly)	(a) Type, make & visual check for material of valve body, gate wedge, spindle and gland (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.	100%	IS 778	As per approved drawing & no visible defect No leakage	P	W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(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/cm2 for 24 hrs.)			(i) No leakage at 5 kg/cm2 for 10 minutes (ii) Max 6 drops/min at 1.5 kg/cm2 (iii) No leak in body and spindle Max 6 drops/min through disc			
21.	Transformer Oil	Routine Test	100%	IS: 335 IEC 60296 IS 6855	As per technical specification	P	W	W
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 (b) Visual Check for a fit up for butt welds on tank walls, base & cover (c) DP test on Butt welds after fit up & load bearing welds (lifting logs, bollards, jacking pads) (d) Air leakage test on assembled tank with turrets & on conservator (e) Visual check of paint shade, paint film thickness (inside & outside) & film adhesion, primer application (f) WPS (Weld procedure specification) approval (g) PQR (Process Qualification Record) (h) Welders Qualification (i) UT (Ultrasonic test) of tank MS Plate of thickness >12mm. (j) RT (Radiography test) of butt weld in bottom plate of tank after fit up (if any) (k) Verification of PWHT (Post weld heat treatment) (l) Surface cleaning by Shot/sand blasting (m) Tank - i. Pressure test (PT)	100% per One design	CBIP Manual Transformer 2013	Free from defect Check for proper welding Check for proper welding No leakage Paint thickness Outside: 155 micron Inside: 30 micron No peel-off Or As per approved drawing Details to be furnished As per Specification/ASME Sec IX Details to be furnished As per Specification/ASME Sec IX Details to be furnished As per Specification/ASME Sec IX Details to be furnished As per Specification/ASME Sec IX Details to be furnished as per Specification i. Withstand-Twice the normal head of oil or normal head+ 35	P	W	V
						P	W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		ii. Vacuum test (VT) iii. Adhesion test iv. Visual Inspection inside transformer tank before PT & VT test			KN/m ² whichever is lower, maintained at base of tank for 8 hrs. ii. Withstand- 3.33 KN/ m ² for 1 hr. iii. Details to be furnished as per manufacturer's standard. iv. Inputs required as per specification			
		(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 (b) DP test on lifting lugs welds (c) Surface cleaning of header support and bracing details by sand/shot blasting (d) Air pressure test on elements (e) Dimensional check after final welding (f) Air pressure test on radiator assembly by water dipping method (g) Visual check of paint shade, paint film thickness & film adhesion (h) WPS (Weld Procedure Specification) approval (i) PQR (Process Qualification Record) (j) Welders Qualification	100%	BS EN 50216-1 IS513 Manufacturer's drawing	As per relevant standards No welding defect Free from surface defect As per relevant standards /CBIP As per approved drawing 2 kg /cm ² for 30 minutes - no leakage As per tech spec, coating thickness more than 70 micron Details to be furnished, if applicable as per Specification/ASME Sec IX Details to be furnished, if applicable as per Specification/ASME Sec IX As applicable As per Specification/ ASME Sec IX	P	W	W/V
24.	OLTC (as applicable)	(a) HV test on Auxiliary circuit (2kV for 1min). (b) Operational test of complete OLTC including functional check of driving mechanism (c) Pressure test on diverter switch oil compartment (d) Mechanical Operation test of diverter switch (endurance test) (e) Mechanical test of tap selector motor drive (f) Sequence test (g) Visual & Dimensional check	100%	IS 8468 IEC 60214	To Withstand for 1 min Satisfactory operation No leakage at 10 Psi for 1 hour No defect after 5000 operations 500 satisfactory operations between extreme taps Switching time within permissible limit Free from defects, dimensions as per drawing	P	P/W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(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			
		(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	Free from cracks and pin holes	P	W	V
		(b) Dimensions		ISO 815	Within tolerance			
		(c) Shore Hardness		ISO 37	70 ± 5 IRHD			
		(d) Tensile Strength		ISO 3865	12.5 N/mm ² min			
		(e) Compression set test		IS 11149	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.		(a) Visual Check		IS 11149	Free from cracks & pinholes	P	W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
	EPDM Gasket for Marshalling Box	(b) Dimensional check (Thickness & Width) (c) Tensile Strength (d) Elongation at break (e) Shore Hardness check as per DIN-53505 (f) Compression test (in air) as per DIN, ISO 815	1 sample/Lot		Within tolerance As per IS 11149 As per IS 11149 As per IS 11149 As per IS 11149			
29.	Bushing CT	Dimensions (Visual check for ID/OD, thickness) Routine test (a) Verification of terminal marking & polarity (b) Overvoltage inter-turn test (c) Determination of error (d) HV Test (Dry power frequency withstand test on secondary winding) (e) Accuracy Ratio (f) Secondary winding resistance for PS/PX class (g) Knee point voltage & excitation current for PS/PX class	100%	IS 16227 IEC 61869-2	As per approved drawing As per IS 16227/ IEC 61869-2 Rated current withstand for 1 min As per IS 16227/ IEC 61869-2 3 kV AC for 1 min withstand As per IS 16227/ IEC 61869-2 As per IS 16227/ IEC 61869-2			
30.	Oil circulating pump (as applicable)	(a) Visual check (b) No load running test (rpm, input power and current) (c) (d) HV test (2kV power frequency withstand voltage test for 1min) (e) Oil pressure test on pumps at 5kg/cm ² for 30 min (f) Locked rotor test	100%	IS 9137	no visual damage/ defect Satisfactory performance & no load losses within limit Should withstand No leakage Satisfactory operation of protection	P	P/W	V
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/cm ² 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

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

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%	As per design drawings	Free from defect	--	P	W
	2. Measurement of Total stack height			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	Proper connection			--	P	V	

	resistance between CC-CL, CC-Yoke bolt, CL-Yoke Bolt by 2kV megger)						
	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

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
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 sharp edge	-	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		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	14. Magnetic balance test		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	15. Magnetizing current test, polarity & vector group		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
V	DRYING OF ACTIVE PART: Vapor Phase Drying (VPD) Validation						
	1. Check of temp of Evaporator	100%	Manufacturer's standards/drawings	Manufacturer's standards/drawings/ checklist	-	P	V
	2. Check temp of Main heating						
	3. Check temp of Sprayed Kerosene						

	4. Check Vacuum Pressure (mbar) of VPD		/checklist				
	5. Check Vacuum Pressure (mbar) of Fine vacuum			Graph of Vacuum Vs Time and Temperature Vs time to be submitted for review			
	6. Check Water Extraction (g / Hr / Ton of Insulation) / Process Termination parameters						
	7. Check total process time (Hrs.)			As per Annexure-L of the document			
	8. Check Oil characteristics before impregnation a. Electric strength b. Water content c. Tan delta at 90°C d. Resistivity at 90°C(For Information)						
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 fitting & connections	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 sharp edge	--	P	V
	5. Visual checks for bushing CT assembly tightness	100%	--	Assembly tightness	--	P	V
	6. Ratio test	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	
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	---

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

Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	Customer

C.	Acceptance Tests For Transformers:	100%	Specification IS: 2026			
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	1.	Appearance, construction and dimension check as assembled for testing	other applicable standard	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 $72.5\text{kV} < U_m \leq 170\text{ kV}$)			P	W
Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	Customer

TC --- Test PD- Perpendicular CD- Cross MD- Machine

PICC-Paper Insulated Copper Conductor CTC-

* Category of Responsibility: P - Actual Test Performance V- Verify and Accept

14.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformers with $U_m > 170$ kV)				P	W
15.	Switching impulse test for the line terminal (SI) (for transformers with $U_m > 170$ kV)				P	W
16.	Applied voltage test (AV)				P	W
17.	Line Terminal AC withstand voltage test (LTAC) (for transformer with 72.5 kV < $U_m \leq 170$ kV)				P	W
18.	Induced voltage withstand test (IVW) (for transformers with $U_m \leq 170$ 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

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 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 temperature rise test is performed)				P	W
	31.	Over excitation test (applicable for 765 kV transformer only)					

D.	Type Tests/Special test		One from Lot	Specification/ IS:2026 60076 /other applicable standard	Specification/		
	<u>For Transformers:</u>						
	1.	Measurement of transferred surge on Tertiary due to HV lightning impulse and IV lightning impulse				P	W

Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	Customer

2.	Measurement of transferred surge on Tertiary due to HV switching impulse and IV switching impulse			
3.	Full wave lightning impulse test for the line terminals (LI) (for $U_m \leq 72.5 \text{ kV}$)			
4.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformer with $U_m \leq 170 \text{ kV}$)			
5.	Lightning impulse test for the neutral terminals (LIN)			
6.	Switching impulse test for the line terminal (SI) (applicable for $U_m > 72.5 \text{ kV}$ & $\leq 170 \text{ kV}$)			
7.	Temperature rise test			
8.	Measurement of Zero seq. reactance (for three phase Transformer only)			
9.	Measurement of harmonic level in no load current			
10.	Determination of sound level			
11.	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)			
12.	Short circuit withstand capability test (Dynamic)			

Annexure-G 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 LoadCell).
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 Analyzer
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 Analyzer (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 a 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-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) shall be as per “Standard Specifications and technical Parameters for Transformers and Reactors (66 kV & above voltage class)” by CEA.

Annexure-L 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 ₂ H 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 Aromatic content	Cyclic (PCA)	IP 346	<3%
3.	Poly Chlorinated Biphenyl content	(PCB)	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.

ANNEXURE- III

TECHNICAL SPECIFICATION FOR ON-LINE DISSOLVED GAS ANALYZER (DGA) SYSTEM SCOPE:

This specification covers design, manufacture, assembly, testing at manufacturer's works before dispatch and supply (FOR Destination), installation, testing and commissioning at site of On-line Dissolved Gas Analyzer (DGA) system specified herein along with all their associated accessories required for satisfactory operation at various EHV substations of Utility.

The scope covers supply, installation & commissioning of On-line Dissolved Gas Analyzer system (Multigas) along with all required accessories suitable for dissolved gas analysis and moisture measurement of insulating mineral oil of transformer for carrying out interpretations as per IEC 60599- 2007-05 The equipment covered in this specification i.e. On-line Dissolved Gas Analyzer system shall meet the technical requirements listed below:

DETAILS OF TECHNICAL REQUIREMENT:

The equipment shall be used for On-line monitoring of fault gas Analysis in transformer oil. It shall measure all seven transformer fault indication gases i.e. Acetylene (C₂H₂), Methane (CH₄), Ethane (C₂H₆), Hydrogen(H₂), Ethylene (C₂H₄), Carbon Dioxide (CO₂), Carbon monoxide (CO) and moisture(H₂O) and the two atmospheric gases i.e. Oxygen(O₂)& Nitrogen(N₂). The Test kit shall meet the technical requirements listed below:

- The equipment shall be suitable for mounting/connecting on EHV transformers/ICTs up to & including 400 kV class without any outage. All the accessories/components required for mounting shall be in the scope of bidder.
- The equipment should be Gas Chromatography based equipment. The equipment shall be capable of extracting the seven Fault gases and the two Atmospheric gases and measuring them individually and reporting the concentrations from transformer oil.
- Moisture Measurement must be through a direct oil immersed Relative Saturation (RS) sensor.
- The monitor shall be equipped with an inbuilt oil circulation system with oil flow monitoring and alarm for stoppage of flow. Inlet and return oil lines must be of Stainless Steel.
- The monitor must have facility for collecting an oil sample for external oil tests, such as an

external quick connect port plus sampling accessories.

- As the equipment is to be connected to transformer by the circulating oil lines, its performance should not be affected by vibrations, noise, transformers hum etc.
- The Equipment shall connect to the transformer main body in two locations. One connection is for supply of oil from the transformer, Second connection is for the return of the oil to the transformer.
- The equipment outfitted with the ability to communicate via modem or FO Port or RS232/RS485. The result shall be communicated to the local computers and as well as transmitted to remote location computers. Communication Protocols required: Modbus, DNP 3 Level 1, IEC 61850
- The equipment shall be able to measure gas concentration and when downloaded should immediately compare it with user selected alarm and caution level for immediate display. The sampling rate shall be selectable as for example 4 or 6 or 12 hrs etc.
- The equipment shall have inbuilt memory to store the results, for a minimum of 3 years
- The equipment should have Front panel display and controls. LCD display to provide up to date information at site level.
- The levels of dissolved gases shall be displayed in PPM. Also it shall be possible to set different alarms levels for dangerous levels immediately.

Detection of Gases:

The gases extracted shall be detected using a portable Gas Chromatograph (GC) with Thermal Conductivity Detector (TCD) or Flame Ionization Detector (FID) method. All the fault gases i.e. H₂, CH₄, C₂H₄, C₂H₆, C₂H₂, CO, CO₂ & two atmospheric gases i.e. O₂ and N₂ concentrations shall be individually measured and displayed. The measurement range, accuracy and repeatability for measurement of each gas shall be as under:

<p style="text-align: center;"><i>G a s e s</i></p>	<p style="text-align: center;"><i>M i n i m u m D e t e c t i o n L i m i t i n p p m</i></p>	<p style="text-align: center;"><i>W o r k i n g R a n g e</i></p>	<p style="text-align: center;"><i>A c c u r a c y (w h i c h e v e r i s g r e a t e r)</i></p>	
<p style="text-align: center;">H y d r o g e n (</p>	<p style="text-align: center;">3</p>	<p style="text-align: center;">U P t o 3 0 0 0</p>	<p style="text-align: center;">± 3 p p m o r ±</p>	

H 2)			p p m	5 %	
M e t h a n e C H 4 ,	5		U p t o 7 0 0 0 p p m	± 5 p p m o r ± 5 %	
E t h a n e C 2 H 6	5		U p t o 5 0 0 0 p p m	± 5 p p m o r ± 5 %	
A c e t y l e n e C 2 H 2	1		U p t o 3 0 0 0 p p m	± 1 p p m o r ± 5 %	
E t h	3		U p	± 3 p	

ethylene C ₂ H ₄			5000 ppm	or ±5%	
Carbon Monoxide (CO)	5		Upper to 10000 ppm	±5 ppm or ±5%	
Carbon Dioxide (C	5		Upper to 30000 ppm	±5 ppm or ±5%	

O 2)				
O x y g e n (O 2)	3 0	U p t o 2 5 0 0 0 p p m	+ 3 0 / - 0 p p m o r ± 5 %	
N i t r o g e n (N 2)	5 0 0 0	U p t o 1 0 0 0 p p m	± 5 0 0 0 p p m o r ± 1 0 %	

Oil temperature Range : -10°C to + 120°C External Temperature Range : -50°C to + 55°C Humidity Range : 5 to 95 %

Pressure withstand : The monitor must withstand pressure from Full Vacuum to 45 psi.

Degree of protection of the enclosure : IP 66

Enclosure material : Aluminium or Stainless Steel

Operating Voltage : 230V AC ± 15%; 50 ± 5% Hz

Communications : RS- 232/RS-485, Ethernet Fiber, USB

Alarm : Sophisticated Programmable alarm system

Calibration:

Instrument must be provided with on-board automated Calibration verification

facility to ensure performance to specifications throughout the service life of the equipment. The Monitor MUST be calibrated with a Reference Calibration Gas Standard that has a NIST Traceability Certificate.

Software:

The software should provide diagnostic report for individual pieces of equipment or for a full system, using the equipment tree. The necessary computer hardware & software shall be supplied for data Archival, Analysis and reporting. Equipment should be supplied with the user friendly PC software which provides fault indication and fault diagnostics including the following:

Fault indication:

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

Fault Diagnosis:

- Key gases
- Ratios (Rogers, IEC. Etc)
- Duval's Triangle

Apart from these tools there shall also be analysis Tool to identify the nature and severity of Transformer faults with greater specificity than other diagnostic tools based on ANN and Expert Analysis Tool. The Tool shall also be able to Harmonic Regression to remove harmonic components in the data, clearly revealing the underlying trends & Piecewise Linear Approximation to accurately assess gassing rate of change

Free hardware and software upgrade shall be supplied by the bidder till expiry of guarantee period.

Accessories:

The equipment shall be supplied with all necessary accessories required for carrying out on-line DGA of transformer oil complete in all respect as per the technical specification. Bidder has to furnish the list of accessories being supplied with the equipments. Free consumables till guarantee period shall be supplied by the bidder till expiry of guarantee period. The following shall be also form a part of supply.

1. Operation Manual
2. DGA Software Manual
3. PC Software manual
4. Compact disc giving operation procedures of Maintenance Manual & Troubleshooting instructions.

DEMONSTRATION:

The acceptance of the kit shall be subjected to the successful demonstration by supplier to the satisfaction of utility at prescribed site. The following functions must be demonstrated.

1. The Oil sampling.
2. The Gas extraction
3. The analysis of the gas sample and reporting the concentrations of the various gases.
4. The Calibration with reference to a NIST traceable gas standard.

The instrument not meeting the requirement will be summarily rejected.

ANNEXURE- IV

ON-LINE INSULATING OIL DRYING SYSTEM (CARTRIDGE TYPE) (IF SPECIFIED IN PS(PRICE SCHEDULE))

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

- Designed for very slow removal of moisture that may enter the oil system or generated during cellulose decomposition. Oil flow to the equipment shall be controlled through pump of suitable capacity (at least 5 LPM).
- The equipment shall display the moisture content in oil (PPM) of the inlet and outlet oil from the drying system.
- In case, drying system is transported without oil, the same shall be suitable for withstanding vacuum to ensure that no air / contamination is trapped during commissioning.

In case, drying system is transported with oil, the oil shall conform to EMPLOYER specification for unused oil. Before installation at site, oil sample shall be tested to avoid contamination of main tank oil.

- Minimum capacity of moisture extraction shall be 10 Litres before replacement of cartridge. Calculation to prove the adequacy of sizing of the on line insulating oil-drying system along with make and model shall be submitted for approval of purchaser during detail engineering.
- The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.
- The equipment shall be capable of transferring data to substation automation system confirming to IEC 61850 through FO port. Necessary interface arrangement shall be provided by the contractor for integration with automation system.

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

**TECHNICAL SPECIFICATION FOR
200MVA, 220/132 KV AUTO TRANSFORMER**

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2. GENERAL TECHNICAL REQUIREMENTS FOR SUPPLY OF POWER TRANSFORMERS

SCOPE

This section provides for design, manufacture, assembly, inspection and testing at manufactures works before dispatch, packing, supply and delivery of power Transformers at destination substation / store complete with all fittings, accessories and associated equipment for efficient and trouble free operation as specified hereinafter, unloading at site/destination, placing on plinth, erection, testing and commissioning.

It is not the intent to specify completely herein all details of the design and manufacture of the equipment. However, the equipment shall conform in all respect to the standards of engineering, design & workmanship listed in this specification and shall be capable of performing continuous commercial operation in a manner acceptable to the purchaser who shall have power to reject the material which in his judgment is not in accordance therewith.

The equipment offered shall be complete will all components in all respects. All such components shall be deemed to be within the scope of supply irrespective of whether those are specifically mentioned in this specification and/or the commercial order or not.

The scope of work shall also include erection, testing and commissioning of the equipment to be supplied against this tender.

In case of parallel operation with the existing transformer,

- i. The impedance, vector group, OLTC connection & range etc. of the transformer is to be matched with that of the existing transformer.
- ii. Necessary provision is to be kept in the transformer control scheme for parallel operation with the existing OLTC control scheme having provision of Master/ Follower/ Independent/ Off operation.
- iii. Matching of physical orientation, mounting rail gauge etc. to facilitate inter-changeability with the existing single phase transformer.

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
IS 2026 : PART 7 : 2009 (Reaffirmed Year : 2019)	-	Power Transformers Part 7 Loading Guidefor Oil-Immersed Power Transformers
IS 2026 : Part 8 : 2009 (Reaffirmed Year : 2019)	-	Power Transformers : Part 8 Applicationsguide
IS 2026 : Part 10 : 2009 (Reaffirmed Year : 2019)	-	Power Transformers : Part 10 Determinationof sound levels
IS 2026 : Part 10 : Sec 1 : 2018	-	Power Transformers part 10 Determinationof 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
IEC 60076 All parts	-	Power Transformers
IS 3024 : 2015	-	Grain Oriented Electrical Steel Sheet andStrip (Third Revision)
IS 8468 : Part 1 : 2018 IEC 60214-1 : 2014	-	Tap-Changers Part 1 Performance Requirements and Test Methods (First Revision)
IEC / IEEE 60214- 2:2019		Tap-changers- Part 2: Application guidelines
IS 8478 : 1977 (Reaffirmed Year : 2016)	-	Application guide for on-load tap changers

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/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 Regulator
IS 1747 : 1972 (Reaffirmed Year : 2016)	-	Nitrogen
IS-5: 2007	-	Colors 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 (Reaffirmed Year : 2019)	-	Rubber Gaskets
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 (twoPack)
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, Regulator
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 Technical Brochure No. 761 (WGA2.49)	Condition assessment of 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)	

In case of difference in provision between IEC and ISS, the stringent one shall be followed.

WARRANTY/ GUARANTEE:

Whether or not the equipment has been installed under his supervision, the Contractor shall be agreeable to the ‘Warranty/ Guarantee’ Clause as stipulated in BSPTCL’s “General conditions of Contract” mentioned in this bidding document, which is 60(sixty) months from date of commissioning or 66(sixty six) months from date of delivery at site whichever comes earlier. However, it may be noted that the contractor shall be agreeable to make this guarantee applicable for the main equipment (i.e. transformer), its fittings and accessories, transformer oil, spares as well as the Fire- prevention and extinguishing system, its fittings and accessories and fiber optic system etc. “The Manufacturer shall also provide warranty/guarantee against any DGA violation in the transformer up to five (5) years from the date of delivery of the Transformer. In the event of any DGA violation, the Manufacturer shall undertake the diagnosis, repair, replacement work of the Transformers without any cost burden to the Purchaser”. Similarly, the checking of “no load loss”, “load loss” etc. may be arranged by BSPTCL just prior to end of guarantee period to verify the performance of machine w.r.t. initial factory test conditions. Violation in test figures beyond reasonable limits may lead tonon- compliance of quality requirement. The obligation under Guarantee clause may be invoked in such conditions.

DRAWINGS

LIST OF DRAWINGS/DOCUMENTS TO BE SUBMITTED BY THE MANUFACTURER

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.

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 Bushing
 - iii) 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/Digital RTCC panel
 - (l) GA drawing for Junction Box
 - (m) GA drawing for Cable Box
 - (n) Cooler Control Scheme: Schematic wiring diagram of cooling arrangement along with write up on scheme
 - (o) Tap Changer Control Scheme: 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) + in support of thermal withstand capability of transformer due to short circuit
 - (u) Calculation of hot spot temperature with heat-map drawings of core and windings
 - (v) Value of air core reactance with a typical write-up of calculation
 - (w) Magnetization 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) Customer inspection schedule**
- (gg) Test procedure of transformer**
- (hh) Manufacturer Quality Program (MQP) and Field Quality Plan (FQP)**
- (ii) Type test reports**
- (jj) O&M manual (hard copy and soft copy) of transformer inter-alia including instructions for Aircell, Oil filling, Bushing removal and Core Coil Assembly un-tanking etc.**

SCOPE OF DESIGN REVIEW

Description
1. Core and Magnetic Design
2. Over-fluxing characteristics up to 1.7 U_m (for transformer)
3. Inrush-current characteristics while charging
4. Winding and winding clamping arrangements
5. Characteristics of insulation paper
6. Typical data and parameters mentioned in GTP
7. Short-circuit withstand capability including thermal stress / withstand capability for 2 seconds
8. Thermal design including review of localized potentially hot area
9. Structural design
10. Cooling design

11. Overload capability
12. Calculations of losses, flux density, core quantity etc.
13. Calculations of hot spot temperature
14. Eddy current losses
15. Seismic design, as applicable
16. Insulation co-ordination
17. Tank and accessories
18. Bushings
19. Mechanical layout design including lead routing and bushing termination
20. Tapping design
21. Protective devices
22. Number, locations and operating pressure of PRD
23. Location, Operating features and size of Sudden Pressure Relay/ Rapid Pressure Rise Relay
24. Radiators, Fans and Pumps
25. Sensors and protective devices– its location, fitment, securing and level of redundancy
26. Oil and oil preservation system (if applicable)
27. Corrosion protection
28. Electrical and physical Interfaces with substation
29. Earthing (Internal & External)
30. Processing and assembly
31. Testing capabilities
32. Inspection and test plan
33. Transport and storage
34. Sensitivity of design to specified parameters
35. Acoustic Noise
36. Spares, inter-changeability and standardization
37. Maintainability
38. Conservator capacity calculation
39. Winding Clamping arrangement details with provisions for taking it “in or out of tank”
40. Conductor insulation paper details
41. Location and numbers of Optical temperature sensors (if provided)

42. The design of all current connections
43. Location & size of the Valves
44. Manufacturing facilities and manufacturing environment (clean, dust free, humidity controlled environment)

All drawings should be in ink and suitable for microfilming. The drawings shall include the following information.

- a) Dimensions and Tolerance on dimensions.
- b) Material designation used for different components with reference to standards.
- c) Fabrication details such as welds, finishes and coatings.
- d) Catalogue or part number for each component and the total assembly with bill of materials.
- e) Identification Marking
- f) Weight of individual components and total assembled weight.
- g) All dimensions and date shall be in S.I Units.

The successful tenderers within 30 (thirty) days after placement of the order, shall furnish six sets of the following drawings for the approval of the purchaser. The drawing in auto-cad should also be submitted.

The purchaser shall communicate his approval/ comment on the drawings to the supplier within reasonable period. **The supplier will depute his engineer for having discussion and design review. In case any modification is required according to the purchaser's comments, the supplier shall modify the drawings and resubmit six copies of the modified drawings for purchaser's approval within one week from the date of communication of comments on the drawings.**

The manufacturing of the equipment shall be strictly in accordance with the approved drawings and no deviations shall be permitted without written approval of the purchaser. All manufacturing & fabrication prior to the approval of the drawing shall be at the supplier's risk.

INSTRUCTION MANUALS

The supplier shall furnish 06 (six) copies of operation, maintenance and erection manual per unit of transformer to the office of the Chief Engineer (Planning & Engineering), Bihar State Power Transmission Co. Ltd. and field officials. The manuals shall be bound volumes and shall contain the following documents/information.

- i Instructions regarding erection, commissioning operation and maintenance of the equipment.
- ii All relevant information and drawings pertaining to the main equipment as well as auxiliary devices.
- iii Marked erection drawing identifying the component parts of the equipment as shipped to enable the purchaser to carry out the erection of the equipment with his own personnel.
- iv Detailed dimensions, assembly and description of all the components.

- v. Apart from the above, each manual shall also contain one set of all the approved drawings, type test reports as well as acceptance/inspection test reports and routing test reports of the corresponding consignment dispatched.

Note: - **These manual shall be invariably furnished to the office of the Chief Engineer (Planning & Engineering), BSPTCL, Patna before dispatch of the transformers and respective field officials before erection.**

DESIGN AND CONSTRUCTION DETAILS

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

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.

Components having identical rating shall be interchangeable.

CLIMATE AND ISOCRERAUNIC CONDITION:

The climate and Iscreraunic conditions at site are given below:

(i)	Maximum ambient temperature in shade	-	50° C
(ii)	Minimum ambient temperature in shade	-	40 ° C
(iii)	Maximum daily average ambient temperature	-	35°C
(iv)	Maximum yearly average ambient temperature	-	30° C
(v)	Maximum relative humidity	-	100%
(vi)	Average number of thunder storm days	-	80 P/U
(vii)	Average rainfall per annum	-	125 cm.
(viii)	Maximum wind pressure	-	150 Kg. /M2
(ix)	Height above sea level	-	Not Exceeding 1000 m
(x)	Earthquake acceleration	-	0.05X2g

3. Design Review

SPECIFIC TECHNICAL REQUIREMENTS

The technical parameters of the Transformer are detailed in Annexure-A: Specific Technical Requirements.

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: (format of GTP) 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.

PERFORMANCE

The power transformers shall be used for **bi-directional flow of rated power**.

Transformers shall be capable of operating under natural cooled condition (ONAN) 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 up to specified load. **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 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 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.

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.

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

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.

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.**

The **maximum flux density** in any part of the core and yoke **at the rated MVA, voltage and frequency** shall be such that **under 10 % continuous over- voltage condition it does not exceed 1.9 Tesla at all tap positions.**

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 duration of 2 seconds** and the same shall be verified during design review.

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

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

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

Transformer shall be capable of withstanding thermal and mechanical stresses due to symmetrical and asymmetrical faults on anyterminals.

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 LV terminals of transformer. The short circuit shall alternatively be considered to be applied to each of the HV and LV transformer terminals.

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 winding hot spots shall be calculated considering the maximum localized losses, insulation thickness at the maximum loss and the oil flow patterns in the winding. The oil temperature rise in the windings shall be used to determine hot spots rather than the bulk top oil temperature. The hot spot for all leads shall be calculated and it shall not exceed the calculated hot spot of the windings.

Tank hotspot temperature under over voltage condition specified above shall **not exceed 110 deg C** considering maximum ambient temperature as 50 deg C.

Also, the most onerous temperature of any part of the core and its supporting structure in contact with insulation or non-metal material shall not exceed the safe operating temperature of that material. Adequate temperature margins shall be provided to maintain long life expectancy of these materials.

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 minimize interference with communication circuits.

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

MAXIMUM LOSSES

The maximum permissible losses (No load loss, I^2R 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	I^2R Losses/Load Losses (Differential of whichever loss is higher shall be considered for penalty)	Rs. 8,00,000/KW
3	Auxiliary Losses	Rs. 8,00,000/KW
Note: For a fraction of a kW, the penalty shall be applied on pro-rata basis.		

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.

DYNAMIC SHORT CIRCUIT TEST REQUIREMENT

The transformer, the design of which is similar to the offered transformer, should have been successfully tested for short circuit withstand capability as per IS 2026 Part-5 within last 5 years. The criteria for similar transformer are specified in Annexure-J of CEA guidelines (File No.CEA-PS-14-169/2/2019-PSETD Division) of transformer. 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.

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.

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.

4. Construction Details

TANK

The tank shall be of proven design of either **Conventional with bolted/welded top cover.**

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

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.

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

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

The tank shall be provided with suitable valves as specified below. Location of valves shall be finalized during design review.

Sr. No.	Description of Valve	Type
1	Drain Valve	Gate
2	Filter valve	Gate
3	Sampling Valve	Globe
4	Radiator isolation valve	Butterfly
5	Buchholz relay isolation valve	Gate
6	Sudden pressure relay	Gate
7	OLTC- tank equalizing valve	Gate / Needle
8	OLTC Drain cum filling valve	Gate
9	Valve for vacuum application on Tank	Gate
10	Conservator Drain valve	Gate
11	Aircell equalizing valve	Gate/Globe/Ball
12	Valve for Conservator vacuum (top)	Gate
13	Filter valve for Cooler Bank (Header)	Gate
14	Cooler Bank isolation valve	Butterfly
15	Pump Isolation valve	Butterfly

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

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.

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.

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 inbetween for complete oil tightness. All matching flanges of gasket sealing joints should be machined(except curb joints). Gasket with intermediate stops is 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.

Foundation, Roller Assembly and Anti Earthquake Clamping Device.

Foundation, Roller Assembly and Anti Earthquake Clamping Device.

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

For transformer to be placed directly on foundation, one set of rollers shall be provided for movement within the yard. The rollers for transformer are to be provided with flanged bi-directional wheels and axles. This set of wheels and axles shall be suitable for fixing to the under carriage of transformer to facilitate its movement on rail track. Suitable locking arrangement along with foundation bolts shall be provided for the wheels to prevent accidental movement of transformer.

The rail track gauge shall be 1676 mm.

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

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.

For support of cooler pipes, Buchholz pipe (if required), Pre-fabricated metallic support from pit shall be provided which shall be further encased with concrete to prevent rusting.

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.

Conservator

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.**

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

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.

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.

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

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.

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 stenciled 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”**.

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.

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

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.

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.

Conservator Protection Relay (CPR)/Air cell puncture detection relay (if required) 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.

Piping works for conservator

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

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.

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

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.

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

BREATHER:-

The main transformer tank/conservator and OLTC tank/ OLTC conservator both shall have breather whose technical specification is mentioned below:-

Technical specification of maintenance free breather for transformers

Objective and Principle of Working of the Breather:

Dehydrating breathers work according to the following principle. When the oil conservator sucks in air (e.g., due to the reduced load), the air flows through a

filter made of high-grade steel wire mesh to the inside of the device. This filter and the dust cap filter dust, sand and other dirt particles from the air. The filtered air flows through the desiccant chamber filled with colorless, moisture adsorbing pellets and are dehydrated. The dehydrated air rises further via the pipe in the oil conservator. The dehydrating breather is mounted on the pipe to the oil conservator. A suitable counter-flange must be installed on the pipe to mount the dehydrating breather. The desiccant contained in the drying assembly is dehydrated using sensor controlled by the built-in heating unit, thus obviating the need for periodic desiccant replacement.

By providing the Maintenance Free Type of Breather the objective is to achieve reduced site inspections, Cost reduction by obviating the complete process of ordering, storage and replacement of the desiccant. It also leads to no pollution and disposal problem of the used up desiccant (which is associated with the conventional pigmented silica gel) is eliminated.

Specification:

1. The main Transformer tank conservator shall be fitted with a silica gel Breather of the Maintenance-Free type, in a convenient floor height at eye level.
2. Each Silica gel breather shall be equipped with a humidity sensor, a condition based microprocessor control unit to ensure that the regeneration of the silica gel is activated only when the transformer is exhaling.
3. A stainless steel filter at the bottom shall protect the silica gel chamber against external environment influences.
4. Insect Protection for the High Grade Filter is also to be provided.
5. This condition controlled application should be environmental friendly.
6. Material of External Construction of the Breather: All external parts must be suitable for mounting for outdoor use, resistant against transformer oil and ultraviolet rays. **Salt water resistance should be made available on request.** No plastic parts shall be used in the construction of the breather.
7. Ambient Temperature: The equipment must be suitable for ambient: 0 to + 80 Deg C.
8. Degree of Protection: Minimum IP55. If the Breather need to be installed in a location where there could be sub-zero temperatures, a filter heater must be provided.
9. The control unit on the breather must be equipped with suitable heater to prevent moisture condensation.
10. The breather should be provided with status LEDs for local display. Also suitable contacts must be provided to take the signal to a remote control room.
11. The moisture and temperature measurement system (sensor) installed should be modular making it easy to replace the same if at all the same is necessary during the

- service of breather. A self-diagnostic system must be provided with LED indication and remote signal through a relay should be provided.
12. To protect against overvoltage, a micro fuse and an additional built in line filter must be provided to avoid failures caused by high-frequency interference.
 13. The control unit in the breather must provide analogue output signal of 4-20mA and also should be equipped with a USB Port for data logging.
 14. Suitable Data Logger should be also provided in the control unit.
 15. The Breather should be equipped with an optional integrated test button. This should allow to carry out a self-test at any time and to check the functions, like the relay circuits, the heating or the signal transmission in the control room.
 16. Rated Insulation Voltage:
500VAC 50 Hz, 1min., voltage supply voltage: against ground;
500VAC 50 Hz, 1min., analog output against ground; 2.5kVAC 50/60Hz, 1 min., relay contact against ground
 17. **Necessary List of Type Test Conducted and Routine Test Certificate issued by the manufacturer of the maintenance free Breather used must be provided for each supply.**

The arrangement and placement of maintenance free breather shall be such that retrofitting with conventional type breather as described above for OLTC is possible with ease. The quantity of silica gel in maintenance free breather shall depend upon the size of transformer and volume of oil contained therein. The bidders are required to indicate this in their offer.

PRESSURE RELIEF DEVICE :

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

PRD shall be provided with special shroud to direct the hot oil in case of fault condition. It shall be provided with an outlet pipe which shall be taken right up to the soak pit of the transformer. The size (Diameter) of shroud shall be such that it should not restrict rapid release of any pressure that may be generated in the tank, which may result in damage to equipment. Oil shroud should be kept away from control cubicle and

clear of any operating position to avoid injury to personnel in the event of PRD operation.

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

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

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

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. Pressurized water ingress test for Terminal Box (routine tests) shall be conducted on Buchholz relay.

TEMPERATURE INDICATOR :

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 wirings 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 degrees 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.

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]. 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 weatherproof and epoxy coating at all sides. Instruments should meet degree of protection of IP55 as per IEC60529. 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 contact 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.

Fiber Optic System

The transformer shall be fitted with optical fiber temperature system for direct/real time temperature monitoring and control. The technical specification for such system is mentioned below:

TECHNICAL SPECIFICATION OF FIBER OPTIC SYSTEM Fiber

Optic Temperature Sensors:

The transformer shall be equipped with fiber optic temperature sensors for monitoring direct hotspots into transformer windings, core, and oil temperature. 13 fiber optic sensors shall be installed for the following measurement points:

- One sensor each on the lateral winding of Primary and Secondary phases
- Two sensors each on the central windings of Primary and Secondary phases
- Two sensors for Top and bottom oil temperatures, preferably where the oil enters and exits center phase winding assembly
- Three sensors positioned to measure the hottest temperatures in the core, between the core and core clamping structure, and of the core clamping structure.

The locations of fiber optic sensors shall be proposed by the Manufacturer and locations finalized by agreement of the Purchaser.

Fiber Optic temperature Sensors shall be based on the proven zero-drift wavelength-shift Gallium Arsenide (GaAs) technology, suitable for all oil types, 200 μm all silica, Torlon disk, with a protection layer in radiant green colored PTFE Teflon protective spiral-wrap for improved visibility and mechanical strength. Sensors shall withstand exposure to hot kerosene vapor during the transformer insulation drying process.

Fiber Optic temperature sensor tips and tip/disk assemblies shall meet the following:

- i The temperature measurement range should be between -80 °C to +250 °C, with a total system accuracy of ± 1 °C.
- ii No greater than 3pC (pico-Coulomb) partial discharge in mineral oil under 60 Hz AC stress per ASTM D149, Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies and negative lightning impulse conditions per ASTM D3426, Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Material using Impulse Waves
- iii Fiber optics sensors to withstand pull test of forces exceeding 60 N (~6 kg-F); 1 kg-f (kilogram-force) is about 10 N (Newton)
- iv End interface ST connectors made of Zirconia for optimal light energy transfer

FO System Accessories:

The optical signal shall be brought out of the tank using a solder-glass optical feedthrough (without use of O-rings or seals), withstanding pressure in excess of 200 PSI. A 316L Stainless steel-based tank wall plate accommodating thirteen optical feedthroughs shall be installed on the tank.

The optical feedthroughs shall be assembled on the Tank Wall Plate and assembly shall be pressure-tested for the expected pressure inside transformer.

A protective 316L stainless steel-based interface box (I-Box) cover designed to mate with the wall plate shall be supplied. The box must be leak proof (IP66 rated), so that all optical feedthroughs and extension cables are protected from moisture and dust ingress.

EARTHING TERMINALS :-

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.**

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 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.

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.

CORE

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

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 rightangles 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.

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.

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.

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

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

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.

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

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

Single point core earthing should be ensured to avoid circulating current. Core earth should be brought separately on the top of the tank to facilitate testing after installation on all transformers. The removable links shall have adequate section to carry ground fault current. Separate identification name plate/labels shall be provided for the 'Core' and 'Core clamp'. Cross section of Core earthing connection shall be of minimum size 80 sq.mm copper with exception of the connections inserted between laminations which may be reduced to a cross-sectional area of 20 sq. mm tinned copper where they are clamped between the laminations.

In case core laminations are divided into sections by insulating barriers or cooling ducts parallel to the plane of the lamination, tinned copper bridging strips shall be inserted to maintain electrical continuity between sections.

Insulation of core to clamp/frame shall be tested at 2.5 kV DC for 1 minute without breakdown after the transformer is filled with liquid and insulation resistance should be at least 500 Mega ohm for new transformer.

WINDINGS

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.**

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.

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.

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.

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.

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.

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

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.

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.

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.

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.

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.

Winding paper moisture shall be less than 0.5%.

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

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.

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.

Winding terminations into bushings

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.

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.

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.

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.

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.

GAS AND OIL-ACTUATED RELAYS

GAS AND OIL-ACTUATED RELAYS

Each transformer shall be fitted with gas and oil-actuated relay equipment having alarm contacts, which close on collection of gas or low oil level, and tripping contacts which close following oil surge conditions. Separate relays shall be provided for on load tap changer.

Each gas and oil-actuated relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

Each relay shall be fitted with a calibrated glass window for indication of gas volume.

To allow gas to be collected at ground level, a small bore pipe shall be connected to the gas release cock of the gas and oil-actuated relay and brought down to a point, approximately 1400 mm above ground level,. Where it shall be terminated by a cock, which shall have provision for locking to prevent unauthorized operation.

The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal-operation of the relay will not take place under normal service conditions, including starting or stopping of oil circulating pumps whether by manual or automatic control under all operating temperatures.

The pipe work shall be so arranged that all gas arising from the transformer will pass into the gas and oil-actuated relay. The oil circuit through the relay must not form a delivery path in parallel with any circulating oil pipe, nor is to be tied into or connected through the pressure relief vent. Sharp bends in the pipe work shall be avoided. For this reason, bushing turrets, if fitted shall have vent pipes, which will route any gas collection through the relay.

A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay.

A straight run of pipe work shall be provided for a length of five times the internal diameter of the pipe on the conservator side of the gas and oil- actuated relay.

The surge float contacts shall close at a rate of steady oil flow between the following limits. As far as possible, the limits shall also be met when the relay is subjected to oil surge conditions, produced by rapid opening of a lever operated gate valve.

The relays shall be so located as to be easily accessible from the top of the tank. Oil Pipe Connection I.D. (mm) Operational Limits for Relay.

[Rising angles of 1° to 9°.]

700-1300

750 – 1400

900-1600

The gas collection contacts shall operate within the angle limits, specified for test:

when a transformer is provided with two conservators, the gas and oil -actuated relays shall be arranged as follows:

- (i) If the two conservators are connected to the transformer by a common oil pipe, one relay shall be installed in the common pipe.
- (ii) If the two conservators are piped separately to the transformer, two relays shall be installed, one in each pipe connection.

4.16.12 The clearance between oil pipe work and live metal shall be not less than the minimum clearances as per standard practice.

INSULATING OIL :-

The insulating oil shall be unused inhibited (Type A, High Grade) 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 10% 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.

TAP CHANGING MECHANISM :

Main OLTC Gear Mechanism

Three phase 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 side), location (physical and electrical) of tap winding (end of common/ series winding or at neutral end), range of voltage variation, no. of steps etc. shall be as given in **Annexure-A**.

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 shall be designed so as to ensure that its operation

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

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.

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.

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.

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

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.

Local OLTC Control Cabinet (Drive Mechanism Box)

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.

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 than 1800mm). 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.

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.

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/contactors 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.

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.

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.

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.

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 input to digital RTCC/relevant BCU (as applicable)/SCADA system. The tap position indicator shall also be provided in control room.

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

For 3-phase transformer, 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

The following minimum contacts shall be available in DM Box. For three phase unit, 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

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.

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

Remote Control & Monitoring of OLTC (through Bay Control Unit/ Digital RTCC Relay, as applicable)

Requirement of digital RTCC relays may be specified by the utility for existing conventional substations as per its practice. For substations/ power plants having Substation Automation System, Control & monitoring of OLTC shall be carried out through Substation Automation System. All the 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. Wherever, digital RTCC relay is required following specification may be followed.

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

Each digital RTCC relay shall be used to control 1 bank of transformers(i.e. 3 Nos. 1-Phase units or 1 No. 3-Phase unit). No. of relays including spare relay, if any, shall be specified by the utility as per requirement.

All digital relays can be housed in a single digital RTCC panel in control room or in the BCU panel in kiosks located in the switchyard.

~~For existing substations, the requirement of digital RTCC panel and relays shall be specified by the utility. However, availability of existing RTCC schemes /Digital RTCC relays need to be specified to finalise matching digital RTCC relays. The Digital RTCC relays envisaged for existing transformers shall be integrated for parallel operations. All required cables for the same shall be deemed to be included in the scope.~~

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.

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.

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.

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.

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

Raise/Lower control: The remote OLTC scheme offered shall have provision to raise or lower taps 3-Phase Transformer.

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.

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.

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.

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.

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

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.

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.

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

- (a) INCOMPLETE STEP alarm
- (b) OLTC motor overload protection alarm
- (c) Supply to DM Motor fail alarm
- (d) OLTC IN PROGRESS alarm
- (e) Local/ Remote Selector switch positions in DM Box
- (f) OLTC upper/lower limits reached alarm
- (g) OLTC Tap position indications for transformer units
- (h) Independent-combined-remote selector switch positions of CMB(in case of single phase transformer)
- (i) 415V, AC Main Supply Fail.
- (j) 415V, AC Standby Supply Fail

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

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

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

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

The Cooler Control Cabinet (CCC)/Individual Marshalling Box (IMB), Common Marshalling Box (CMB), 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 1.6mm. Digital RTCC panel shall be made of CRCA sheet of minimum thickness of 2.0 mm and shall be painted suitably as mentioned in this specification.

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

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.

All the contacts of various protective devices mounted on the transformer and all the secondary terminals of the bushing CT shall also be wired up to the terminal board in the Marshalling Box. All the CT secondary terminals in the Marshalling Box shall have provision for shorting to avoid CT open circuit while it is not in use. All the necessary terminations for remote connection to Purchaser's panel shall be wired up to the Common Marshalling Box.

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.

AUXILIARY POWER SUPPLY FOR OLTC, COOLER CONTROL AND POWER CIRCUIT

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.

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.

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).

All relays and operating devices shall operate correctly at any voltage within the limits specified below:

Normal Voltage	Variation in voltage	in	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%.

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/Common Marshalling Box for failure of normal source and for transfer to standby source and also for failure to transfer.
- d) Automatic re-transfer to normal source without any intentional time delay following re-energization of the normal source.
- e) Both the transfer and the re-transfers shall be dead transfers and AC feeders shall not be paralleled at any time.

For spare unit which is not connected through isolator switching arrangement, 415 volt, three phase four (4) wire AC supply shall be provided for heater,.

TRANSFORMER BUSHINGS :-

4.21.1 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 for 400 kV and below voltage class transformers	RIP/RIS
Bushings of 36 kV and below	Solid porcelain
Bushings of other rating	OIP/RIP/RIS

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

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.

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

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

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.

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.

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

Bushings of **identical rating of different makes shall be interchangeable** to optimise the requirement of spares.

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.

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

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

Clamps and fittings shall be of hot dip galvanized/stainless steel except for Aluminium Clamps and connectors.

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

No arcing horns shall be provided on the bushings.

Corona shield (wherever required or not, as per calculation at the time of bid), shall be provided at bushing terminal (air end) to minimize corona.

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.

Oil end portion of RIP/RIS type bushings shall be fitted with metal housing with positive dry air pressure and a suitable pressure monitoring device shall be fitted on the metal housing during storage to avoid direct contact with moisture with epoxy. The pressure of dry air need to be maintained in case of leakage.

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

Tan delta measurement at variable frequency (in the range of 20 Hz to 350 Hz) shall be carried out on each condenser type bushing(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.

Tan δ value of 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.

COOLING :-

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.

The cooler shall be designed using **tank mounted radiators**. Design of cooling system shall satisfy the performance requirements.

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

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.

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

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.

Cooling fans 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 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.

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.

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.

Automatic operation control of fans 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. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.

Suitable manual control facility for cooler fans 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 manually.

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) Common thermal overload trip
- g) Thermal overload trip for each fan
- h) Stand by fan

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.

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.

All the necessary terminations for remote connection to Purchaser's panel shall be wired up to the Marshalling Box (3-Ph unit).

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.

CLEANING AND PAINTING :-

Before painting or filling with oil or compound, all ungalvanised parts shall be completely cleaned and made free from rust, scale and grease and all external rough surfaces in castings, shall be filled by metal deposition. The interior of all transformer tanks and other oil filled chambers and internal structural steel work shall be cleaned of all scale and rust by sand blasting or other approved method. These surfaces shall be painted with an oil resisting varnish or paint. Unexposed welds not be painted.

PAINTING PROCEDURE

PAINTING	Surface preparation	Primer coat	Intermediate undercoat	Finish coat	Total Dry Film Thickness (DFT)	Colour shade
<u>External surfaces:</u> Main tank, pipes, conservator tank, oil storage tank & Driving Mechanism (DM) Box etc. ()	Shot Blast cleaning Sa 2 1/2*	Epoxy base Zinc primer (30-40µm)	Epoxy high build Micaceous iron oxide (HB MIO) (75µm)	Aliphatic polyurethane (PU) (Minimum 50µm)	Minimum 155µm	RAL 7035

Internal surfaces: Main tank, pipes (above 80 NB#), conservator tank, oil storage tank & DM Box etc. ()	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

5.0 QUALITY ASSURANCE PROGRAMME

INTRODUCTION

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) Organization 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.

GENERAL REQUIREMENTS - QUALITY ASSURANCE

All materials, components and equipment required for transformer 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.

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 Organization, 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.

List of testing equipment available with the manufacturer for stage/final testing of transformer 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.

The transformer 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 authorized 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.

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.

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

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.

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 organization, 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.

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.

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.

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.

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

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.

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.

Transformer 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 authorized agency, during various stages of site activities starting from receipt of materials/equipment at site till commissioning.

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.

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.

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.

QUALITY ASSURANCE DOCUMENTS

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.

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.

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.

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.

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.

Note:- The word 'Inspector' shall mean the authorized representative and to inspect and examine the materials and workmanship of the works during its manufacture or erection.

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

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).

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.

5.04.2 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.

Virtual Stage inspection & Factory Acceptance Test (FAT)

The conventional practice of witnessing Stage inspection and Factory Acceptance Test (FAT) of transformers 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.

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 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.

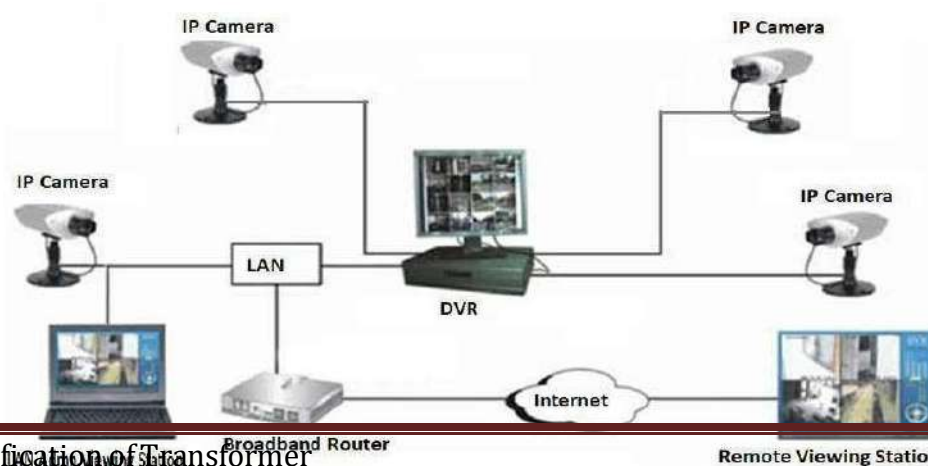
(Note: Issues of screen blinking may be observed during chopped wave lightning impulse due to earthing issues and should be ignored)
- (c) Qualified engineers well-conversant with technology shall be deployed to effectively handle online stage inspection/FAT.
- (d) Online applications like Microsoft 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 visualization 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.

Procedure for virtual inspection / testing:

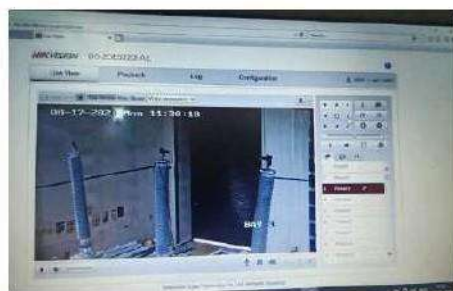
- (a) Manufacturer's QA/QC in-charge will plan, verify the process checklist and ensure that the Stage inspection/Routine/FAT are conducted as per approved quality plan in line with the Technical Specification.
- (b) Manufacturer will submit soft copies of Photographs and Calibration Certificates with proper index sheet duly certified from their end in order to demonstrate readiness of Transformer for inspection/testing.
- (c) The Date and time and arrangement for online stage inspection/FAT shall be finalized 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 utilities'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 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 authorized 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 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 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 may be moved to next stage of manufacturing process and after getting FAT Clearance from utility/purchaser.

- (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.

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.

Deleted

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.

The inspection by the Inspector and issue of **Joint Inspection report 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.**

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.

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.
- d) Calibration certificates for all the testing equipments, test certificates of raw materials etc.

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.

Factory Tests

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.

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.

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

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.

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 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 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

islower, 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.

Stage Inspection

Stage inspection will be carried out by the Inspector **on Core, Winding, core-coil assembly & Tank during the manufacturing stages** of the transformer. 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.

Stage inspection will be carried out on at least one Transformer 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.

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.

1. Invoice of supplier
2. Mills' approved test certificates
3. Packing list
4. Bill of lading
5. Bill of entry certificate by custom.
6. Description of material, electrical analysis, physical inspection, certificate for surface defects, chemical composition certificate, thickness and width of the materials
7. 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 organization of repute and not through any agent.

Typical example for calculation of flux density, core quantity, no-load loss and weight of copper during stage inspection shall be as per "Standard Specifications and technical Parameters for Transformers and Reactors (66 kV & above voltage class)".

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)
- 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)

Pre-shipment Checks at Manufacturer's Works

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

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

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

Ensure following setting of impact recorder at the time of installation with transformer 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.

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

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.

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

7.0 UNLOADING OF TRANSFORMERS INCLUDING HANDLING AND PLACEMENT ON PLINTH, ERECTION, TESTING & COMMISSIONING OF TRANSFORMERS AT SITE:

The supplier shall have to do unloading of transformers including handling and placement on plinth, erection, testing & commissioning of the transformers at site supplied by them. They shall quote charges accordingly in the schedule of price. Such quoted rates shall be considered for tender evaluation.

The charge for deputation of their service engineer on per day basis shall also be quoted in the price bid. This will not be considered for tender evaluation.

Upon the transformer having successfully erected & completed the required site tests and commissioned, the purchaser or its authorized engineer, after satisfying that the equipment is in full and satisfactory working condition, will issue a Job completion certificate which will form basis for payment of their service bills.

8.0 SPARE PARTS & MAINTENANCE EQUIPMENTS:

The tenders shall quote separately for mandatory spares as specified in the schedule. The make and type of such spares offered shall be same as those offered along with the main transformer and inter changeable with the similar items. The prices offered for supply of these spares shall be taken into consideration for the purpose of bid evaluation.

The tenderers shall also indicate in their proposal and quote their rates for any other spares recommended for the trouble free operation of the equipment for five years. The prices of these optional spares shall not be taken into consideration for the purpose of bid evaluation. The purchaser shall decide the actual quantities of spare parts to be included in the order on the basis of this list and the items wise prices of spare parts.

9.0 ERECTION AND MAINTENANCE TOOLS:

The tenderers shall separately list out in their tender the sets of tools required for initial erection and subsequent maintenance for the power transformer and the associated equipment. The prices quoted for such tools shall not be taken into consideration for the purpose of bid evaluation.

10.0

VENDOR SELECTION FOR MOUNTING ACCESSORIES:

S. No.	ItemDescription	Proposed make
1.	Core	Core materials to be procured directly from authorized dealer of CRGO manufacturer as following:
		POSCO, Korea
		NIPPON, Japan
		JFE, Japan
2.	Winding	HINDALCO
		Hindustan Copper
		Sterlite
	CTC Conversion	Asta India, Vadodara
		KSH International, Chakan
		Precision Wires, Silvassa
		Sri Cables & Conductors (P) Ltd., Bhopal
	3.	Transformer Oil
4.	Paper Insulation for Conductor	Weidman Electrical, Switzerland
		Smurift Munksjo, Sweden
5.	Pre-compressed Board	ABB, Sweden
		H Weidman, Switzerland
		Senapathy Whiteley, Bangalore
		Raman Boards, Mysore
6.	Un-impregnated Densified Wood	Permalli Wallace, Bhopal
		Western India Plywood, Cannanore
7.	Bushing CT	Mahindra Electricals, Mumbai
		BHEL, Bhopal
		Pragati Electricals Pvt. Ltd., Thane
		A.U. Electric Machines, Allahabad
8.	Tank	Self manufacturing as well as out sourced
	Sheet	SAIL, RINL, TISCO, IISCO
	Tank fabricator	Satyam Industries, Bhopal
		Allahabad Enterprises, Allahabad
9.	OIP Bushing	Alstom
		CGL, Nasik/Aurangabad

		ABB
10.	Porcelain Bushing Insulator	CJI, Khurja
		W S Industries, Chennai
		Jayashree Insulators, Halol
		BHEL, Bangalore
11.	Rubber Gasket	Nu Cork Products, Bhiwadi
		Bombay Oil Seal Mfg Co., Mumbai
12.	Marshalling Box	BHEL, Bhopal
		Pyrotech, Udaipur
		C&S, Noida
		United Industrial Components Co., Navi Mumbai
		Ashoka Electronic, Bhopal
		Own make subject to valid type test report
13.	Terminal Connector	Nootan, Vadodara
		Milind Engineering, Mumbai
14.	Bucholz Relay	EMB,Germany
15.	OTI/WTI	Perfect Control, Chennai
		Precimeasure, Bangalore
16.	OLTC	BHEL, Bhopal
		CTR, Pune
		ABB, Sweden
		Easun MR, Chennai
17.	Radiators	CTR, Pune
		Transpares, Ahmedabad
		Hi Tech Radiators, Mumbai
		Thermal Transfer, Bangalore
		Gururaj Radiators Pvt. Ltd., Naini
18	Silicagel Breather (Maintenance free)	MESSKO,ABB
19.	Fibre Optic Sensor	Rugged Monitoring Inc, Canada,Qualitrol
20.	Valves	Leader Valves, Jalandhar
		GG Valves Ltd, Udaipur
		Petson Valves, Coimbatore
21.	PRV (Pressure Release Valve)	Sukrut, Pune
		Qualitrol Company, USA
		MESSKO, Germany

22.	Cooling fan	Marathon, Kolkata
		Khaitan, Kolkata
		CGL

ANNEXURE –A GTP for 200 MVA 220/132 kV, 3-Phase Auto Transformer

S. No.	Description	Unit	TECHNICAL PARAMETERS
1.	Voltage ratio (Line-to-Line)	kV	220/132
2.	Rated capacity (HV and LV)	MVA	200
3.	No of phases		3 (Three)
4.	Vector Group		YNa0
5.	Type of transformer		Auto Transformer
6.	Applicable Standard		IEC 60076 / IS 2026
7.	Cooling type		ONAN/ONAF/OFAF
8.	Rating at different cooling	%	60 /80/ 100
9.	Cooler Bank Arrangement		2 X 50%
10.	Frequency	Hz	50
11.	Tap changer		
i)	Type		On-load tap changer
ii)	Tapping range and steps		-10% to +10% 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	%	10.3
ii)	Principal tap	%	12.5 (No negativetolerance)
iii)	Min. Voltage tap	%	15.4
13.	Tolerance on Impedance	%	As per IEC with no negative tolerance
14.	Service		Outdoor
15.	Duty		Continuous
16.	Overload Capacity		IEC 60076-7
17.	Temperature rise over 50°C ambient temp.		
i)	Top oil measured by thermometer	°C	45
ii)	Average winding measured by resistance method	°C	50
18.	Winding hot spot rise over yearly weighted temperature of 32 °C	°C	61
19.	Tank hot spot temperature	°C	110
20.	Maximum design ambient temperature	°C	50
21.	Windings		

i)	Lightning Impulse withstand Voltage		
	HV	kV _p	950
	LV	kV _p	650
	Neutral	kV _p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV _p	1045
	LV	kV _p	715
iii)	Switching Impulse withstand Voltage		
	HV	kV _p	750
	LV	kV _p	540
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV _{rms}	395
	LV	kV _{rms}	275
	Neutral	kV _p	38
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	245
	LV	kV	145
	Neutral		36
ii)	Rated current (Min.)		
	HV	A	1250
	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV _p	1050
	LV	kV _p	650
	Neutral	kV _p	170
iv)	Switching Impulse withstand voltage onHV	kV _p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV _{rms}	505
	LV	kV _{rms}	305

	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		7595
	LV	mm	4495
	Neutral	mm	1116
vii)	Maximum Partial discharge level at U _m on HV & LV	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	75
25.	Maximum Permissible Losses of Transformers		
i)	Max. No Load Loss at rated voltage and frequency	kW	35
ii)	Max. Load Loss at rated current and frequency and at 75°C at principal tap for HV & LV	kW	260
iii)	Max. I ² R Loss at rated current and frequency and at 75°C at principal tap for HV & LV	kW	190
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	8

ANNEXURE –B DETAILS OF BUSHING CT AND NEUTRAL CT for 200 MVA Transformer

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

Note:

- i) Parameters of WTI CT for each winding shall be provided by the contractor and finalized at the time of approval.
- ii) For estimation of spares, one set of CTs shall mean one CT of each type used in transformer.
- iii) The CT used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
- iv) Class (for the relevant protection & duties) as per IEC 185.

ANNEXURE-C GUARANTEED AND OTHER TECHNICAL PARTICULARS FOR POWER TRANSFORMER

(To be filled in by the manufacturer)

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
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/Auto iii) GT/Step-down/ICT/Station Start-up/ Auxiliary/ Rail Trackside Supply iv) Bi directional			
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 Capacity / Full load rating (HV/LV)	MVA		
9.	3-Phase/Bank of Three Single Phase (A,B,C)			
10.	Rated No Load Voltages (HV /LV)	kV		
11.	Currents at normal tap (HV /LV)	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 10% extra oil	kg		
	ix) Weight of core	Kg		
	x) Weight of copper (HV/LV/ Regulating)	kg		

	xi) Insulating Oil volume (excluding 10% extra oil)	Ltrs		
	xii) Quantity of oil in OLTC	Ltrs		
15.	Transport limitation			
16.	LV Winding i) Stabilizing tertiary (Yes/No) ii) Loaded (Yes/No)			
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 ² R Loss at rated current & frequency (at 75 ^o C) at principal tap	kW		
	Tolerance (to be considered for loss evaluation)	%		
	iii) Eddy current and stray loss at rated current & frequency (at 75 ^o C) at principal tap	kW		

	iv) Load Loss(I^2R +Eddy and Stray) at rated current & frequency (at 75°C) at principal tap	kW		
	v) Guaranteed Auxiliary loss at rated voltage and frequency	kW		
	Tolerance (to be considered for loss evaluation)	%		
	vi) Calculated Fan Loss	kW		
	vii) Calculated Pump Loss	kW		
	viii) Air core reactance of HV winding	%		
	ix) Guaranteed Impedance (at Highest MVA base)	%		
	(a) HV-LV(at Principle tap)			
	Tolerance			
	x) Impedance at extreme tappings at Highest MVA base [for HV-LV for two winding transformer]	%		
	a) Max. Voltage tap			
	b) Min. Voltage tap			
	Tolerance	%		
	xi) Zero sequence impedance at principal tap (for 3-phase transformers)			
19.	Capacitance to earth for HV/LV	pF		
20.	Regulation at full load at 75 °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	kA		

	current)			
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% 140% 150% 170%	msec		
29.	Free space required above the tank top for removal of core			
30.	Maximum Partial discharge level at $1.58 U_r/\sqrt{3}$	pC		

A. MAGNETIC SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufa-cturer
1.	Core Type: i) 3 Phase 3 Limb (3 wound limbs) ii) 3 Phase 5 Limb (3 wound limbs) iii) 1 Phase 2 Limb (2 wound limbs) iv) 1 Phase 3 Limb (1 wound limb) v) 1 Phase 4 Limb (2 wound limbs) vi) 1 Phase 5 Limb (3 wound Limbs)			
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	
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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	oC		

B. 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) LV	A/mm ² & sq. mm				
5.	Maximum current density under short circuit: i) HV ii) LV	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 °C	ohm				
8.	Number of Turns/Phase					
9.	Insulating material used for HV/LV winding					
10.	Insulating material used between : i) HV and LV winding ii) Regulating winding and adjacent winding/core					
11.	Details of special arrangement					

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				

C. COOLING SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	Type of Cooling [ONAN (or) ONAN/ONAF (or) ONAN / ONAF / OFAF(or) ONAN / ONAF/ ODAF (or) ONAN / ONAF1 / ONAF2 etc.]			
2.	Percentage Rating Corresponding to Cooling Stages (HV/LV)			
3.	No. of Cooler banks (2x50% / 2x100% / 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 temperature when supply to fans and / or pumps 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	°C		
7.	Type of Cooler: i) Radiator Bank ii) Oil to Air Heat Exchanger (Unit Cooler) iii) Oil to Water Cooler (Single Tube) iv) Oil to Water Cooler (Double Tube) v) Tank Mounted vi) Header Mounted vii) Separately Mounted viii) Degree of Protection of terminal box			

8.	<p>Cooling Fans:</p> <ul style="list-style-type: none"> 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: <ul style="list-style-type: none"> • natural cooling • forced air cooling vii) Degree of Protection of terminal box 			
9.	<p>Oil Pumps:</p> <ul style="list-style-type: none"> 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.	<p>Coolers (Oil to Air):</p> <ul style="list-style-type: none"> i) Quantity (Running + Standby) ii) Type and Rating 			
11.	<p>Coolers (Oil to Water):</p> <ul style="list-style-type: none"> 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.	<p>Radiators:</p> <ul style="list-style-type: none"> i) Width of elements (mm) ii) Thickness (mm) iii) Length (mm) iv) Numbers 			
13.	Cooler loss at rated output, normal ratio, rated voltage, rated frequency at ambient temperature of 50°C	kW		

D. DIELECTRIC SYSTEM

Sl. No.	Description	Unit	Offered by manufacturer				
1.	Geometric Arrangement of winding with respect to core e.g: Core-LVHV-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	IV	LV	HV-N	IV-N
	i) Lightning Impulse withstand voltage (1.2/50 μ s)	kV _p					
	ii) Chopped wave Lightning Impulse withstand voltage	kV _p					
	iii) Switching Impulse withstand voltage (250/2500 μ s)	kV _p					
	iv) Power frequency withstand voltage	kV _{rms}					

	(one minute / 5 minutes)						
6.	Tan delta of windings at ambient temperature	%					

E. 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				
	viii) One minute Power frequency withstand voltage (dry & wet)	kV _{rms}				
	ix) Minimum Creepage Distance	mm				
	x) Quantity of oil in bushing and specification of oil used					
	xi) Make and Model					
	xii) Tan delta of bushings	%				
	xiii) Max Partial discharge level at U _m	pC				
	xiv) Terminal Pad details					
	xv) Weight of assembled bushings	kg				
	xvi) Whether terminal connector for all bushings included in the scope of supply					

4.	Minimum clearances between bushings (for HV, IV and LV) (a) Phase to phase (b) Phase to ground			
5.	Indicator / Relay			
	i) Winding temperature thermometer/indicator: Range Accuracy			
	iii) Oil temperature thermometer/indicator: Range Accuracy			
	iii) Temperature sensors by fiber optic			
	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 valve 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))			

	<ul style="list-style-type: none"> 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.	<p>Press Board:</p> <ul style="list-style-type: none"> i) Make ii) type 			
19.	<p>Conductor Insulating Paper</p> <ul style="list-style-type: none"> 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.	<p>Weights and Dimensions:</p> <ul style="list-style-type: none"> i) Weights: <ul style="list-style-type: none"> a. Core b. Windings c. Tank d. Fittings e. Oil f. Total weights of complete transformers with oil and fittings ii) Dimensions; <ul style="list-style-type: none"> a. Overall Height above track b. Overall length 			

	<p>c. Overall breadth</p> <p>iii) Minimum bay width required for installation of the transformer</p> <p>iv) Weight of the heaviest package of the transformer arranged for transportation</p>			
23.	<p>Lifting Jacks</p> <p>i) Number of jacks included</p> <p>ii) Type and Make</p> <p>iii) Capacity iv) Pitch</p> <p>v) Lift</p> <p>vi) Height in close position</p>			
24.	<p>Rail Track gauges</p> <p>i) 2 Rails or 3 rails or 4 rails</p> <p>ii) Distance between adjacent rails on shorter axis</p> <p>iii) Distance between adjacent rails on longer axis</p>			

ANNEXURE-D TEST PLAN AND PROCEDURES

Tests for Transformers

No.	Test	Um ≤ 170kV	Um > 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.	Tan delta of bushing at variable frequency (Frequency Domain Spectroscopy)	Routine	Routine
11.	Full wave lightning impulse test for the line terminals (LI)	Type (for Um≤72.5kV) Routine (for 72.5kV< Um≤170 kV)	-
12.	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
13.	Lightning impulse test for the neutral terminals (LIN)	Type	Type
14.	Switching impulse test for the line terminal (SI) (Not applicable for Um≤72.5 kV)	Type	Routine
15.	Applied voltage test (AV)	Routine	Routine
16.	Line terminal AC withstand voltage test (LTAC) (Not applicable for Um≤72.5 kV)	Routine	Type
17.	Induced voltage withstand test (IVW)	Routine	-
18.	Induced voltage test with PD measurement (IVPD)	Routine*	Routine
19.	Measurement of transferred surge on Tertiary due to HV lightning impulse and LV lightning impulse	=	Type

20.	Measurement of transferred surge on Tertiary due to HV Switching impulse and LV Switching impulse	-	Type
21.	Test on On-load tap changer (Tap changer fully assembled on the transformer)	Routine	Routine
22.	Measurement of dissolved gasses in dielectric liquid	Routine	Routine
23.	Check of core and frame insulation	Routine	Routine
24.	Leak testing with pressure for liquid immersed transformers (tightness test)	Routine	Routine
25.	Appearance, construction and dimension check	Routine	Routine
26.	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.	Routine	Routine
27.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine	Routine
28.	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine	Routine
29.	Tank vacuum test	Routine	Routine
30.	Tank pressure test	Routine	Routine
31.	Check of the ratio and polarity of built-in current transformers	Routine	Routine
32.	Temperature rise test	Type	Type
33.	Overload testing in short-circuit method (applicable for 765 kV transformer only)	-	Type
34.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)	Routine	Routine
35.	Over excitation test (applicable for 765 kV transformer only)	-	Routine
36.	Measurement of Zero seq. reactance (for three phase Transformer only)	Type	Type
37.	Measurement of harmonic level in no load current	Type	Type
38.	Determination of acoustic sound level	Type	Type
39.	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)	Type	Type
40.	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 G Ω 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 whichever applicable (HV-IV, HV-LV, IV-LV or otherwise 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.

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 (as applicable)

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) + IV (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 result in highest temperature rise for the test.

The Temperature rise type test results shall serve as a “fingerprint” 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 or ONAF1 and 24 hours for ODAF or OFAF or ONAF2 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, steadyperiod 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)

ANNEXURE-E MANUFACTURING QUALITY PLAN

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

TC --- Test PD- Perpendicular CD- Cross MD- Machine PICC-Paper Insulated

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	P	V	W/V
					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 Tolerance (%) Thickness (mm) 0.25 to 0.5 - 10 Over 0.5 to 1.3 - 7.5 Over 1.3 - 5			

		(b) Resistivity at 20 deg.C		IS 13730	For annealed conductor: 0.01727 ohm/mm ² /m (max)	P	V	W/V
					For half hard conductor: 0.01777 ohm-mm ² /m (max)			
		(c) Insulation test for bunched conductor/ between strands of CTC (if applicable)		IS 13730	Maximum Charging current	P	V	W/V
		(d) Elongation test for annealed conductors (if applicable)		IS 7404 IS 13730	Thickness Elongation (mm)% 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	-

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) Up to 1.0 - 1.01 to 1.60 - 1.61 to 2.24 - 2.25 to 3.55 - 3.56 to 5.60 - (Tolerance $\pm 25\%$)	Corner Radius (mm) 0.50 x nominal thickness 0.50 0.65 0.80 1.00	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	Paper to be smooth, unglazed surface, free from dust particles and no surface defect Thickness tolerance within specified value $\pm 10\%$		P	V	--
		(b) Density			Nominal value ± 0.05 gm/cm ³				
		(c) Substance (grammage)		f Test	Thickness(μ m) Sub(g/m ²) 50 40 65 52 75 60 90 72 Tolerance: For material ≤ 45 g/m ² $\pm 10\%$ For material > 45 g/m ² $\pm 5\%$				
		(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 μ m/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 (Klemm Method)			10 %				

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 160o bend without fracture			
		(d) Surface insulation resistivity check			Average value: 10 Ω cm ² (min.) Individual value: 05 Ω 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	IS 3024	As per table no. 2 of IS 3024	--	P	V
		(h)Magnetic Polarisation	from	IS 3024	As per appropriate tables of IS 3024	--	P	V
		(i) Grade of CRGO	offered lot	Approved drawing/ Document	Approved Drawing/Document/ Manufacturer standard	P	V	V
		(j) Permeability at 800 A/m				P	V	V

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/cm ³)	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 (Crev) (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						

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer

					> 3-3.6 mm - 30 kV / mm > 6-8 mm TK - kV/mm			
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		(l) Ash Content (%)			1 % maximum																		
		(m) Elongation (MD, CD)			<table border="1"> <thead> <tr> <th></th> <th>MD</th> <th>CD</th> </tr> </thead> <tbody> <tr> <td>Up to 1.6</td> <td>- 3 %</td> <td>4 %</td> </tr> <tr> <td>>1.6-3 mm</td> <td>- 3 %</td> <td>4 %</td> </tr> <tr> <td>>3-3.6 mm</td> <td>- 3 %</td> <td>4 %</td> </tr> <tr> <td>>6-8 mm TK</td> <td>- 3 %</td> <td>4 %</td> </tr> </tbody> </table>		MD	CD	Up to 1.6	- 3 %	4 %	>1.6-3 mm	- 3 %	4 %	>3-3.6 mm	- 3 %	4 %	>6-8 mm TK	- 3 %	4 %			
	MD	CD																					
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) <ul style="list-style-type: none"> 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) <ul style="list-style-type: none"> 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 size each 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 /cm2																		
		(g) Compressive strength test			Min for LD - 1400 KV /cm2																		
		(h) Shear strength age-wise			Min for LD - 450 KV /cm2																		
		(i) Thickness			<table border="1"> <thead> <tr> <th>Thickness (mm)</th> <th>Tolerance (±mm)</th> </tr> </thead> <tbody> <tr> <td>10 to 25</td> <td>1.4</td> </tr> <tr> <td>26 to 50</td> <td>2.0</td> </tr> <tr> <td>51 to 150</td> <td>-</td> </tr> </tbody> </table>				Thickness (mm)	Tolerance (±mm)	10 to 25	1.4	26 to 50	2.0	51 to 150	-							
Thickness (mm)	Tolerance (±mm)																						
10 to 25	1.4																						
26 to 50	2.0																						
51 to 150	-																						
		(j) Shrinkage (MD, CD)	IEC 61061/Plant standard																				
		(k) pH Value																					

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(l) Breakdown voltage, parallel to the laminations						
7.	Porcelain Bushings (Hollow)	(a) Visual & dimensional check.	10% Sample per lot	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/ IEC		As per IS 3347/IS 8603/ IEC 60137			
8.	Polyester Impregnated Glass Resin 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			<ul style="list-style-type: none"> • 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 ($\pm 3\%$)			
		(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) Lightning 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			

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(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) <ul style="list-style-type: none"> • BDV • Water content • Tan delta at 90°C • IFT at 27°C 			<ul style="list-style-type: none"> • BDV: Min 70 kV • Water content: Max 5 ppm • Tan Delta at 90°C Max:0.0025 • IFT at 27°C: Min 0.04 N/m 	P	W	V
		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			As per approved drawing			

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		operations, alarms, interlocks and sequential operations						
		(d)BOM check for Component type, make & rating			As per approved drawing			
		(e) DOP check by thin paper insertion method			As per technical specification			
		(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 /cm ² (10Kpa) for 24 hrs			No leakage for 24 hours	P	W	V
		(b) 10 times inflation and deflation test at 0.105 Kg /cm ²			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	Free from surface defect	P	V	--

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(b) Mechanical Properties & Chemical composition of raw material used for shaft & roller forging	One sample per melt/heat treatment batch	IS 28 IS 2026	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 (b) Accuracy (c) HV test at 2kV for 1 min between all terminals & earth (d) Switch contact operation test (e) Contact Rating	100%	--	As per approved drawing ± 1.5% of FSD Withstand for 1 min Operation within ± 2.5° C of setting As per Manufacturer's std.	P	P/W	V
18.	Pressure Relief Device	(a) Type & Make (b) Air Pressure Test (c) Liquid Pressure Test (d) Switch/contact testing (e) Leakage test at 75% operating pressure (f) HV test (g) Functional test/Calibration (h) Contact Rating	100%	As per specification	As per approved drawing & free from defect Operate at Specified pressure ± 0.07 kg/cm ² Satisfactory operation at pressure release No leakage for 24 hrs 2 kV withstand for 1 min As per Manufacturer's std.	P	P/W	W/V
19.	Magnetic Oil Level Gauge (MOG)	(a) Type & make (b) Dial Calibration for level (c) 2kV HV test for 1 min between all terminal & earth (d) Leak test with air for 6 Hours (e) Switch/contact operation test (f) Contact Rating	100%	--	As per approved drawing & free from defect Check pointer position for Max, Min and center level (within tolerance as per specifications) Withstand for 1 minute No leakage at 4 kg /cm ² Operate at Min level indication As per Manufacturer's std.	P	P/W	W/V
20.	Valves (Gate, Globe & Butterfly)	(a) Type, make & visual check for material of valve body, gate wedge, spindle and gland (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.	100%	IS 778	As per approved drawing & no visible defect No leakage	P	W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(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/cm2 for 24 hrs.)			(i) No leakage at 5 kg/cm2 for 10 minutes (ii) Max 6 drops/min at 1.5 kg/cm2 (iii) No leak in body and spindle Max 6 drops/min through disc			
21.	Transformer Oil	Routine Test	100%	IS: 335 IEC 60296 IS 6855	As per technical specification	P	W	W
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 (b) Visual Check for a fit up for butt welds on tank walls, base & cover (c) DP test on Butt welds after fit up & load bearing welds (lifting logs, bollards, jacking pads) (d) Air leakage test on assembled tank with turrets & on conservator (e) Visual check of paint shade, paint film thickness (inside & outside) & film adhesion, primer application (f) WPS (Weld procedure specification) approval (g) PQR (Process Qualification Record) (h) Welders Qualification (i) UT (Ultrasonic test) of tank MS Plate of thickness >12mm. (j) RT (Radiography test) of butt weld in bottom plate of tank after fit up (if any) (k) Verification of PWHT (Post weld heat treatment) (l) Surface cleaning by Shot/sand blasting (m) Tank - i. Pressure test (PT)	100% per One design	CBIP Manual Transformer 2013	Free from defect Check for proper welding Check for proper welding No leakage Paint thickness Outside: 155 micron Inside: 30 micron No peel-off Or As per approved drawing Details to be furnished As per Specification/ASME Sec IX Details to be furnished As per Specification/ASME Sec IX Details to be furnished As per Specification/ASME Sec IX Details to be furnished As per Specification/ASME Sec IX Details to be furnished as per Specification i. Withstand-Twice the normal head of oil or normal head+ 35	P	W	V
						P	W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		ii. Vacuum test (VT) iii. Adhesion test iv. Visual Inspection inside transformer tank before PT & VT test			KN/m ² whichever is lower, maintained at base of tank for 8 hrs. ii. Withstand- 3.33 KN/ m ² for 1 hr. iii. Details to be furnished as per manufacturer's standard. iv. Inputs required as per specification			
		(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 (b) DP test on lifting lugs welds (c) Surface cleaning of header support and bracing details by sand/shot blasting (d) Air pressure test on elements (e) Dimensional check after final welding (f) Air pressure test on radiator assembly by water dipping method (g) Visual check of paint shade, paint film thickness & film adhesion (h) WPS (Weld Procedure Specification) approval (i) PQR (Process Qualification Record) (j) Welders Qualification	100%	BS EN 50216-1 IS513 Manufacturer's drawing	As per relevant standards No welding defect Free from surface defect As per relevant standards /CBIP As per approved drawing 2 kg /cm ² for 30 minutes - no leakage As per tech spec, coating thickness more than 70 micron Details to be furnished, if applicable as per Specification/ASME Sec IX Details to be furnished, if applicable as per Specification/ASME Sec IX As applicable As per Specification/ ASME Sec IX	P	W	W/V
24.	OLTC (as applicable)	(a) HV test on Auxiliary circuit (2kV for 1min). (b) Operational test of complete OLTC including functional check of driving mechanism (c) Pressure test on diverter switch oil compartment (d) Mechanical Operation test of diverter switch (endurance test) (e) Mechanical test of tap selector motor drive (f) Sequence test (g) Visual & Dimensional check	100%	IS 8468 IEC 60214	To Withstand for 1 min Satisfactory operation No leakage at 10 Psi for 1 hour No defect after 5000 operations 500 satisfactory operations between extreme taps Switching time within permissible limit Free from defects, dimensions as per drawing	P	P/W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(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			
		(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	Free from cracks and pin holes	P	W	V
		(b) Dimensions		ISO 815	Within tolerance			
		(c) Shore Hardness		ISO 37	70 ± 5 IRHD			
		(d) Tensile Strength		ISO 3865	12.5 N/mm ² min			
		(e) Compression set test		IS 11149	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.		(a) Visual Check		IS 11149	Free from cracks & pinholes	P	W	V

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
	EPDM Gasket for Marshalling Box	(b) Dimensional check (Thickness & Width) (c) Tensile Strength (d) Elongation at break (e) Shore Hardness check as per DIN-53505 (f) Compression test (in air) as per DIN, ISO 815	1 sample/Lot		Within tolerance As per IS 11149 As per IS 11149 As per IS 11149 As per IS 11149			
29.	Bushing CT	Dimensions (Visual check for ID/OD, thickness) Routine test (a) Verification of terminal marking & polarity (b) Overvoltage inter-turn test (c) Determination of error (d) HV Test (Dry power frequency withstand test on secondary winding) (e) Accuracy Ratio (f) Secondary winding resistance for PS/PX class (g) Knee point voltage & excitation current for PS/PX class	100%	IS 16227 IEC 61869-2	As per approved drawing As per IS 16227/ IEC 61869-2 Rated current withstand for 1 min As per IS 16227/ IEC 61869-2 3 kV AC for 1 min withstand As per IS 16227/ IEC 61869-2 As per IS 16227/ IEC 61869-2			
30.	Oil circulating pump (as applicable)	(a) Visual check (b) No load running test (rpm, input power and current) (c) (d) HV test (2kV power frequency withstand voltage test for 1min) (e) Oil pressure test on pumps at 5kg/cm ² for 30 min (f) Locked rotor test	100%	IS 9137	no visual damage/ defect Satisfactory performance & no load losses within limit Should withstand No leakage Satisfactory operation of protection	P	P/W	V
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/cm ² 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

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

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	Proper connection			--	P	V	

	resistance between CC-CL, CC-Yoke bolt, CL-Yoke Bolt by 2kV megger)						
	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

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
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 sharp edge	-	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		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	14. Magnetic balance test		As per IS 2026 / IEC 60076	Tolerance as per standards	-	P	V
	15. Magnetizing current test, polarity & vector group		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
V	DRYING OF ACTIVE PART: Vapor Phase Drying (VPD) Validation						
	1. Check of temp of Evaporator	100%	Manufacturer's standards/drawings	Manufacturer's standards/drawings/ checklist	-	P	V
	2. Check temp of Main heating						
	3. Check temp of Sprayed Kerosene						

	4. Check Vacuum Pressure (mbar) of VPD		/checklist				
	5. Check Vacuum Pressure (mbar) of Fine vacuum			Graph of Vacuum Vs Time and Temperature Vs time to be submitted for review			
	6. Check Water Extraction (g / Hr / Ton of Insulation) / Process Termination parameters						
	7. Check total process time (Hrs.)			As per Annexure-L of the document			
	8. Check Oil characteristics before impregnation a. Electric strength b. Water content c. Tan delta at 90°C d. Resistivity at 90°C(For Information)						
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 fitting & connections	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 sharp edge	--	P	V
	5. Visual checks for bushing CT assembly tightness	100%	--	Assembly tightness	--	P	V
	6. Ratio test	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	
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	---

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

Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	Customer

C.	Acceptance Tests For Transformers:	100%	Specification IS: 2026			
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1.	Appearance, construction and dimension check as assembled for testing		other applicable standard	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 $72.5\text{kV} < U_m \leq 170\text{ kV}$)				P	W
Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	Customer

TC --- Test PD- Perpendicular CD- Cross MD- Machine

PICC-Paper Insulated Copper Conductor CTC-

* Category of Responsibility: P - Actual Test Performance V- Verify and Accept

14.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformers with $U_m > 170$ kV)				P	W
15.	Switching impulse test for the line terminal (SI) (for transformers with $U_m > 170$ kV)				P	W
16.	Applied voltage test (AV)				P	W
17.	Line Terminal AC withstand voltage test (LTAC) (for transformer with 72.5 kV $< U_m \leq 170$ kV)				P	W
18.	Induced voltage withstand test (IVW) (for transformers with $U_m \leq 170$ 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

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 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 temperature rise test is performed)				P	W
	31.	Over excitation test (applicable for 765 kV transformer only)					

D.	Type Tests/Special test		One from Lot	Specification/ IS:2026 60076 /other applicable standard	Specification/		
	<u>For Transformers:</u>						
	1.	Measurement of transferred surge on Tertiary due to HV lightning impulse and IV lightning impulse				P	W

Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	Customer

2.	Measurement of transferred surge on Tertiary due to HV switching impulse and IV switching impulse			
3.	Full wave lightning impulse test for the line terminals (LI) (for $U_m \leq 72.5 \text{ kV}$)			
4.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformer with $U_m \leq 170 \text{ kV}$)			
5.	Lightning impulse test for the neutral terminals (LIN)			
6.	Switching impulse test for the line terminal (SI) (applicable for $U_m > 72.5 \text{ kV}$ & $\leq 170 \text{ kV}$)			
7.	Temperature rise test			
8.	Measurement of Zero seq. reactance (for three phase Transformer only)			
9.	Measurement of harmonic level in no load current			
10.	Determination of sound level			
11.	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)			
12.	Short circuit withstand capability test (Dynamic)			

Annexure-G 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 LoadCell).
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 Analyzer
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 Analyzer (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 a 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-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) shall be as per “Standard Specifications and technical Parameters for Transformers and Reactors (66 kV & above voltage class)” by CEA.

Annexure-L 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 ₂ H 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 Aromatic content Cyclic (PCA)	IP 346	<3%
3.	Poly Chlorinated Biphenyl content (PCB)	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.

ANNEXURE- III

TECHNICAL SPECIFICATION FOR ON-LINE DISSOLVED GAS ANALYZER (DGA) SYSTEM SCOPE:

This specification covers design, manufacture, assembly, testing at manufacturer's works before dispatch and supply (FOR Destination), installation, testing and commissioning at site of On-line Dissolved Gas Analyzer (DGA) system specified herein along with all their associated accessories required for satisfactory operation at various EHV substations of Utility.

The scope covers supply, installation & commissioning of On-line Dissolved Gas Analyzer system (Multigas) along with all required accessories suitable for dissolved gas analysis and moisture measurement of insulating mineral oil of transformer for carrying out interpretations as per IEC 60599- 2007-05 The equipment covered in this specification i.e. On-line Dissolved Gas Analyzer system shall meet the technical requirements listed below:

DETAILS OF TECHNICAL REQUIREMENT:

The equipment shall be used for On-line monitoring of fault gas Analysis in transformer oil. It shall measure all seven transformer fault indication gases i.e. Acetylene (C₂H₂), Methane (CH₄), Ethane (C₂H₆), Hydrogen(H₂), Ethylene (C₂H₄), Carbon Dioxide (CO₂), Carbon monoxide (CO) and moisture(H₂O) and the two atmospheric gases i.e.Oxygen(O₂)& Nitrogen(N₂). The Test kit shall meet the technical requirements listed below:

- The equipment shall be suitable for mounting/connecting on EHV transformers/ICTs up to & including 400 kV class without any outage. All the accessories/components required for mounting shall be in the scope of bidder.
- The equipment should be Gas Chromatography based equipment. The equipment shall be capable of extracting the seven Fault gases and the two Atmospheric gases and measuring them individually and reporting the concentrations from transformer oil.
- Moisture Measurement must be through a direct oil immersed Relative Saturation (RS) sensor.
- The monitor shall be equipped with an inbuilt oil circulation system with oil flow monitoring and alarm for stoppage of flow. Inlet and return oil lines must be of Stainless Steel.
- The monitor must have facility for collecting an oil sample for external oil tests, such as an external quick connect port plus sampling accessories.
- As the equipment is to be connected to transformer by the circulating oil lines, its performance should not be affected by vibrations, noise, transformers hum etc.
- The Equipment shall connect to the transformer main body in two locations. One connection is for supply of oil from the transformer, Second connection is for the return of the oil to the transformer.

- The equipment outfitted with the ability to communicate via modem or FO Port or RS232/RS485. The result shall be communicated to the local computers and as well as transmitted to remote location computers. Communication Protocols required: Modbus, DNP 3 Level 1, IEC 61850
- The equipment shall be able to measure gas concentration and when downloaded should immediately compare it with user selected alarm and caution level for immediate display. The sampling rate shall be selectable as for example 4 or 6 or 12 hrs etc.
- The equipment shall have inbuilt memory to store the results, for a minimum of 3 years
- The equipment should have Front panel display and controls. LCD display to provide up to date information at site level.
- The levels of dissolved gases shall be displayed in PPM. Also it shall be possible to set different alarms levels for dangerous levels immediately.

Detection of Gases:

The gases extracted shall be detected using a portable Gas Chromatograph (GC) with Thermal Conductivity Detector (TCD) or Flame Ionization Detector (FID) method. All the fault gases i.e. H₂, CH₄, C₂H₄, C₂H₆, C₂H₂, CO, CO₂ & two atmospheric gases i.e. O₂ and N₂ concentrations shall be individually measured and displayed. The measurement range, accuracy and repeatability for measurement of each gas shall be as under:

<i>Gasses</i>	<i>Minimum Detection Limit in ppm</i>	<i>Working Range</i>	<i>Accuracy (whichever is greater)</i>	<i>Repeatability</i>
Hydrogen (H ₂)	3	Up to 3000ppm	±3ppm or ±5%	<2%
Methane CH ₄ ,	5	Up to 7000ppm	±5ppm or ±5%	<1%
Ethane C ₂ H ₆	5	Up to 5000ppm	±5ppm or ±5%	<1%
Acetylene C ₂ H ₂	1	Up to 3000ppm	±1ppm or ±5%	<2%
Ethylene C ₂ H ₄	3	Up to 5000ppm	±3ppm or ±5%	<1%
Carbon Monoxide (CO)	5	Up to 10000ppm	±5ppm or ±5%	<2%
Carbon Dioxide (CO ₂)	5	Up to 30000ppm	±5ppm or ±5%	<1%
Oxygen (O ₂)	30	Up to 25000ppm	+30/-0ppm or ±5%	<1%
Nitrogen (N ₂)	5000	Up to 100000ppm	±5000ppm or ±10%	<20%

Oil temperature Range	: -10°C to + 120°C
External Temperature Range	: -50°C to + 55°C
Humidity Range	: 5 to 95 %
Pressure withstand protection of the enclosure	: The monitor must withstand pressure from Full Vacuum to 45 psi. Degree of protection of the enclosure : IP 66
Enclosure material	: Aluminium or Stainless Steel
Operating Voltage	: 230V AC ± 15%; 50 ± 5% Hz
Communications	: RS- 232/RS-485, Ethernet Fiber, USB
Alarm	: Sophisticated Programmable alarm system

Calibration:

Instrument must be provided with on-board automated Calibration verification facility to ensure performance to specifications throughout the service life of the equipment. The Monitor MUST be calibrated with a Reference Calibration Gas Standard that has a NIST Traceability Certificate.

Software:

The software should provide diagnostic report for individual pieces of equipment or for a full system, using the equipment tree. The necessary computer hardware & software shall be supplied for data Archival, Analysis and reporting. Equipment should be supplied with the user friendly PC software which provides fault indication and fault diagnostics including the following:

Fault indication:

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

Fault Diagnosis:

- Key gases
- Ratios (Rogers, IEC. Etc)
- Duval's Triangle

Apart from these tools there shall also be analysis Tool to identify the nature and severity of Transformer faults with greater specificity than other diagnostic tools based on ANN and Expert Analysis Tool. The Tool shall also be able to Harmonic Regression to remove harmonic components in the data, clearly revealing the underlying trends & Piecewise Linear Approximation to accurately assess gassing rate of change

Free hardware and software upgrade shall be supplied by the bidder till expiry of guarantee period.

Accessories:

The equipment shall be supplied with all necessary accessories required for carrying out on-line DGA of transformer oil complete in all respect as per the technical specification. Bidder has to furnish the list of accessories being supplied with the equipments. Free consumables till guarantee period shall be supplied by the bidder till expiry of guarantee period. The following shall be also form a part of supply.

1. Operation Manual
2. DGA Software Manual
3. PC Software manual
4. Compact disc giving operation procedures of Maintenance Manual & Troubleshooting instructions.

DEMONSTRATION:

The acceptance of the kit shall be subjected to the successful demonstration by supplier to the satisfaction of utility at prescribed site. The following functions must be demonstrated.

1. The Oil sampling.
2. The Gas extraction
3. The analysis of the gas sample and reporting the concentrations of the various gases.
4. The Calibration with reference to a NIST traceable gas standard.

The instrument not meeting the requirement will be summarily rejected.

ANNEXURE- IV

ON-LINE INSULATING OIL DRYING SYSTEM (CARTRIDGE TYPE) (IF SPECIFIED IN PS(PRICE SCHEDULE))

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

- Designed for very slow removal of moisture that may enter the oil system or generated during cellulose decomposition. Oil flow to the equipment shall be controlled through pump of suitable capacity (at least 5 LPM).
- The equipment shall display the moisture content in oil (PPM) of the inlet and outlet oil from the drying system.
- In case, drying system is transported without oil, the same shall be suitable for withstanding vacuum to ensure that no air / contamination is trapped during commissioning.

In case, drying system is transported with oil, the oil shall conform to EMPLOYER specification for unused oil. Before installation at site, oil sample shall be tested to avoid contamination of main tank oil.

- Minimum capacity of moisture extraction shall be 10 Litres before replacement of cartridge. Calculation to prove the adequacy of sizing of the on line insulating oil-drying system along with make and model shall be submitted for approval of purchaser during detail engineering.
- The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.
- The equipment shall be capable of transferring data to substation automation system confirming to IEC 61850 through FO port. Necessary interface arrangement shall be provided by the contractor for integration with automation system.

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