भारत सरकार, रेल मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

सत्यमेव जयते

कर्षण संस्थापन निदेशालय
TRACTION INSTALLATION DIRECTORATE

8 एमवीऐ, 12.3 एमवीऐ और 16.5 एमवीऐ, ओनऐन, 55 केवी/27.5 केवी ऑटोट्रांसफार्मर के लिए तकनीकी विनिर्देश
Technical Specification for
8MVA, 12.3MVA & 16.5MVA, ONAN, 55KV/27.5KV Autotransformer

विशिष्टि संख्या: टीआई/एसपीसी/पीएसआई/एयूटीओटीआर/1201
Specification No. TI/SPC/PSI/AUTOTR/1201

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NOTE:

(i) This Specification is the property of RDSO. No reproduction shall be done without the permission of DG (TI) RDSO.
(ii) All clauses of this specification shall be enforced from the cut-off date **01.10.2025**.
(iii) This specification supersedes the specification No. TI/SPC/PSI/AUTOTR/1200 with A & C slip No. 1.

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Technical Specification for 8MVA, 12.3MVA & 16.5MVA, ONAN, 55kV/27.5kV Autotransformer

Specification No. TI/SPC/PSI/AUTOTR/1201

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1.0 Scope:

1.1 This specification supersedes the specification No. TI/SPC/PSI/AUTOTR/1200 with A&C slip no.1.

1.2 It is to be noted that the "Make in India" Policy of the government of India shall be applicable.

1.3 This specification applies to the 8 MVA, 12.3 MVA & 16.5 MVA, ONAN, 55kV/27.5kV Autotransformer for Autotransformer (AT) feeding system for installation in Indian Railway's Traction Sub-Stations, which may be manned or unattended type.

1.4 RDSO's ISO procedure: "All the provisions contained in RDSO's ISO procedures laid down in Document No. - QO-D-8.1-11 version No. 3.4 dated 18.03.2025 or latest (titled "Vendor-changes in approval status") and subsequent versions/amendments thereof, shall be binding and applicable on the successful vendor/vendors in the contracts floated by Railways to maintain quality of products supplied to Railways."

1.5 It is the responsibility of the transformer manufacturer to comply with the complete specification including for the accessories.

1.6 Traction Power supply system (2X25kV AT Feeding System)

1.6.1 General scheme

1.6.1.1 The electric power for traction is supplied in AC 50 Hz, single phase through 2 x 25 kV AT feeding system, which has a feeding voltage (2x25kV) from the Traction Sub-Station (TSS) two times as high as catenary voltage (25 kV) with respect to earth/rail. The power is fed from the TSS through, a catenary wire and the feeder wire is stepped down to the catenary voltage by use of autotransformers (ATs) installed about every 13 to 17 km along the track, and then fed to the locomotives. In other words, both the catenary voltage and feeder voltage are 25 kV with respect to earth/rail, although the sub-station feeding voltage between the catenary and feeder wires is 50 kV. Therefore, the catenary voltage is the same as that of the conventional 25 kV system.

1.6.1.2 Since the power is supplied at two times higher voltage (50kV), the 2 x 25 kV AT feeding system is suitable for a large power supply, and it has the following advantages, compared with conventional feeding systems:
(a) Less voltage drops in the feeder circuit.
(b) Increase spacing between traction sub-stations.
(c) Less interference with adjacent telecommunication lines, if any.

1.6.1.3 The power is obtained from 220 or 132kV or 110kV or 100kV or 66kV, three phase effectively earthed transmission network of the State Electricity Board, through Scott-connected/single phase transformers installed at the Traction Sub-Stations. The primary windings of the single-phase transformer are connected to two phases of the transmission network. Where Scott Connected transformers are used, the primary windings are connected to the three phases of the transmission network. The single-phase transformers at TSS are connected to the same two phases of the transmission network (referred as single-phase connection), or alternatively to different pairs of phases to three single-phase transformers forming a delta connection on the primary side. Out of three single-phase transformers, one transformer feeds the OHE on either side of the TSS, and the third remains standby. Thus, two single-phase transformers which feed the OHE constitute an open-delta connection (alternatively, referred to as V-connection) on the three-phase transmission network. The Scott-connected transformer and V-connected single-phase transformers reduce voltage imbalance caused by the traction loads on the transmission

network of the Electricity Board. The spacing between adjacent sub-stations is normally between 70 to 100 km.

1.6.1.4 In the case of V Connected and 54MVA Scott Connected Transformers, One outer side terminal of the secondary windings of the traction transformer is connected to the catenary, and the other outer side terminal is connected to the feeder. Two inner side terminals are, via series capacitors or directly, connected to each other, and their joint is solidly earthed and connected to the Traction Rails. However, in the case of 60/84/100MVA Scott Connected Transformer, there are one M phase and one T phase secondary and these are connected to the autotransformer of which the mid-point is earthed.

1.6.1.5 Generally, the load current (current drawn by electric locomotives) from the sub-station flows through the catenary and returns to the sub-station through the feeder. For a train in an AT-cell (distance between two consecutive ATs), most of the current is fed to the electric locomotive by the ATs of that AT-cell; the current returns to the rails/earth and is boosted up to the feeder through the neutral terminals of the autotransformers.

1.6.1.6 Approximately midway between two adjacent TSSs, a sectioning and paralleling post (SP) is provided. In order to prevent the wrong phase coupling of the power supply, a dead zone known as a neutral section is provided in the OHE opposite the TSS as well as SP. At the TSS, there are two feeder circuit breakers for either side of the TSS for controlling the power fed to the OHE, in a double track section. Out of the two feeder Circuit Breakers for one side, one feeds the OHE of that side while the other remains (open) on standby. There is also a paralleling interrupter, which is normally closed, for either side of the TSS for paralleling the OHE of UP and DOWN tracks. For maintenance work and keeping the voltage drop within limits one or more sub-sectioning and paralleling posts (SSPs) are provided between TSS and SP. In a double-track section, an SSP has four sectioning interrupters and one paralleling interrupter whereas an SP has two bridging circuit breakers (which remain open under normal feeding conditions) and two paralleling interrupters. In case of a fault in the OHE, the corresponding feeder circuit breaker of the TSS trips to isolate it.

1.6.1.7 A figure showing the principle of the AT feeding system is placed in Annexure-5.

1.6.2 PROTECTION SYSTEM

1.6.2.1 The Protection system of the Traction Transformer comprises the following:

a. Differential protection.
b. IDMT over current protection on HV & LV sides.
c. Instantaneous over-current protection on the Primary side.
d. Earth fault protection on HV & LV sides.
e. Protection against phase failure on the secondary side. (i.e. to detect a malfunction of a feeder/transformer circuit breaker)
f. Auxiliary relays for transformer faults i.e. Buchholz, excessive winding and oil temperature trip and alarm, pressure relief device trip and alarm and low-oil level etc.

1.6.2.2 The protection system for the OHE comprises the following:

a. Distance protection
b. Delta-I type fault selective protection.
c. Instantaneous Overcurrent protection.
d. Under voltage protection to avoid wrong phase coupling.

1.6.3 OHE General Data

1.6.3.1 The OHE consists of

a. A grooved copper conductor wire of 107mm^2 section suspended directly from a stranded cadmium copper catenary of 65 mm^2 section by several vertical dropper wires, usually at regular intervals (the contact wire and catenary wire together being referred to as 'catenary' or 'catenary wire'.
b. A feeder wire of standard "All Aluminium Conductor (AAC)" (size 19/3.99mm) of 240 mm^2 section.

1.6.4 Traction Power Transformer – General Data

1.6.4.1 The Traction Power Transformer is either single phase of 38/53/63 MVA (ONAN/ONAF/OFAF) rating or Scott-Connected of 60/84/100 MVA (ONAN/ONAF/OFAF) rating.

1.6.5 Nature of Traction Load on the OHE System

1.6.5.1 Traction loads are frequently and rapidly varying in nature and may fluctuate between no load and overloads. The TSS equipment is subject to earth faults/short circuits caused by the failure of insulation, snapping of OHE touching the earth, wire dropped by bird connecting the OHE to earth/overline structure and miscreant activity. The average number of faults/short circuits per month is about 40, but in exceptional cases, the number could be as high as 120. The magnitude of the fault current may vary between 40% and 100% of the dead short circuit value. These faults are cleared by the feeder circuit breaker on the operation of the distance, delta-I and instantaneous overcurrent relays associated with the concerned feeder circuit breaker.

1.6.5.2 The AC electric locomotives are fitted, for conversion of AC to DC, with Single Phase Bridge connected silicon rectifiers with smoothing reactor for feeding the DC Traction motors. The rectifiers introduce harmonic currents in the 25kV Power Supply system. On a few of the electrified sections, locomotives fitted with phase-controlled asymmetrical thyristor bridge, in place of silicon rectifiers are also in use; these introduce further harmonics in the system. The Typical percentage of harmonic present in the Traction Current with the Electric Locomotives are as follows:

Harmonics	With Diode Rectifier	With Thyristor
3rd (150Hz)	15%	32%
5th (250Hz)	6%	18%
7th (350Hz)	4%	8%
9th (450Hz)	-	4%
11th (550Hz)	-	5%

1.6.5.3 The average power factor of electric locomotives and electric multiple units generally varies between 0.7 and 0.8 lagging, without reactive power compensation.

1.6.5.4 Auxiliary Power at Traction Substation (TSS)
The following auxiliary power supplies are available at a traction substation.
a. 110 V DC from a battery (+15% & - 30%).
b. 240V AC, Single Phase form Auxiliary Transformer.

1.6.5.5 Alarm/Trip devices, relays and motor for the tap changer on the traction power transformer shall operate by 110V DC.

1.7 **Scope of supply, including accessories:** The transformer shall be supplied complete with all parts, fittings and accessories necessary for its efficient operation. All such parts, fittings and accessories shall be deemed to be within the scope of this specification, whether or not specifically mentioned herein.

1.7.1 **Conservator tank:** It shall be of adequate capacity and complete with a supporting bracket or structure, oil filling cap and drain valve of size 25 mm. The cylindrical portion of the conservator tank shall be of single-piece construction without any gasketed joint. Suitable air cell/separator arrangement of high-quality material shall be provided in the conservator to ensure that the transformer insulating oil does not come in contact with air. The material of the cell/separator shall be coated fabric consisting of – highly resistant polyamide fabric, externally coated with transformer oil-resisting coating (chemical), inner coating resisting ozone and weathering. Suitable instructions may please be provided for installation/commissioning and future maintenance of the air cell/separator arrangement. An air cell/separator leak detector to detect cell rupture /damage or significant air leakage to the fluid side shall be provided.

For the Nitrogen sealed design of the Autotransformer, the oil conservator tank is not required.

1.7.2 **Oil level gauge:** It shall be of magnetic type having a dial diameter of 250mm. The gauge shall have markings corresponding to minimum oil level, maximum oil level and oil level corresponding to oil temperature of 30^{0}C, 45^{0}C and 85^{0}C. The oil level indicator shall be so designed and mounting that the oil level is clearly visible to an operator standing on the ground. The oil level gauge shall also have the provision of the low and high fluid level alarms.

1.7.3 **Silica gel breather:** Online non-carcinogenic regenerative type breather i.e. self-dehydrating type silica gel breather is to be provided with the oil conservator type Autotransformer. For the Nitrogen sealed design of the Autotransformer, the silica gel breather is not required. The Online non-carcinogenic regenerative breather shall be able to automatically dehydrate its own silica gel using moisture sensors and report the status of the dehydration through LEDs application. All the external parts of the breather shall be suitable for outdoor use and & resistive to transformer oil. The control box degree of protection shall be at least IP65. The type test certificate for the same must be submitted. Breather should also be equipped with a manual regeneration button to test the regeneration functionality. The equipment shall operate at an input supply of 230V AC, 50 Hz. The self-dehydrating silica gel breather shall have 2 tanks/cylinders each containing a silica gel (round balls 2 to 5 mm) of a quantity of a minimum of 2kg. The breather should be connected with flange mounting pipes controlled through different valves as per IEC 60076-22-7 & IS:3401.

1.7.4 **Pressure relief device:** Conventional type PRD or Smart PRD to be provided.

(a) Conventional type PRV. It shall be designed to operate to release internal pressure at preset value without endangering the equipment or operator and shall be of instantaneous reset type. A Shroud Pressure Relief Device will be used and have the provision of discharge of oil from PRD to a safe place by closed pipeline. This avoids hazards of fire, and it is safe for people working near the Transformer & it is environmentally friendly.

(b) Smart PRD: Along with the conventional features, the smart PRD shall be capable of continuously indicating the pressure in the main tank through 4-20mA analog communication. The PRD shall have the provision of digital communication through Modbus or a similar protocol. This shall be suitable for integration with SCADA if required. Also, PRD should be capable of giving soft alarms in the system. This device detects and reports pressure increase as well as pressure relief valve operation.

1.7.5 **Filter valves:** The bottom and upper filter valves shall be 50mm in size and suitably baffled to reduce aeration of oil. The valves shall be flanged to seat a 40 mm adapter threaded to thread size P 1 - 1/2 for connection to the oil filtration plant.

1.7.6 **Drain valve:** It shall be of size 80 mm and fitted with an oil sampling device of size 15 mm.

1.7.7 **Equipment Earthing terminals**: Two earthing terminals shall be provided on the tank for its earthing with the help of 3 mild steel flats, each of size 75 mm x 8 mm. The terminals shall be clearly marked for earthing.

1.7.8 **Buchholz relay:** Conventional type Buchholz relay or Smart Buchholz relay to be provided.

(a) Conventional type Buchholz relay: It shall be of double float type, with two shut-off valves of 80 mm size, one between the conservator tank and Buchholz relay and the other between the transformer tank and Buchholz relay. The relay shall have one alarm contact and one trip contact, none of the contacts being earthed. The contacts shall be a magnetic switch or micro switch type, electrically independent and wired up to the marshalling box. A testing petcock shall be brought down through a pipe for the purpose of sampling the gas, if any, collected in the Buchholz relay.

(b) Smart Buchholz relay: In addition to conventional features, the smart Buchholz relay shall be capable of continuously communicating the oil level through 4-20mA analogue output. The Buchholz relay shall have the provision of digital communication through Modbus or a similar protocol. This shall be suitable for integration with SCADA if required.

For the Nitrogen sealed design of the Autotransformer, the Buchholz relay is not required.

1.7.9 **Oil temperature indicator (OTI):** It shall have one alarm contact, one trip contact and two normally open spare contacts, none of the contacts being earthed. The contacts shall be electrically independent.

1.7.10 **Winding temperature indicator (WTI):** It shall have one alarm contact, one trip contact and two normally open spare contacts, none of the contacts being earthed. The contacts shall be electrically independent.

1.7.11 **Thermometer pockets**: A separate thermometer pocket with a cap shall be provided on the bell tank for measuring the top oil temperature in the tank.

1.7.12 All valves shall be of the double flange type and fitted with suitable blanking plates on the outer face of the exposed flange.

1.7.13 The capillary tubes for temperature indicators shall be able to withstand normal bending. They shall be supported properly without sharp or repeated bends or twists.

1.7.14 (i) The manufacturers of Parts, Fittings and Accessories for the Transformer shall be mentioned in the SOGP, BOM & QAP and these documents shall be approved by RDSO. During the prototype test the accessories will be tested & performance monitored by Test Certificate (TC i.e. Routine test certificate as per the governing IS/IEC of accessory) verification of the accessory as categorized below:

SN	Name of the accessory	Category
1.	Bucholz relay	TC Verification
2.	Pressure Relief Device	TC Verification
3.	Magnetic Oil Level Gauge	TC Verification
4.	Bushing Current Transformer	TC Verification
5.	Silica Gel Breather	TC Verification
6.	Wheel Valve, Double Flanged valve	TC Verification
7.	Analogue Type Temperature Indicators	TC Verification
8.	Terminal Connectors	TC Verification
9.	Radiators	TC Verification

(ii) Henceforth, while ordering a Traction Power Transformer, a copy of the approved SOGP should be called for by the users. This document shall form the basis for ordering accessories in the future.

(iii) In case manufacturers desire to change a particular make of accessories, prior approval of RDSO would be required on SOGP, Bill of Material (BOM) and Quality Assurance Plan (QAP).

2.0 Environmental & Operating Conditions

2.1 The transformer shall be suitable for outdoor use in dry arid and also tropical climates and in areas having heavy rainfall, pollution due to industry and coastal environment and severe lightning. The limiting weather conditions, that the equipment has to withstand in service, are indicated below:

S. No.	Parameters	Value
1.	Maximum ambient air temperature	50 ^{0} C
2.	Minimum ambient air temperature	- 2 ^{0} C
4.	Maximum relative humidity	100%
5.	Annual rainfall	Ranging between 1750 mm & 6250 mm
6.	Number of thunderstorm days per annum	85 (Max)
7.	Number of dust storm days per annum	35 (Max)
8.	Number of rainy days per annum	120 (Max)
9.	Maximum basic wind pressure	216 kgf/m^2
10.	Altitude above m.s.l. (max)	1000 m
11.	Pollution level	Very Heavy as per IEC:60815 & IS: 13134

2.2 The transformer installation would be subject to vibrations on account of the passage of trains on nearby tracks. The amplitudes of these vibrations which occur with rapidly varying time periods in the range of 15 to 70 ms, lie in the range of 30 to 150 microns with instantaneous peaks up to 350 microns.

2.3 The AC electric locomotives are fitted, for conversion of AC to DC, with Single Phase Bridge connected silicon rectifiers with smoothing reactors for feeding the DC Traction motors. The rectifiers introduce harmonic currents in the 25kV Power Supply system. On a few of the electrified sections, locomotives fitted with phase-controlled asymmetrical thyristor bridge, in place of silicon rectifiers are also in use; these introduce further harmonics in the system. The Typical percentage of harmonic present in the Traction Current with the Electric Locomotives are as follows:

Harmonics	With Diode Rectifier	With Thyristor
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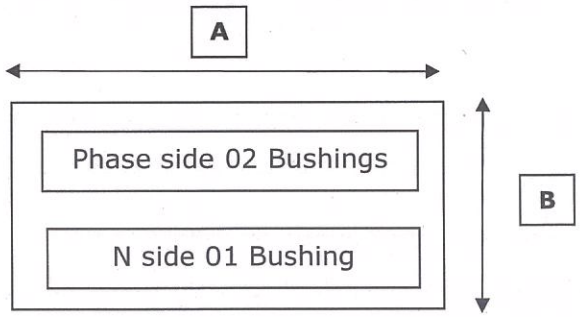
5th (250Hz)	6%	18%
7th (350Hz)	4%	8%
9th (450Hz)	-	4%
11th (550Hz)	-	5%

3.0 Design and Constructional Features

3.1 Overall Dimensions:

The overall dimensions of the transformer shall be kept as low as possible and in any case shall not exceed the values given below (see sketch at annexure-4)



MVA	Dimensions (mm)		Height (mm)
	A	B	
8MVA	4000	3000	4000
12.3MVA	4500	3500	4500
16.5MVA	5000	4000	4800

3.2 TRANSFORMER TANK

3.2.1 The tank for the transformer shall be of Bell Type Construction or Top Cover Mounted with flanges on the outside and shall have a flat top. The flanges of the upper and lower tanks shall be joined by bolts, nuts and suitable plain/spring/beveled washers. A suitable gasket and metallic stoppers shall be provided between the flanges of the upper and lower tank to prevent leakage of Insulating Oil. The tank shall be so designed that the winding and core get fully exposed when the bell tank cover is lifted.

3.2.2 The tank shall be constructed from mild steel of a quality that allows welding without any defect/flaw, with a single-tier construction so shaped as to reduce welding to the minimum. The welded joints shall be made using the latest welding techniques. The tank shall be adequately strengthened for general rigidity to permit the hoisting of the transformer filled with Oil by crane. The tank body shall be designed to withstand a vacuum of 760 mm of Hg.

3.2.3 The tank shall be fitted with four lifting pads at the lower end to enable the lifting of the transformer filled with oil by means of lifting jacks.

3.2.4 The tank shall be fitted with an undercarriage and mounted on four bi-directional swiveling type flanged rollers for being rolled on a 1676 mm (5' 6") gauge track on which it shall also rest in the final position. The rollers shall be provided with a detachable type locking arrangement to enable their locking after installing the transformer in the final position to prevent any accidental movement of the transformer.

3.2.5 There shall be an adequate number of inspection covers of suitable size on the tank to enable inspection of the lower portions of bushings and the leads.

3.2.6 The rubberised cork/gaskets used in the transformer shall conform to IS: 4253 (Part - II) or equivalent/better.

3.2.7 All valves used in the transformer shall conform to IS: 3639 and shall be of good quality and leakproof. The manufacturer shall ensure that suitable anti-theft measures are provided on these valves so as to prevent theft of oil during transit/service.

3.2.8 Suitable support shall be provided on the tank for fixing of Aluminum ladder for ease of maintenance at the site. A suitable ladder of Aluminium shall be provided on the tank for ease of maintenance. The removable aluminium ladder shall be a part of the transformer supply.

3.2.9 The top of the transformer tank shall have a slope of at least 10mm from HV to LV side to avoid accumulation of water on the tank top.

3.2.10 The emblem/identification of the Transformer Tank manufacturer with a year of manufacture of at least 10mm in size is to be engraved on all the jacking pads in the tank. The marking shall be provided in the format; TTT/AAA/YY/SNO. Where the First abbreviation i.e. 'TTT' shall indicate the name of the tank manufacturer, the Second abbreviation i.e. 'AAA' shall indicate the address of the tank manufacturer (ex. BPL for Bhopal, BRC for Vadodara & MUM for Mumbai), Third abbreviation i.e. 'YY' shall indicate the year of manufacture (ex. 23 for 2023) and Fourth abbreviation i.e. 'SNO' is the sr. No. of completely fabricated Transformer Tank.

3.3 MARSHALLING BOX

3.3.1 A Vermin-proof, weatherproof and well-ventilated marshalling box made of a steel sheet of thickness not less than 2 mm, strengthened with adequate stiffeners (if required), shall be provided on the transformer tank. It shall have a hinged door with provision for pad locking. The door opens outward horizontally.

3.3.2 The marshalling box shall have a sloping roof. The top of the marshalling box shall be at a height of about 2 m from the rail level.

3.3.3 The marshalling box shall house the winding and oil temperature indicators. To prevent condensation of moisture in the marshalling box metal clad space heater, controlled by an associated thermostat and switch, shall also be provided. Cable glands shall be provided for the incoming and outgoing cables. A cable gland plate shall be provided at the bottom of the Marshaling Box.

3.3.4 The temperature indicators shall be so mounted that their dials are at a height of not more than 1.6 m from the rail level. Transparent windows of tough acrylic plastic or similar non-fragile transparent material shall be provided on the marshalling box so as to enable reading of the temperature indicators without opening the door of the marshalling box.

3.3.5 All cables from the Bushing Current Transformers, Buchholz Relay, Magnetic Oil Level Gauge, Pressure Relief Device and temperature indicators shall be run through suitable conduits/perforated covered cable trays up to the marshalling box. The cables shall be of 1100 V grade, PVC insulated, PVC sheathed, steel wire armoured, stranded copper conductor conforming to IS: 1554 (Part - I) or XLPE insulated, XLPE sheathed, steel wire armoured, stranded copper conductor confirming to IS:7098 (Part-1). The cables shall be adequately insulated from heat from the tank surface and the sun.

3.3.6 All wiring in the marshalling box shall be clearly identified by lettered / figured ferrules of the interlock type, preferably of yellow colour with black letters /figures. The AC and DC circuits shall be clearly distinguished and well separated from each other.

3.3.7 Suitable legend and schematic diagram plates made of stainless steel or anodized Aluminium with black lettering and lines shall be fixed on the inside surface of the marshalling box door.

3.4 CORE

3.4.1 The core shall be built from high permeability Cold Rolled Grain Oriented (CRGO) silicon steel laminations conforming to IS: 3024. The flux density in any part of the core and yokes at the rated primary voltage and frequency shall not exceed 1.7T. The manufacturer shall furnish calculations to prove that this value shall not be exceeded. The core has to be boltless design to avoid the possibility of local heating. Indian transformer manufacturers shall use core material as per the above specification with BIS certification.

3.4.2 The laminations for the core shall be free from waves, deformation and signs of rust. Both sides of the laminations shall be coated with suitable insulation capable of withstanding stress relief annealing. In assembling the core, air gaps shall be avoided. Necessary cooling ducts, if required, shall be provided in the core and yoke for heat dissipation. The core-clamping frame shall be provided with the lifting eyes for the purpose of tanking and untanking the core and winding of the transformer.

3.4.3 The core, core clamps and tank should be insulated from each other with a single location-conscious earth connection. The insulation shall be high-temperature, non-deteriorating (non-cellulose) material. The earth connection shall be accessible without draining any oil to allow the testing of the insulation resistance.

3.4.4 The core shall be electrically connected to the tank.

3.4.5 The transformer is required to be continuously in service, preferably without requiring any attention from the date of its energisation up to the periodical overhaul (POH) which is generally done after 12 years of service. The need, therefore, for tightening of core clamping bolts should not normally arise before the POH of the transformer. The manufacturer of the transformer shall take this aspect into account during core assembly.

3.5 WINDINGS

3.5.1 The type of winding is to be decided by the transformer manufacturer after ensuring that all the parameters mentioned in the specification are fulfilled with the decided type of winding. The windings shall be uniformly insulated. The two outer line terminals of the winding shall be brought out through 52kV OIP condenser bushings, whereas the neutral terminal (center tapping) through 36kV Oil Communicating Porcelain Bushing. All Bushings shall have BCT of the required rating.

3.5.2 The windings shall be made of continuous electrolytic copper conductor, thermally upgraded paper insulated to Class-A insulation or epoxy-bonded continuously transposed conductor. The conductor shall not have sharp edges which may damage the insulation. Insulation paper covering over the bunch of the epoxy bonded continuously transposed conductor is also to be provided with thermally upgraded paper.

3.5.3 Normally, no joints shall be used in the winding conductor. If a joint becomes inescapable, it shall be brazed with high silver alloy grade BA Cu Ag6 conforming to IS: 2927 or electrically butt-welded.

3.5.4 The size (width & thickness) of the conductor is to be decided by the transformer manufacturer and to ensure that tilting of conductors does not take place when the windings are subjected to axial and radial forces during short circuits. This size of the

conductor should be mentioned in the SOGP. Whenever the manufacturer desires to change the size from the type-tested design, type testing of the transformer including the short circuit test shall be repeated.

3.5.5 The transformer windings shall be designed for the following rated withstand withstand voltages:

1.	Highest voltage for equipment Um, kV	52
2.	Rated short duration power frequency withstand voltage, kV	95
3.	Rated lightning impulse withstand voltage, kV peak	250

3.5.6 The windings shall be designed to withstand the magnetising inrush currents due to repeated switching on of the transformer.

3.5.7 The axial pre-compression on the windings shall preferably be double the calculated axial thrust that may be set up under dead short-circuit conditions to ensure that the windings do not become loose due to frequent short circuits in service.

3.5.8 During short circuits, the stresses set up in conductors, spacers, end blocks, clamping rings and such other parts of the transformer shall not exceed one-third of the maximum permissible values.

3.5.9 Pre-compressed spacers shall be used between disc-shaped coils of the windings to transmit the axial forces generated due to the short circuits.

3.5.10 Wood insulation, if used, on the core and winding shall be seasoned, dried and well compressed and shall have adequate strength.

3.5.11 A uniform shrinkage shall be ensured during the drying of the individual coils or assembly of coils by providing a uniform clamping force with the help of hydraulic jacks or similar devices.

3.5.12 In order to cater for shrinkages that may occur in service, substantial clamping rings shall be provided at the tops of the windings, being pressed down upon them by means of adjustable pressure screws or oil dashpots or any other suitable device, to maintain constant pressure and obviate the need for any retightening in between successive periodical overhauls.

3.5.13 The coil and core assembly shall be retightened after oil impregnation. The manufacturer shall ensure that there is no further shrinkage of the coil assembly in any additional cycle after the final curing.

3.5.14 The manufacturer shall furnish details of various stages of drying of coils, coil assembly up to and including oil impregnation and final tightening of the coil assembly. Values of pressure, duration, temperature and degree of vacuum maintained at various stages of drying shall also be indicated.

3.5.15 The core and winding of the transformer must be dried using Vapour Phase Drying (VPD). To ensure the removal of moisture from the transformer the PI value after drying must be achieved equal to or more than 2 (two) in the manufacturing at the works.

3.5.16 To keep unbalanced axial forces due to non-uniform shrinkage/unequal height of the coils to the minimum wedges of pre-compressed wood or similar such material shall be used.

3.5.17 To prevent displacement of the radial spacers used in the windings, closed slots shall be provided, and a vertical locking strip shall be passed through these slots.

3.5.18 The vertical locking strips and slots of the radial spacers shall be so designed as to withstand the forces generated due to short circuits.

3.5.19 The vertical locking strips and radial spacers shall be made of a pre-compressed pressboard conforming to grade PSP: 3052 of DIN: 7733 or as per IEC: 60641.

3.5.20 To prevent end blocks from shifting, a pre-compressed pressboard ring shall be provided between the two adjacent blocks. Coil clamping rings made of densified wood or mild steel shall be located in a position with pressure screws or pressure pads.

3.5.21 Leads from the windings to the other interconnections shall be properly supported and secured.

3.5.22 The following particulars/documents in respect of the radial spacer blocks (winding blocks), vertical locking strips (axial ribs), end blocks, insulating cylinder, angle rings, paper insulation of the conductor and coil clamping plates used in the manufacture of the windings shall be furnished.

1. Reference to specification and grade of material.
2. Source(s) of supply.
3. Test certificates.

3.6 Insulating Oil

The transformer shall be supplied with new inhibited Mineral Insulating Oil confirming Type-A of IEC: 60296. In addition, 10% extra oil by volume shall be supplied in non-returnable steel drums. The characteristics of the insulating oil before the energisation of the new transformer and during its maintenance and supervision in service shall conform to IS 1866: 2017. For the sources of Insulating Oil, refer to the CLW vendor Directory (Item ID:2100653) available on the IREPS website.

3.7 Bushings and Terminal Connectors

3.7.1 Both the line and neutral bushings shall conform to IS/IEC: 60137. On the line side, 52kV OIP condenser bushings of applicable current rating shall be used. On the neutral side, 36kV Oil Communicating porcelain bushing shall be used. The dimensions of the 52KV bushings shall conform to IS: 12676 and the dimensions of the 36KV bushing shall conform to IS:3347 (Part V) or IS:8603.

3.7.2 The bushings on both the line and neutral side shall be designed for the current rating mentioned in Para number 5.0-16 of this specification. The temperature rise of any part of the bushing shall not exceed 40^0C over an ambient temperature of 50^0C while carrying the rated current continuously.

3.7.3 The porcelain housing of the bushing shall be of a single-piece construction i.e. there shall be no joint in the porcelain. The shed profile shall have a lip at the extremities but free from ribs on the underside to avoid accumulation of dust and pollutants and to permit easy cleaning.

3.7.4 The OIP bushings shall have a non-breathing oil expansion chamber. The expansion chamber shall be provided with an oil level indicator, which shall be so designed and dimensioned that the oil level is clearly visible from ground level.

3.7.5 A test tap shall be provided for dielectric or power factor measurement for OIP bushings.

3.7.6 The bushings shall be designed for the following insulation level:

1	Highest system voltage of Bushing to be used Um, kV	52	36
2.	Rated short duration wet power frequency withstand voltage, kV	95	70
3.	Rated lightning impulse withstand voltage, kV peak	250	170

3.7.7 Adjustable arcing horns shall be provided on both the primary and neutral bushings. The horn gap setting shall be variable as indicated below:

1.	Highest system voltage of Bushing to be used Um, kV	52	36
2.	Arcing horn gap setting variable between, mm	150 and 500	150 and 500

3.7.8 The design and construction of the bushing shall be such that stresses due to expansion and contraction in any part of the bushing shall not lead to its deterioration/ breakage.

3.7.9 The bushings shall be free from corona and shall not cause radio interference.

3.7.10 The bushing terminals shall be provided with terminal connectors of bimetallic type and shall be such that there is no hot spot formation even during the extreme overload condition of ONAN rating with 200% overloading. Expansion type terminal connector to suit 50mm overall diameter Aluminium Tubular Bus and shall match with the size of bushing stud on the other side, the connector shall be as per the firm's drawing approved by RDSO.

3.7.11 The terminal connectors shall conform to IS: 5561. The design shall be such as to be connected to the equipment terminal stud with a minimum of four 12 mm diameter bolts, nuts, springs and flat washers. The fasteners shall conform to clause 3.11 of this specification.

3.8 Bushing Type Current Transformers

3.8.1 The 52 kV side bushings shall be so arranged as to accommodate bushing-type current transformers (BCTs) for the biased differential protection of the transformer. The neutral side bushing shall also be so arranged as to accommodate bushing-type current transformers (BCT). Thus, BCTs are to be provided in all Bushings. The BCTs shall conform to IS: 2705 and meet with the stipulations in clause 5.1(17) of this specification.

3.8.2 The BCTs shall be so designed as to withstand thermal and mechanical stresses resulting from frequent short circuits experienced by the transformer on which these are fitted.

3.8.3 Apart from the BCTs required for the biased differential protection, a BCT of accuracy class 5 and conforming to IS: 2705, with suitable tappings, shall be mounted inside a line bushing for use with the winding temperature indicators.

3.8.4 The BCTs and the bushings shall be so mounted that removal of a bushing without disturbing the current transformers, terminals and connections or pipe work is easy and convenient.

3.8.5 The leads from the BCTs shall be terminated in terminal boxes provided on the bushing turrets. Suitable links shall be provided in the terminal boxes for shorting the secondary terminals of the BCTs, when not connected to the external measuring circuits.

3.8.6 The leads from the secondary winding of the BCTs terminated in the terminal box on the bushing turret up to the marshalling box shall be of 1100 V grade, PVC insulated, PVC sheathed, armoured, stranded copper cable of cross-section not less than 4 mm^2 to IS: 1554 (Part-I) or 1100 V grade, XLPE insulated, XLPE sheathed, steel wire armoured, stranded copper cable of cross section not less than 4 mm^2 confirming to IS: 7098 (Part-1).

3.8.7 Cable glands of proper size shall be provided in the terminal boxes to lead in/lead out of the cables.

3.9 Clearances

The relative orientation in space of the bushings fitted with terminal connectors, the main tank, radiators, conservator, pressure relief device, oil piping and other parts when mounted on the transformer shall be such that the various clearances in air from bushing live parts shall not be less than the appropriate values given hereunder:

Highest voltage for equipment Um, kV	52	36
Minimum clearance, mm	500	350

The same distance shall apply for clearance phase–to–earth (including oil piping work, conservator, pressure relief device and such other parts), phase–to-phase and towards terminals of a lower voltage winding.

3.10 Cooling Equipment

3.10.1 The transformer shall be designed for ONAN type of cooling.

3.10.2 The radiators shall consist of a pressed steel plate assembly formed into elliptical oil channels (as per the Indian Electrical & Electronic Manufacturers Association's (IEEMA) standard) or a series of separate elliptical tubes. The radiators shall be designed in such a manner that the temperature-rise limits specified under Clause 5.0(11) of this specification are not exceeded. Collector/ header pipes in the radiators are to be ERW pipes of thickness 4.5 mm. The external painting of the radiator has to be as per clause 3.13 of this specification. The radiators & accessories should be given external paint coats. First coat of epoxy zinc rich (having minimum 83% zinc) primer (50 micron thickness), intermediate coat of epoxy chemical and corrosion resistant High Build Epoxy Intermediate paint (100 micron thickness) and final coat of Glossy Aliphatic Acrylic Polyurethane Coating paint (50 micron thickness). The total dry film thickness of the paints shall be a minimum 200 micron. The shade of paint shall be grey as shade 631 of IS: 5. Alternatively, Radiators with Hot Dip Galvanised in place of painting with a minimum thickness of 40μm (min) may also be provided.

3.10.3 The radiators shall be removable (after isolating the same from the main tank) to facilitate transportation of the transformer. A drain plug of size 19 mm and an air-release plug of size 19 mm shall be provided at the bottom and the top of each radiator bank for draining and filling of oil respectively. Each radiator bank shall also be provided with shut-off valves of size 80 mm. In case of the use of headers, isolating valves of size 80mm shall be used between the tank and headers.

3.10.4 The radiators shall preferably be supported directly on the transformer tank. Each radiator bank shall be fitted with two hooks, one at the centre for lifting the radiator and the other for tying the unit in service.

3.11 Fasteners

All fasteners of 12 mm diameter and less exposed to the atmosphere shall be of stainless steel and those above 12 mm diameter shall preferably be of stainless steel or mild steel hot dip galvanized to 610 g / m^2 of zinc. The material of the stainless-steel fasteners shall conform to IS: 1570 (Part- V). Grade X04Cr17Ni12Mo2 or equivalent/better.

3.12 Painting

3.12.1 Shot blasting / sand blasting shall be done on the transformer tank to remove all scales, rust and other residue before applying the paint inside the tank. All steel surfaces which are in contact with insulating oil shall be painted with heat-resistant oil insoluble insulating varnish.

3.12.2 All steel surfaces exposed to the weather shall be properly descaled/grit blasted. The epoxy and polyurethane protective paints as per ISO/EN 12944 must be provided for proper protection against corrosive and coastal environments and give a life of approx. 12-15 years.

All the external surfaces of the Transformer shall be given a first coat of epoxy zinc rich (having minimum 83% metallic zinc) primer (50 micron thickness), an intermediate coat of epoxy chemical and corrosion resistant High Build Epoxy Intermediate paint (100-micron thickness) and final coat of Glossy Aliphatic Acrylic Polyurethane Coating paint (50 micron thickness). The total dry film thickness of the paints shall be a minimum 200 micron. The shade of paint shall be grey as shade 631 of IS: 5. Same paints have to be applied to damaged surfaces, if any, at the site during the erection /commissioning of the transformer. One final coat of polyurethane paint has to be applied to ensure proper smoothness and finish.

3.12.3 For panels like marshalling Box Powder Coating painting of minimum 80 micron thickness is to be done. The shade of paint shall be shade 631 of IS: 5.

4.0 List of Related Specifications

4.1 In the preparation of this specification assistance has been derived from the following standards and Codes of Practices (Latest Version) and Indian Electricity Rules wherever applicable.

1.	IS:5	Colour for ready-mixed paints and enamels.
2.	IEC:60296	Inhibited Mineral Insulating Oil.
3.	IS:1554 (Pt.-I)	PVC Insulated (Heavy Duty) Electric Cables for working voltage up to and Including 1100 Volts.
4.	IS:1570 (Pt.-V)	Stainless and Heat Resisting Steels.
5.	IS:1576	Solid Pressboard for Electric Purpose.
6.	IS:1866	Code of Practice for maintenance and supervision of mineral insulating oil in equipment.
7.	IS:2026	Power Transformer
8.	IS:2705	Current Transformer
9.	IS:2927	Brazing Alloys
10.	IS:3024	Electrical Steel Sheets (Oriented)
11.	IS:3637	Gas Operated Relays.
12.	IS:3639	Fittings and accessories for Power Transformers.
13.	IS:4253 (Pt. II)	Cork and Rubber
14.	IS:5561	Electrical Power connectors.
15.	IS:5621	Hollow Insulators for use in Electrical Equipments.
16.	IS:13234	Guide for Short Circuit Calculations in 3 phase ac system
17.	IS:6209	Methods for Partial Discharge Measurement.
18.	IS:6600	Guide for loading of Oil Immersed Transformers.
19.	IS:10028	Code of Practice for selection, installation and maintenance of Transformers.
20.	IS:10593	Method of evaluating the analysis of gases in oil filled electrical equipment in service.
21.	IS:12676	Oil impregnated paper Insulated Condenser Bushing- Dimensions and requirements.
22.	IS/IEC:60137	Bushings for alternating voltages above 1000 volts.
23.	DIN:7733	Laminated Products, pressboard for electrical engineering types.

4.2 In case of any overlapping or conflict between the contents of the above standards and this specification, the stipulation of this specification shall prevail.

4.3 Any deviation from this specification proposed by the manufacturer for improving the performance, utility and efficiency of the equipment, will be given due consideration provided full particulars of the deviation with justification are furnished. In such case, the manufacturer shall quote according to this specification and the deviations, if any, proposed by him shall be quoted as alternate/alternatives.

5.0 Rating, name-plate details and other information

The Rating Plate shall indicate the ratings of the Transformer, the connection diagram of the windings, the particulars of the Bushing Current Transformers and other details as per IS:2026. The rating plate shall be both in Hindi and English. The rating plate shall be made of stainless steel or anodized aluminium material. The rating and general data of the transformer shall be as follows:

SN					
	Rated primary voltage, kV		55		
1.	Maximum permissible primary voltage, kV		60		
2.	Short circuit current (symmetrical)		25 (Twenty five) times the rated current		
3.	Rated Power, (MVA)		8	12.3	16.5
4.	Rated current (A)	Primary {(MVA*1000)/55}	145	224	300
		Secondary {(MVA*1000)/27.5}	291	447	600
5.	Maximum permissible losses, kW	No Load	6.5	7.5	8
		Load	14	21.5	25.5
	Maximum leakage impedance as seen from the secondary side (ohm)		0.45		
6.	Type		ONAN cooled single phase autotransformer with center tapping (neutral terminal), double limb wound, core-type for outdoor installation.		
7.	Windings		One winding with center tapping, uniformly insulated shall be provided. The outer (line) terminals of the winding shall be brought out through 52kV class bushings, whereas the neutral terminal (center tapping) through 36kV class bushing.		
8.	Rated secondary voltage (at no - load), kV		27.5kV		
9.	Rated frequency, Hz		50 +/-3%		
10.	Non - cumulative overload capacity after the transformer has reached steady temperature on continuous operation at rated load(i.e. at rated power)		1. 150% rated load for 15 min. 2. 200% rated load for 5 min.		
11.	Temperature rise		1. The temperature rise over an ambient temperature of 50°C both at rated and overload conditions shall not exceed the value indicated below: a. Winding: 50 °C at rated load, and 60 °C for overloads as specified in Clause 5.0(10) (temperature measured by resistance method). b. Top oil: 40 °C (temperature rise measured by thermometer).		

		c. Current carrying parts in air: 40 ^{0}C (temperature rise measured by thermometer). 2. The winding hot-spot temperature under the rated and overload conditions shall not exceed 115^0 C (Please refer to the temperature rise test, Para)
12.	Ability to withstand short circuit of 25 (Twenty five) times of the rated current, sec.	Thermal ability: 3 s Dynamic ability: 0.25 s
13.	Flux density at rated voltage and frequency	Shall not exceed 1.7 tesla
14.	Current density in the windings at rated current	Shall preferably not exceed 2.5 A/mm^2
15.	Acoustic sound level when energized at rated voltage and at no-load	Not more than 75 dB at a distance of one meter.

Note: Non-cumulative power load means overload which occurs at sufficient intervals of time apart such that the temperature rise limits, both Oil and Winding do not exceed the values specified in clause 5.0(10) of this specification. The interval time between two successive non-cumulative overloads shall not be less than 3 hours.

16. Bushings:

SN	Item	Line Terminal			Neutral Terminal		
1.	Type	OIP condenser			OIP condenser		
2.	Highest voltage for Bushing Um, kV	52			36		
3.	MVA	8	12.3	16.5	8	12.3	16.5
4.	Rated current, A	800			800	1250	1600
5.	Minimum creepage distance in air, mm	1300			900		

17. Bushing Type Current Transformers for differential protection of transformer and on neutral bushing for fault locator

SN	Item	Line Terminal			Neutral Terminal		
1.	Highest voltage for Bushing Um, kV	52			36		
2.	MVA	8	12.3	16.5	8	12.3	16.5
3.	CT Ratio	300/5	500/5	600/5	600/5	1000/5	1200/5
4.	Class of accuracy as per IS:2705 (Part IV)	PS			PS		
5.	Minimum knee-point emf, V	150	175		125	175	
6.	Maximum excitation current at knee-point voltage, A	0.25	0.75		0.25	0.75	
7.	Maximum resistance of the secondary winding, ohm	0.5	0.5		0.25	0.5	
8.	Frequency, Hz	50+/-3%					

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6.0 Testing of Transformer

6.1 General

6.1.1 Once the design and drawings as well as QAP have been approved and written advice has been given by RDSO, the manufacturer shall take up the manufacture of the prototype for inspection/testing by RDSO. It is to be clearly understood that if any changes or modifications by the above authorities are to be made in the prototype, the same shall be done expeditiously, notwithstanding approval having already been given for the designs and drawings.

6.1.2 Before giving a call to the purchase/DG(TI), RDSO, Lucknow for inspection and testing of the prototype, the manufacturer shall submit a detailed test schedule consisting of schematic circuit diagrams for each of the tests and the number of days required to complete all the tests at one stretch. Also, the Internal Test Report (ITR) of the Transformer as well as Test Certificates of the Brought-Out Items (BOM) are to be submitted. Tests specified in Para 6.3.4.2 are to be conducted for the Internal Test Report. Once the schedule is approved, the tests shall invariably be done accordingly. However, during the process of type testing or even later, the DG/TI/RDSO, Lucknow reserves the right to conduct any additional test(s), besides those specified herein, on any equipment/item to test the equipment/item to his satisfaction or for gaining additional information and knowledge. In case any dispute or disagreement arises between the manufacturer and the representative of the DG/TI/RDSO, Lucknow during the process of testing as regards the procedure for type tests and/or the interpretation and acceptability of the results of type tests, it shall be brought to the notice of the DG/TI/RDSO, Lucknow as the case may be whose decision shall be final and binding. Only after the prototype of the equipment is manufactured and ready in all respects, shall the manufacturer give the actual call for the inspection and testing with at least 15 days' notice for the purpose.

6.1.3 Type tests shall be carried out on prototype unit of Traction power Transformer with relevant standards as modified or amplified by this specification where applicable at the works of the manufacturer or a reputed testing laboratory. At the works of the manufacturer, the testing shall be conducted in the presence of the authorised representative of the purchaser/DG (TI)/RDSO, Lucknow. However, for the tests in the third-party laboratory the presence of the representative of the purchaser/DG (TI)/RDSO, Lucknow may be decided by the RDSO.

6.2 Tests during Manufacture

6.2.1 Though the tests described below shall form a part of the type tests, the manufacturer shall carry out these tests on each and every unit during the process of manufacturing and submit the test reports to the Purchaser's Inspector deputed for witnessing the routine tests. However, the 'Vacuum test' described under clause 6.2.1.2 and the 'Pressure test' in Clause No. 6.2.1.3 shall be conducted only on the prototype unit.

1. Oil leakage test.
2. Vacuum test.
3. Pressure test.
4. Test for pressure relief device.
5. Measurement of Capacitance and tan delta values

6.2.1.1 Oil leakage test: The transformer with its radiators, conservator tank and other parts, fittings and accessories completely assembled shall be tested for oil leakage by being filled with oil conforming to Type A of IEC:60296 (Para 6.3.8.8 of this specification) at the ambient temperature and subjected to a pressure corresponding to twice the normal static oil head

or to the normal static oil head plus 35 kN/m^2 (0.35 kgf/cm^2), whichever is lower, the static oil head being measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 h, during which time no leakage shall occur.

6.2.1.2 Vacuum test: The transformer tank only shall be tested at a vacuum of 3.33 kN/m^2 (0.0333 kgf/cm^2) for 60 min (The applied vacuum shall be current atmospheric pressure in mmHg at the testing location – 25mmhg). The permanent deflection of flat plates after the release of the vacuum shall not exceed the values specified below:

Horizontal length of flat plate (i.e. Total length of Tank Wall)	**Permanent deflection, mm**
Upto and including 750 mm	5.0
751 mm to 1250 mm	6.5
1251mm to 1750 mm	8.0
1751 mm to 2000 mm	9.5
2001 mm to 2250 mm	11.0
2251 mm to 2500 mm	12.5
2501 mm to 3000 mm	16.0
Above 3000 mm	19.0

6.2.1.3 Pressure test: Every transformer tank shall be subjected to an air pressure corresponding to twice the normal static head of oil or to the normal static oil head pressure plus 35 kN/m^2 (0.35 kgf/cm^2), whichever is lower, as measured at the base of the tank. The pressure shall remain constant for 1 h to indicate that there is no leakage. Also, the permanent deflection of flat plates after pressure has been released shall not exceed the values specified in clause 6.2.1.2 without affecting the performance of the transformer. The conservator shall be subjected to the same air pressure and shall remain constant for 1 h to indicate that there is no leakage.

6.2.1.4 Test for pressure relief device: Every pressure relief device shall be subjected to gradually increasing oil pressure. It shall operate before the pressure reaches the test pressure specified in Clause 6.2.1.3 hereof and the value at which it has operated shall be recorded.

6.2.1.5 Measurement of Capacitance and Tan-Delta values: The measurement of capacitance and tan-Delta (Dielectric Loss factor) of the Transformer windings and OIP Bushings shall be made by Schering Bridge.

6.2.2 During the prototype approval, at the following manufacturing stages the tests may be witnessed by the representative of the purchaser /DG (TI), RDSO, Lucknow at the works of the manufacturer. In case the inspection of the transformer tank is conducted at the works of the sub-vendor of the transformer manufacturer, the presence and witness of a representative of the transformer manufacturer shall also be required.

6.2.2.1 Transformer Tank
6.2.2.2 Transformer CORE.
6.2.2.3 Transformer Winding Assembly

Tests to be conducted during these manufacturing stages are as detailed below.

6.2.2.1 Transformer Tank: The following tests shall be conducted:

(i) The pressure test and vacuum test shall be done as per Clause No. 6.2.1.2 & 6.2.1.3 of this specification.
(ii) The Dye Penetration (DP) Test at the jacking and lifting pads.

(iii) The thickness of the sheets used on the side wall, top and bottom of the tank, and conservator shall be measured and verified as declared by the manufacturer in SOGP.
(iv) Height of the HV & LV side of the tank to be measured to verify that, there is a minimum 10 mm difference in height of the HV & LV side.
(v) Test certificates of the used sheets to be submitted.

6.2.2.2 Transformer CORE.
(i) 2 kV r. m. s. withstand voltage between the Core Frame and core laminations for 60 seconds.
(ii) Stack height, Diameter and window dimensions as per the approved drawings.
(iii) The Thickness of all the steps to be measured and calculation of the flux density on the measured values to be submitted by the manufacturer.
(iv) The manufacturer test certificate of the core material shall be submitted.

6.2.2.3 Transformer Winding Assembly: The following measurements/inspection shall be conducted on winding.
(i) Thickness of the bare and insulated conductor.
(ii) Width and Thickness of the conductor.
(iii) Number of Discs in windings.
(iv) Calculation of the current density as per the measured values to be submitted by the manufacturer.
(v) The test certificate of the used conductor and thermally upgraded paper to be submitted.

6.2.3 The purchaser or their representative may, if he so desires, carry out any checks or tests on the quality of manufacture at any stage during coil winding, drying of coils, assembly of coils on core and method of drying, vacuum impregnation, tightness of core clamping bolts, adequacy of pressure on coils or any other aspects as deemed to ensure that proper quality is maintained.

6.3 TYPE TESTS

The type tests shall be carried out on the prototype transformer at the works of the manufacturer or any reputed laboratory in the presence of the representative of the purchaser /DG (TI), RDSO, Lucknow, and in accordance with the relevant specifications and as altered, amended or supplemented by this specification. The following shall constitute the type tests:

1. Temperature-rise test.
2. Lightning impulse test.
3. Test with lightning impulse, chopped on the tail.
4. Short-circuit test.
5. Measurement of acoustic sound level.
6. Measurement of partial discharge quantity.
7. Measurement of harmonics of no-load current.

6.3.1 Temperature - Rise test

6.3.1.1 The temperature-rise test shall be done with IS: 2026 (Part II) except as modified hereunder:

1. At rated load.
2. At 150% rated load for 15 min after continuous operation at rated load for 1 h.
3. At 200% rated load for 5 min after continuous operation at rated load for 1 h.

The tests shall be done continuously without any power supply interruption. In case interruptions of power supply do take place for some reason, then the entire test shall be repeated after steady-state conditions are attained.

6.3.1.2 The points to be ensured during the temperature-rise test shall be:

1. The following tests shall be conducted on the sample of oil drawn from the transformer tank before and after temperature rise tests:
   i) The Dissolved Gas Analysis (DGA)
   ii) Water Content (ppm)
   iii) Electric strength (BDV)
2. The ambient temperature shall be measured using alcohol in glass thermometers or by thermocouple or by electronic thermometers.
3. The winding temperature shall be determined by the resistance method only.
4. The temperature of the top oil shall be measured by an alcohol in glass thermometer placed in an oil-filled thermometer pocket.
5. The average oil temperature shall be calculated as the difference between the top oil temperature and half the temperature drop in the cooling equipment (radiators).
6. The temperature of the hot - spot in the winding shall be the sum of the temperature of the top oil and 1.1 times the temperature rise of the winding above the average oil temperature.

6.3.1.3 The test shall be carried out as described below:

6.3.1.3.1 **100% load**

1. A quantum of power equal to the sum of the measured losses viz. No-load loss and load losses, corrected to 75^0C plus 10% of such sum shall be fed to the primary winding of the transformer with the secondary windings short-circuited.
2. The power so fed to the transformer shall be continuously maintained till such time as the steady state temperature is reached i.e. the top oil temperature rise does not vary by more than 1^0 C during four consecutive hourly readings.
3. On attaining the steady state temperature, the current in the primary winding of the transformer shall be brought to the rated current which shall be maintained for 1 h. At the end of the period, the power supply to the transformer shall be switched off and the time of switching off recorded.
4. The measurement of hot resistance (between HV terminals i.e. 1.1 & 1.2) shall commence as soon as possible after switching off. The first reading of the resistance shall be taken before the expiry of 90 seconds from the instant of switching off and the first ten readings shall be taken at intervals of 15 seconds apart. Thereafter, another ten readings shall be taken at intervals of 30 seconds apart.
5. The time at which each of the resistance values is read shall also be recorded.
6. The temperature of the ambient, top oil and the top & bottom radiator header oils shall also be recorded at half-hourly intervals throughout the test starting from the instant power supply is switched on to commence the test till it is switched off.
7. The WTI and OTI readings shall also be recorded at half-hourly intervals right from the instant the power supply is switched on to commence the test till it is switched off.
8. After the power supply is switched off, the readings of OTI and WTI shall be recorded at intervals of 1 minute apart for 30 minutes.

6.3.1.3.2 **150% load**

1. After completion of the test at 100 % load, the transformer shall be fed with power, which shall be a value to cause circulation of the rated current in the primary winding with secondary windings short-circuited. This current shall be circulated for 1 h.

2. The current shall thereafter be increased to 150% of the rated current and maintained for a period of 15 minutes. At the end of the 15 minutes period, the power supply shall be switched off and the time of switching off shall be recorded.
3. Thereafter the readings as indicated in Clauses 6.3.1.3.1(4 to 8) shall be recorded.
4. The temperature of ambient, top oil, the top and bottom radiator header oils and the temperatures indicated by OTI and WTI shall also be recorded at the time of switching on 150% load as well as at the time of switching off the power supply.

6.3.1.3.3 **200% load**

1. After completion of the test at 150 % load, the transformer shall be fed with power, which shall be a value to cause circulation of the rated current in the primary winding with secondary windings short-circuited. This current shall be circulated for 1 h.
2. The current shall thereafter be increased to 200% of the rated current and maintained for 5 minutes. At the end of the 5 minutes, the power supply shall be switched off and the time of switching off shall be recorded.
3. Thereafter the readings as indicated in Clauses 6.3.1.3.1 (4 to 8) shall be recorded.
4. The temperature of ambient, top oil, the top and bottom radiator header oils and the temperatures indicated by OTI and WTI shall also be recorded at the time of switching on 200% load as well as at the time of switching off the power supply.

6.3.1.4 Determination of thermal time constant of the windings: The thermal time constant of the primary and secondary windings under both rated and overloads shall be verified during the temperature - rise tests.

6.3.1.5 The temperature rise of the oil, windings and current carrying parts in the air under both the overload conditions stipulated in Clauses 6.3.1.3.2, 6.3.1.3.3 and 6.3.1.4 above shall not exceed the values stipulated in Clause 5.0 (11) of this specification. The winding hot-spot temperature under the overload conditions shall not exceed 115^0 C

6.3.1.6 Testing and calibration of the temperature indicators: The functioning of the OTI and WTI shall be verified during the tests described above. Both the OTI and WTI shall be recalibrated, if necessary, to reflect the respective temperatures correctly. In particular, the reading of the WTI shall be the same as the calculated value of the hot-spot temperature of the winding.

6.3.1.7 Determination of the thermal time constant of the WTI: The thermal time constant of the WTI shall be determined for comparison with the thermal time constant of the winding of the transformer with respect to the transformer oil. For this purpose, the indications of the WTI and the OTI shall be recorded every 1 or 2 min during the first 1 h from the instant the transformer is loaded. From the slope of the curve plotted with the time on the X-axis and the difference between the readings of the WTI and OTI at the particular time on the Y-axis, the thermal time constant of the WTI shall be determined. This value shall not vary appreciably from the thermal time constant of the winding as calculated theoretically and as ascertained from the slope of the cooling curves.

6.3.2 LIGHTNING IMPULSE TEST

This test shall be done in accordance with IS: 2026 (Part III). Each of the line terminals of the autotransformer winding shall be tested with the following voltages:

1.	Highest voltage for equipment, Um, kV	52
2.	Lightning impulse withstand voltage, kV peak	250

6.3.3 TEST WITH LIGHTNING IMPULSE, CHOPPED ON THE TAIL

This test shall be done on the line terminals in accordance with IS: 2026 (Part III). The peak value of the chopped impulse shall be 10 % higher than for the full impulse test voltage stipulated in Clause 6.3.2 above.

6.3.4 SHORT - CIRCUIT TEST

6.3.4.1 The short-circuit test shall be conducted in accordance with IS: 2026 (Part I) with the following schedule:

6.3.4.2 Before the commencement of the test, the following measurements/ tests shall be made. These tests can be conducted at the works of the transformer manufacturer.

1. Insulation resistance of the windings with respect to the earth.
2. No- load current.
3. No- load loss.
4. Resistance of the windings.
5. Percentage impedance voltages.
6. Load loss.
7. Voltage ratio.
8. Di- electric tests comprising:
   - i Separate - source voltage withstand test.
   - ii Induced over-voltage withstand test.
9. Recording of Recurrent Surge Oscillogram (RSO).
10. Frequency response analysis (FRA) of the transformer.

6.3.4.3 Test to be done at a third-party laboratory. The test shall be done by the PRE-SET method, which is shown below:

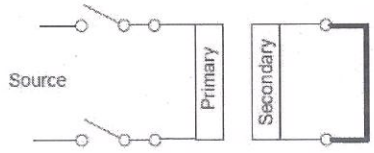

Fig: Single line diagram for the PRE-SET Method

In this method, the secondary of the transformer is short-circuited previously and Circuit Breaker at the primary side is closed to apply a shot.

6.3.4.4 The transformer shall be subjected to a total of seven shots in the following sequence:

Shot	Current
1st shot	Symmetrical Current.
2nd shot	Asymmetrical Current.
3rd shot	Asymmetrical Current.
4th shot	Symmetrical Current.
5th shot	Symmetrical Current.
6th shot	Asymmetrical Current.
7th shot	Symmetrical Current.

6.3.4.5 The duration of each shot shall be 0.25 seconds.

6.3.4.6 Percentage impedance voltage or inductance shall be measured after each shot.

6.3.4.7 Further testing and inspection of the transformer subjected to the short-circuit test shall be carried out as per IS: 2026 (Part-I) with the modification that:

1. The dielectric routine tests shall be at 100% of the original test value.
2. The percentage impedance voltages measured after the short-circuit test shall not vary by more than 2% from those measured before the short-circuit test.

6.3.4.8 On completion of the short-circuit test, the transformer shall be untanked for inspection of the core and windings. In case the inspection of the core and windings do not reveal any apparent defects and the results of the short–circuit test, the values of percentage impedance voltages as also the results of the routine tests done after the short-circuit test are in order, the transformer shall be deemed to have passed the short-circuit test. If any of the results of the tests are not in order or the inspection of the core and windings reveals any defect, then the transformer shall necessarily have to be dismantled completely for detailed inspection.

6.3.4.9 Frequency response analysis (FRA) of the prototype transformer is to be carried out before and after the short circuit test to judge the healthiness of the transformer after the short circuit and this can be kept as a reference for the future. Similar Frequency response analysis (FRA) records for other transformer units may preferably be furnished to be used for future reference.

6.3.5 Measurement of Acoustic Sound Level

Measurement of the acoustic sound level of the transformer, energized at rated voltage and frequency, shall be carried out in accordance with IS 2026 (Part 10): 2009.

6.3.6 Measurement of Partial Discharge Quantity

The partial discharge quantity of the windings shall be measured in accordance with IS: 6209 and IS: 2026 (Part – III).

6.3.7 Measurement of Harmonics of No-Load Current

The magnitude of harmonics of no-load current, as expressed in percentage of the fundamental, shall be measured by means of a harmonics analyzer, in accordance with IS: 2026 (Part- I).

6.3.8 Type Tests on Parts, Fittings and Accessories. The type tests on accessories specified in this clause are not normally conducted during the transformer approval.

6.3.8.1 **Condenser Bushings**

6.3.8.1.1 The type tests shall be carried out in accordance with IS: 5621 on the porcelain housing of the condenser bushings. The following shall constitute the type tests:

1. Visual inspection.
2. Verification of dimensions.
3. Electrical routine test.
4. Porosity test.
5. Temperature cycle test.
6. Bending test.

6.3.8.1.2 The type tests shall be carried out in accordance with IS/IEC: 60137 on the prototype of the condenser bushings. The following shall constitute the type tests:

1. Wet power frequency withstand voltage test.
2. Dry lightning impulse voltage withstand test.
3. Thermal stability test.
4. Temperature rise test.
5. Thermal short-time current withstand test.
6. Cantilever load withstand test.

7. Tightness test.
8. Test of tap insulation.
9. Tightness test at flange or another fixing device.
10. Measurement of partial discharge quantity.

6.3.8.2 **Bushing type Current Transformers**

The bushing-type current transformers shall be tested in accordance with IS: 2705 (Part-I & IV).

6.3.8.3 **Buchholz Relay**

The Buchholz relay shall be tested in accordance with IS: 3637.

6.3.8.4 **Terminal Connectors**

The terminal connectors shall be tested in accordance with IS: 5561.

6.3.8.5 **Temperature Indicators**

The following tests shall be conducted on prototypes of OTI and WTI.

1. Accuracy with reference to a standard instrument.
2. Calibration of the indicators to reflect the actual temperature of the oil/winding.
3. Dielectric test at 2.5 kV for 60 s.
4. Vibration test.

4.1 Parameter for applying vibration; Frequency - 20Hz to 60Hz, Acceleration -0.5g, Duration - 01 Hour/Axis and Axis - X, Y & Z

4.2 Observations:

(a) There shall be no evidence of any external mechanical damage observed after the test.

(b) Temperature Indicator measurements should be taken with reference to standard indicator before and after the vibration test and there shall be no variation.

(c) The switch operation reading in both forward and reverse shall be taken before and after the vibration test and there shall be no variation.

5. Dust and water splash test to IP 55 degree of protection.

6.3.8.6 **Pressure Relief Device**

The following tests shall be conducted on the prototype of the pressure relief device:

1. Air pressure test.
2. Leakage test.
3. Contact rating and operation test.
4. Dielectric test on contacts at 2.5 kV for 60 s.

6.3.8.7 **Radiators**

The radiators shall be tested for air leakage at a pressure of 2.5 kg/cm sq. The pressure shall remain constant for 1 h to indicate that there is no leakage.

6.3.8.8 **Insulating Oil**

Inhibited Mineral Insulating Oil as per Type-A of IEC: 60296.

6.4 Routine Tests

The following routine tests shall be performed on each transformer including the prototype unit in accordance with IS: 2026:

1. Visual examination
2. Insulation resistance test.

3. Measurement of no-load current.
4. Measurement of no-load loss.
5. Measurement of resistance of the windings.
6. Measurement of percentage impedance voltages.
7. Measurement of load loss.
8. Voltage ratio test.
9. Dielectric tests comprise:
   1) Separate- source voltage withstand test.
   2) Induced over-voltage withstand test.
10. Recording of recurrent surge oscillogram (RSO).
11. Measurement of capacitance and tan-delta values of transformer windings and Bushings.
12. Sweep Frequency Response Analysis (SFRA) Test

6.4.1 Visual Examination: A general examination shall be made to check that the transformer conforms to the approved drawings. Various items are accessible for maintenance, the quality of workmanship and finishing are of acceptable standards and all parts, fittings and accessories are provided.

6.4.2 Insulation Resistance Test: The insulation resistance of the windings with respect to the earth and between the windings shall be measured using a 5 kV megger. The PI value (i.e. IR at 600Sec/IR at 60Sec) should be ≥ 2.0. However, if the IR reading at 60 seconds is >10 GΩ, then the PI value > 1.5 is also accepted.

6.4.3 Measurement of No–Load Current: Measurement of no-load current referred to the primary side shall be done at 90%, 100% and 110% of the rated voltage.

6.4.4 Measurement of No-Load Loss: Measurement of no-load loss referred to the primary side shall be done at 90 %, 100% and 110% of the rated voltage.

6.4.5 Measurement of Resistance of Windings: The resistance of the windings between the line and neutral terminals shall be measured and computed at 75^0 C.

6.4.6 Measurement of Percentage Impedance Voltages: The percentage impedance voltage shall be measured at rated current and ambient temperature and computed at 75^0 C.

6.4.7 Measurement of Load Loss: Load losses at rated current shall be measured at ambient temperature and computed at 75^0.

6.4.8 Voltage Ratio Test: Voltage ratio shall be measured.

6.4.9 Dielectric Tests

6.4.9.1 Induced Over Voltage Withstand Test: The test shall be done as per IS: 2026(Part III).

6.4.9.2 Separate-Source Voltage Withstand Test: The test voltage of 70kV shall be applied between the winding and tank.

6.4.10 Recording of Recurrent Surge Oscillogram (RSO): The oscillograms shall be taken.

6.4.11 Measurement of Capacitance and Tan-Delta Values: The measurement of capacitance and tan-delta (dielectric loss factor) of the transformer Windings and Bushings shall be made by Schering bridge.

6.4.12 Sweep Frequency Response Analysis (SFRA) Test: The SFRA graphs shall be plotted for all the combinations.

6.5 During the routine tests on any unit, if it is found that the sum of the measured losses (i.e. no-load and load losses), corrected to 75^0C exceeds the value defined in Clause 6.3.1.3.1(1), or if the no-load loss/ load loss exceeds the maximum guaranteed figures, then the transformer shall be rejected.

6.6. The prototype approval shall be accorded as per the relevant RDSO's ISO procedures. If the prototype of a transformer conforming to this specification has already been approved in connection with previous supplies to Indian Railways, fresh type testing may be waived at the discretion of the Purchaser, provided that no changes whatsoever in the design or material(s) used or the process of manufacture have been made. However, the Purchaser reserves the right to conduct type tests if he deems it necessary to do so in the light of experience gained from previous supplies.

6.7 Only after approval of the type test, drawings, Schedule of Guaranteed Performance (SOGP) & Quality Assurance Plan (QAP) after incorporating changes, if any, as a result of the prototype tests and clear written approval of the results of the tests on the prototype is communicated by the Purchaser/DG (TI), RDSO, Lucknow, to the manufacturer, shall he take up bulk manufacture of the transformer which shall be strictly with the same material and process of manufacturing adopted for the prototype. In no circumstances shall materials other than those approved in the design/drawings and/or during the prototype testing be used for bulk manufacture on the plea that they had been obtained before the approval of the prototype.

7.0 Maintenance Manual, tools gauges etc.

7.1 Five copies of the Erection, Commissioning, Operation and Maintenance Manual shall be supplied to each consignee, in case the order is more than 10 nos. In case the order is less than 10 nos. 2 copies of the manual shall be supplied. Two copies of manuals shall be supplied to the Purchaser and DG (TI), RDSO, Lucknow (India) for record.

7.2 The manufacturer shall list out the special tools, gauges and testing instruments/kits that will be required for inspection, adjustment and maintenance of the transformer. Individual prices for the items included in the above list shall also be furnished. The exact quantities of tools, gauges and testing instruments /kits to be procured initially shall be decided at the time of contract for the interrupters based on the above price list.

8.0 Training of Indian Railway's personnel

The offer shall include the training of two personnel of the Indian Railways free of cost at the manufacturer's works in India or abroad and at the maintenance depots/workshops on a Railway system or other public utility where transformers of similar/identical design are in operation. The total duration of training for each personnel shall be 2 weeks of which approximately one week will be at the manufacturer's works and one week on a Railway system or other public utility. The training should cover Installation procedures, maintenance procedures, familiarisation with accessories and features etc. If the country of the manufacturer is not India, the cost of travel to that country and back will be borne by the Indian Railways. Other details shall be settled at the time of finalizing the contract/Purchase Order.

9.0 Packing, Delivery, Commissioning etc.

9.1 The transformer shall be transported depending upon the transport facilities available for the route i.e. by rail or truck or ship.

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9.2 The transformer shall be dispatched with its core and windings in the transformer tank filled with oil and the space above the oil filled with dry air or nitrogen gas at a pressure slightly above atmospheric pressure. However, if there are limitations on account of weight, the tank shall be filled with dry air or nitrogen gas under pressure and the oil for the first filling shall be supplied separately in steel drums. In case the tank is filled with dry air or nitrogen gas air the temperature and pressure at the time of filling shall be marked conspicuously on the transformer.

9.3 All openings created on the tank by the removal of any items shall be closed with suitable blanking plates. All the parts, fittings and accessories such as conservator tank, bushings, silica gel breather, radiator, Buchholz relay, temperature indicators and other items shall be packed/crated separately along with a packing list/checklist in each crate containing the following particulars:

Crate No.	Description of item/ component in the crate	Approx. gross weight in kg	Approx. outside dimensions in mm

All the matching parts shall be identical with the transformer Sl. No. or Work Order No. to avoid any mismatching at the site.

9.4 The packing shall be done properly so that no damage occurs during transit.

9.5 All the parts, fittings and accessories for each transformer shall be so dispatched that they arrive at the site together to enable the erection of the complete without delay.

9.6 Necessary instructions for handling and storage of all items shall be included along with the packing lists.

9.7 In case of overseas supply, packing shall be seaworthy.

9.8 The transformer shall be erected and commissioned by the Purchaser. The successful tenderer/manufacturer shall invariably make available at the site the services of an engineer of his to ensure, by his continued presence, that the process of erection, testing and commissioning of the transformer is in accordance with established practices. For this purpose, prior intimation regarding the dates/period and locations at which the transformers are to be erected and testing/commissioning done shall be given by the Purchaser to the successful tenderer/manufacturer. No charges shall be payable by the purchaser to the successful tenderer/manufacturer for the services of his engineer in this regard.

9.9 If any transformer has been received at the site in a damaged condition and the opinion of the Railway's Engineer at the site it is required to be repaired at the successful tenderer/manufacturer's works, the transformer shall be taken back to the works promptly and after repair, all necessary tests including the routine tests shall be done on the complete transformer in the presence of and to the satisfaction of the Railway's Engineer before returning the transformer to site. Such tests are necessary to ensure that the quality of the workmanship during repairs is satisfactory and shall be done free of cost. Any tests, as decided by the Railway's Engineer at site shall also be conducted on the transformer at site free of cost.

10.0 Warranty

10.1 The manufacturer shall warrant that all equipments shall be free from defects and faults in design, material, workmanship, manufacture and are of the highest grade consistent with the established and generally accepted standards. The equipments are in full conformity with this specification and shall operate properly.

10.2 This warranty shall cover inspection of, payment for and acceptance of the equipment, but shall expire 30 (Thirty) months after the delivery at the ultimate destination in India, or 24 (Twenty Four) months from the date of commissioning and proving test of the equipment at ultimate destination in India, whichever period expires earlier, except in respect of complaints, defects and/or claims notified to the successful tenderer/manufacturer within 3(Three) months of the expiry of such date. Any approval or acceptance by the Purchaser of the equipment shall not in any way limit the manufacturer's liability.

10.3 The manufacturer's liability in respect of any complaint, defects and/or claims shall not be limited to the furnishing and installation of replacement of parts free of any charge or the repair of defective parts only to the extent that such replacement or repairs are attributable to or arise from faulty workmanship or material or design in the manufacture of the goods, provided that the defects are brought to the notice of the manufacturer within 3(Three) months of their being first discovered during the warranty period of 3(Three) months from the date of expiry of warranty period, or at the option of the Purchaser, to the payment of the value, expenditure and damage as hereafter mentioned

10.4 The manufacturer shall, if required, replace or repair the equipment of such portion thereof as is rejected by the Purchaser free of cost at the ultimate destination or the option of the Purchaser. The manufacturer shall pay the Purchaser value thereof at the contract price or in the absence of such equipment at a price decided by the Purchaser and such other expenditure and damages as may arise because of the breach of the conditions herein specified.

10.5 All replacement and repairs that the Purchaser shall call upon the manufacturer to deliver or perform under this warranty shall be delivered and performed by the manufacturer, promptly and satisfactorily and in any case within 2(Two) months of the date of advice to this effect.

10.6 If the manufacturer so desires, the parts that are removed may be taken over by him or his representative for disposal as he deems fit at the time of replacement with good parts. No claim whatsoever shall lie on the Purchaser thereafter for the parts so removed.

10.7 The warranty herein contained shall not apply to any material which shall have been repaired or altered by the Purchaser or on his behalf in any way without the consent of the manufacturer, to affect the strength, performance or reliability or to any defects to any part due to misuse, negligence or accident.

10.8 The decision of the Purchaser in regard to the manufacturer's liability and the amount, if any, payable under this warranty shall be final and conclusive.

11.0 Technical Data & drawings

The manufacturer shall furnish the following information along with the drawings-

11.1 Calculations for:

1. Temperature rise of winding at rated current.
2. Hot-spot temperature of the winding at 150% and 200% rated loads for 15 min and 5 min respectively.
3. Thermal withstand capacity of the windings for a short circuit of 3 seconds duration.
4. Mechanical forces in respect of the following as per IEEMA (Indian Electrical & Electronic Manufacturer's Association) formulae given in Annexure-2.
   - i Hoop stress in primary and secondary windings.
   - ii Compressive pressure in the radial spacers.
   - iii Internal axial compressive force.
   - iv Axial imbalance force.
   - v Radial bursting force.
   - vi Resistance to collapse.

vii Bending stress on clamping ring and densified wood.
viii Maximum allowable torque on pressure screws for coil clamping bolts at the time of tightening, if any.

5. Flux density with the characteristic curve.
6. Maximum value of inrush current.
7. No Load Losses
8. Load Losses
9. Short circuit current (for both symmetrical and asymmetrical shots)

11.2 Following detailed dimensioned drawings in sizes of 210mm x 297mm or any integral multiples thereof:-

1. Outline the general arrangement of the transformer indicating plan, front elevation, side elevation with all parts, fittings and accessories, electrical clearances as well as salient guaranteed particulars.
2. Internal arrangement of the transformer indicating line and neutral bushing lead connections, core-to-core-clamp earthing, core-clamp-to-tank earthing, core-clamp to core-base bolting, and the locking arrangement of the core & coil assembly with the tank.
3. Cross-sectional view of the core and windings with material specifications and makes.
4. Details of the pressure screws/oil dashpot/ coil clamping bolts or other devices and their location with materials specifications and makes.
5. Schematic view of the valves used on the transformer and the antitheft devices as to diagram.
6. Transport outline dimensional diagram.
7. General arrangement of the marshalling box indicating protection control equipment.
8. Wiring diagram of marshalling box.
9. Schematic diagram of protection and control circuits in a marshalling box with cable schedule.
10. Legend plate showing protection and control circuits for fitment in the marshalling box.
11. OIP Condenser Bushing for line & oil bushing for neutral side including cross-sectional view, shed profile and salient electrical and mechanical characteristics.
12. Type test report of the proposed make(s) of bushings, issued by government/NABL accredited laboratory.
13. Dimensional drawing, V-I characteristic and rating plate for bushing types of current transformers.
14. Terminal connector for line and neutral side bushing terminal.
15. Rating plate diagram of connections, both in English and Hindi versions.
16. Details of radiators.
17. Details of breather.
18. External cables run with cable schedule.
19. Any other drawings considered necessary by the manufacturer and/ or purchaser.

12.0 Clause-wise conformity, déviations etc.

12.1 The manufacturer shall specifically indicate in a statement attached with his offer, his compliance with each clause and sub-clause of this specification. A separate statement shall be attached with the offer indicating references to the clauses where the tenderer deviates therefrom together with detailed remarks/justification. If there are no deviations, a 'NIL' statement shall be attached.

12.2 Any deviation from this specification which the tenderer proposes to improve upon the performance, utility and efficiency of the equipment will be given due consideration, provided full particulars of the deviation with justification thereof are furnished, and are found acceptable by RDSO.

13.0 CAPITALISATION OF TRANSFORMER LOSSES

The capitalized value of transformer losses shall be as low as possible and commensurate with optimum no-load and load losses. The capitalized value shall be computed as detailed in Annexure -3 and furnished with the offer. Capitalized value calculated, as per Annexure-3 shall be added to the unit cost of the transformer for taking into consideration the cost of losses during its service life.

Annexure-1

1. Schedule of Guaranteed Performance, Technical and Other Particulars

SN	DESCRIPTION	UNIT	VALUE/ INFORMATION
1	2	3	4
A	**RATINGS/PARTICULARS**		
1.	Name of the manufacturer		
2.	Country of manufacture		
3.	Reference to specification based on which performance data is prescribed		
4.	Rated power	MVA	
5.	Rated Primary current at: i) Rated Load ii) 150% rated load for 15 min. iii) 200% rated load for 5 min.	 A A A	
6.	Rated Secondary current at: i) Rated Load ii) 150% rated load for 15 min. iii) 200% rated load for 5 min	 A A A	
7.	Rated voltage: i) Primary ii) Secondary (at no-load)	 kV kV	
8.	Rated frequency	Hz	
9.	Temperature rise above ambient temperature of 50°C: **1) Oil:** i)At rated load ii)At 150% rated load for 15 min iii)At 200% rated load for 5 min **2)Winding:** i)At rated load ii)At 150% rated load for 15 min iii)At 200% rated load for 5 min	 °C °C °C °C °C °C	
10.	Hot -spot temperature of winding over ambient temperature of 50 °C: i) At rated load ii) At 150% rated load for 15 min iii) At 200% rated load for 5 min.	 °C °C °C	
11.	Interval of time between two successive overloads after continuous working at full load, at maximum ambient temperature of 50°C: i)Between two consecutive overloads of 50% for 15 min ii)Between two consecutive overloads of which one is of 50% for 15 min and the other of 100% for 5 min	 Min. Min	
12.	No-Load current referred to primary side at rated frequency and at: i) 90% rated Voltage ii) Rated Voltage iii) 110% Rated Voltage	 A A A	
13.	Power factor of no-load current at Rated Voltage and rated frequency		
14.	Value of the inrush current at rated voltage on primary side, the secondary side being open circuited.	A	

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15.	Losses: (i) No-Load loss at rated frequency and at: (1) 90% rated voltage (2) rated voltage (3) 110% rated voltage (ii) Load loss (at 75 °C) with rated current and frequency: (iii) Total Losses at rated current and frequency:	 kW kW kW kW kW	
16.	Resistance voltages (at 75°C) at rated current and frequency	%	
17.	Reactance voltages (at 75°C) at rated current and frequency	%	
18.	Impedance voltage (at 75 °C) at rated current and frequency	%	
19.	Resistance (at 75 °C) of the primary winding	Ω	
20.	Resistance (at 75 °C) of the secondary winding	Ω	
21.	Reactance of winding	Ω	
22.	Regulation (at 75 °C) with rated current and at a power factor of: (1)Unity (2)0.8 lagging	 % %	
23.	Efficiencies: i) Efficiency (at 75 °C) at unity power factor at 1) 100% Load 2) 75% Load 3) 50% Load 4) 25% Load ii) Efficiency (at 75 °C) at 0.8 power factor lagging at 1) 100% Load 2) 75% Load 3) 50% Load 4) 25% Load iii) Percentage of rated load at which maximum efficiency occurs	 % % % % % % % % %	
24.	Ability to withstand short-circuit: i) Thermal ii) Dynamic	 s s	
25.	Thermal time constant (calculated) i) For primary and secondary windings with respect to oil at : 1) Rated current 2) 150% Rated current 3) 200% Rated current ii) Complete Transformer at rated current	 min min min min	
26.	Temperature gradient between oil and winding at: i) rated current ii) 150% rated current for 15 min. iii) 200% rated current for 5 min.	 °C °C °C	
27.	The temperature rise of oil: i) Calculated average temperature rise of oil at 1) Rated current 2) 150% rated current for 15 min. 3) 200% rated current for 5 min. ii) Estimated temperature rise of top oil at: 1) Rated current	 °C °C °C °C	

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	2)150% rated current for 15 min. 3)200% rated current for 5 min.	^{0}C ^{0}C	
28.	Details of core: i) Type of core ii) Flux density at rated voltage and frequency. iii) Flux density at 110% rated voltage and frequency. iv) Thickness of steel stampings v) Grade of core material and conforming specification. vi) Exciting VA/kg for core stampings at: 1) Flux density of 1.7 tesla 2) Flux density at rated voltage 3) Flux density at 110% rated voltage vii) Exciting VA/kg for the assembled core at: 1) Flux density of 1.7 Tesla 2) Flux density at rated voltage 3) Flux density at 110% rated voltage. viii) Type of insulation between core laminations ix) Type of joint between the core limbs and yoke.	 Tesla Tesla mm VA/kg VA/kg VA/kg VA/kg VA/kg VA/kg	
29.	Details of windings: i)Type of winding: 1) Primary 2) Secondary 3) Number of turns of the primary winding 4) Number of turns of secondary Winding 5) Number of parallel paths in the primary winding 6) Number of parallel paths in the secondary winding 7) Is interleaving of the winding adopted to ensure better impulse voltage distribution? 8) Are the insulation of end turns of winding reinforced? ii) Mode of connection (i.e. in series or in parallel) of the portions of the windings on the two limbs of the core, if applicable: iii) Dimensions of the copper conductor used in the winding: 1) Primary 2) Secondary iv)Current density at rated current: 1)Primary 2)Secondary v) Insulation used over the conductor (details of material and specification thereof) vi)Type of joints, if any, in the windings vii) Dielectric strength for windings: 1) Full-wave lightening Impulse withstand voltage: a) Line terminals 2)Lightening impulse chopped on tail withstand voltage: a) Line terminals 3)Separate source power frequency withstand voltage 4)Induced overvoltage withstand value	 Yes/No Yes/No mmxmm mmxmm A/mm^2 A/mm^2 kV peak kV peak kV kV	

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	viii) Minimum flashover distance to earth in oil of : 1) Winding to core 2) Winding to yoke 3) Winding to tank ix) Material used for coil clamping rings and specification thereof x) Can a Neutral Terminal be connected directly to Earth? xi) Magnitude of axial pre-compressive force on the winding xii) Calculated maximum axial thrust in the windings due to dead short at the terminals. xiii)Calculated short circuit forces: 1) Hoop stress in the primary winding 2) Hoop stress in the secondary winding 3) Compressive pressure in the radial spacers 4) Internal axial compressive force 5) Axial imbalance force 6) Resistance to collapse 7) Bending stress on the clamping ring 8) Radial bursting force xiv) Arrangement to maintain constant pressure on the windings xv) Maximum permissible torque on pressure screws for coil clamping at the time of tightening, if any.	 mm mm mm Yes/No T T kgf/cm^2 kgf/cm^2 kgf/cm^2 kgf kgf kgf kgf/cm^2 kgf Nm	
30.	Bushings: **i) Line terminal:** 1) Name of the manufacturer 2) Country of origin 3) Governing specification 4) Type designation (specify as to whether it is OIP condenser Bushing) 5) Voltage class 6) Rated current 7) Visible power frequency discharge voltage 8) Wet one-minute power frequency withstand voltage 9) Lightening impulse withstand voltage 10) Creepage distance 11) Weight of assembled bushing **ii) Neutral terminal:** 1) Name of the manufacturer 2) Country of origin 3) Governing specification 4) Type designation 5) Voltage class 6) Rated current 7) Visible power frequency discharge voltage 8) Wet one-minute power frequency withstand voltage 9) Lightening impulse withstand voltage 10) Creepage distance 11) Weight of assembled bushing	 kV A kV rms kV rms kV peak mm Kg kV A kV kV kV peak mm Kg	
31.	Bushing type current transformers: **i) line terminal:** 1) Name of the manufacturer 2) Governing specification 3) Transformation ratio		

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	4) Accuracy Class and rated Accuracy limit factor 5) Rated current 6) Rated output 7) Exciting current at the rated knee point voltage 8) Rated knee point voltage 9) Secondary winding resistance corrected to 75^{0}C 10) Short-time thermal current and duration **ii) Neutral terminal:** 1) Name of the manufacturer 2) Governing specification 3) Transformation ratio 4) Class of accuracy 5) Rated current 6) Rated output 7) Exciting current at the rated knee point voltage 8) Rated knee point voltage 9) Secondary winding resistance corrected to 75^{0}C 10) Short-time thermal current and duration **(iii) Line terminal for WTI:** 1) Name of the manufacturer 2) Governing specification 3) Transformation ratio 4) Accuracy Class 5) Rated current 6) Rated output 7) Short-time thermal current and duration	A VA mA V Ω kA, sec A VA mA V Ω kA, sec A VA kA,s	
32.	Insulating oil: i) Governing specification ii) Source of supply		
33.	Type of transformer tank		
34.	Details of radiators: i) Make and type ii) Type of mounting iii) Overall dimensions (LxWxH)	 mmxmmxmm	
35.	Details of Buchholz relay: i) Make and type ii) Governing specification iii) Provision of shut-off values on either side of the relay iv) Provision of alarm contact v) Provision of trip contact vi) Rated current of contacts	 Yes/No Yes/No Yes/No A	
36.	Details of winding temperature indicator: i) Make and type ii) Governing specification iii) Number of contacts provided iv) Rated current of contacts v) Dielectric withstands the value of contacts.	 A kV	
37	Details of oil temperature indicator: i) Make and type		

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	ii) Governing specification iii) Number of contacts provided iv) Rated current of contacts v) Dielectrics withstand value of contacts	 A KV	
38.	Details of magnetic oil level gauge: i)Make and type ii) Governing specification iii)Diameter of dial iv)Number of contacts provided v)Rated current of contacts vi)Dielectric withstand value of contacts	 mm A kV	
39.	Details of pressure relief device: i) Make and type ii) Governing specification iii) Does it rest itself?	 Yes/No	
40.	Bimetallic terminal connectors: **i)Line terminal:** 1. Source of supply 2. Governing specification 3. Type 4. Rated current 5.Temperature rise over an ambient temperature of 50^0C while carrying rated current 6. Short time current and duration **ii)Neutral terminal:** 1.Source of supply 2.Governing specification 3.Type 4.Rated current 5.Temperature rise over an ambient temperature of 50^0C while carrying rated current 6.Short time current and duration	 A ^{0}C kA, sec. A ^{0}C kA, sec	
41.	Acoustic sound level at a distance of 1 m, when energised at rated voltage and rated frequency without load.	dB	
42.	Partial discharge value at 1.58 Ur/$\sqrt{3}$ kV rms	pC	
43.	Weights and dimensions: i)Net weight of core ii)Net weight of copper: a) Primary winding b) Secondary winding iii) Net untanking weight of core, frame and coils. iv)Net weight of insulating oil v)Volume of insulating oil vi)Total weight of cooling equipment vii) Total weight of transformer without oil. viii)Total shipping weight of complete transformer including all detachable parts, fittings and assemblies ix)Shipping weight of the largest package x) Crane lift (excluding slings) for untanking core and coils xi) Crane lifts (excluding slings) for removal or primary side bushings.	 kg kg kg kg kg L kg kg kg Kg mm mm	

	xii) Dimensions of the complete transformer including all parts, fittings and accessories: 1) Overall length 2) Overall breadth 3) From the rail level to the topmost point xiii) Minimum thickness of steel plate/ sheet used: 1) Bell /Top cover mounted Tank 2) Tank top 3) Tank bottom 4) Conservator 5) Radiator 6) Marshalling box. xiv) Overall shipping dimensions of the largest package (LxBxH) xv) Mode of transportation of transformer unit (filled with Oil/nitrogen gas)	 mm mm mm mm mm mm mm mm mm mm x mm x mm	
B.	**Other Particulars**		
44.	Is the transformer tank fitted with lifting pads? If yes what is the number of pads?	Yes/No	
45.	What is the number of inspections covers provided?	Nos.	
46.	Are conduits/trays provided for cable run?	Yes/No	
47.	Is the core electrically connected to the tank?	Yes/No	
48.	Will the gaskets to be used in the transformer give trouble-free service for at least 12 years? If not, indicate the life.	Yes/No	
49.	Are the magnetic shunt pockets of core lamination provided inside the tank surface to absorb stray flux? If yes, the material specification shall be furnished	Yes/No	
50.	What is the number of radial spacers used in the winding		
51.	What is the number of joints provided in the winding		
52.	Are the spacers/blocks/angle rings of pre-compressed press boards? If not, indicate the material with specification.	Yes/No	
53.	Are arrangements made to ensure automatic constant pressure on the coils? If no give the reasons.	Yes/No	
54.	Are the closed slots provided on the outermost winding for locking the vertical strips? If no give the reasons	Yes/No	
55.	What is the periodicity for tightening the coil clamping arrangement	Years	
56.	What are the calculated short circuit currents for: i)Symmetrical: 1)Primary winding 2)Secondary winding. ii)Asymmetrical: 1)Primary winding 2) Secondary winding.	 A A A A	
57.	What is the over-flux withstand capability of the transformer (max. permissible limit of flux density)?	Tesla	
58.	Are windings pre-shrunk?	Yes/No	
59.	Have the details of the drying cycles of the coils/coil assembly including final tightening values of pressure, temperature and degree of vacuum at various stages of drying been furnished?	Yes/No	
60.	Are arcing horns provided for line and neutral bushings?	Yes/No.	
61.	Is a test tap provided in the line bushings?	Yes/No	

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62.	Is the porcelain housing of the bushings of single-piece construction?	Yes/No	
63.	Is the shed profile of the porcelain of the bushing free from under the ribs but has a lip?	Yes/No	
64.	Is the bushing type current transformer of low reactance type?	Yes/No	
65.	Is clause by Clause" Statement of compliance" attached?	Yes/No	
66.	Is the "Statement of deviation" if any attached?	Yes/No	
67.	Is the Buchholz relay provided with two shut-off valves, one on either side?	Yes/No	
68.	Are fasteners of 12 mm diameter and less exposed to the atmosphere of stainless steel to grade X04 Cr 17 Ni 12 Mo2 to IS 1570 Part-V or equivalent /better?	Yes/No	
69.	Are the fasteners of more than 12 mm diameter exposed to the atmosphere of stainless steel or MS hot dip galvanized?	Stainless steel/hot dip galvanized	
70.	Are test certificates for tests as per clause 6.3 attached?	Yes/No	
71.	Are all the calculations required as per clause 11.1 attached?	Yes/No	
72.	Are all the drawings required as per clause 11.2 attached?	Yes/No	
73.	Is adequate space provided in the marshalling box for housing the wiring and components /equipment?	Yes/No	
74.	Is the warranty as per clause 10.0?	Yes/No	
75.	Is the list of spares furnished or not?	Yes/No.	

Annexure-2

FORMULA FOR CALCULATION OF SHORT CIRCUIT MECHANICAL FORCES

Nomenclature

Ai=Total supported area of the inner radial spacer in cm^2.
Ao=Total area of the outer radial spacer in cm^2.
At=Area of tie rods in cm^2.
a=per unit turns, out of the circuit, in the winding.
bi=Thickness of inside winding conductor in cm.
Dmi=Mean diameter of inside winding in cm.
di=Diameter of the inner winding conductor in cm.
δ=Current density in A/cm^2
E=Modulus of Elasticity of conductor in kg/cm^2
ez=per unit impedance
Fa=Axial imbalance force due to tapping within winding in kgf.
Fc=Internal axial compression force in kgf.
Fr=Radial bursting force in kgf.
hw=Winding height in cm.
Iph=Rated phase current in A.
Isc=First peak value of asymmetrical short circuit current in A.
N=Number of turns per phase in the circuit.
Ns=Number of supports to be provided in the winding.
Nt=Number of tie rods.
Pi=Compressive pressure in the inner radial spacers in kg/cm^2.
Po= Compressive pressure in the outer radial spacers in kg/cm^2.
Pt=Tensile stress in the rods in kg/cm^2.
R=Sum of the resistance of the transformer and system in ohm.
Rdc=dc resistance of the phase at 75^0c in ohm.
Sn=Rated kVA.
X=Sum of he reactance of the transformer and system in ohm.
m= Hoop or compressive stress in kg/cm^2.

Scope

The calculation methods discussed below would be applicable to two winding transformers, having core-type construction and concentric winding with taps placed within the body of the outer winding.

1. **Calculation of first peak value of Asymmetrical short circuit current.**

Isc=k√2(Iph/e)A.

k√2 values are appended below(Ref. IS:2026 Part-I Clause 16.11.2)

X/R=	1	1.5	2	3	4	5	6	8	10	≥14
k√2=	1.51	1.64	1.76	1.95	2.09	2.19	2.27	2.38	2.46	2.55

Note: For other values of X/R between 1 and 14, the factor k√2 may be determined by linear interpolation.

2. **Calculation of Asymmetrical short circuit Ampere-turns:** N x Isc

3. **Hoop Stress**

$\sigma m=(kxIph^2 \times Rdc) / (hw \times ez^2)$ kg/cm^2

$k\ (Cu)=0.03(k\sqrt{2})^2/(2.55)$

$k\sqrt{2}$ as derived from item 1 above.
The figure so calculated shall be less than 1250kg/cm^2.

Note: The value of $(Iph^2xRdc)/hw$ referred to inner or outer winding shall be incorporated in the formula depending upon whether inner or outer winding stress is required to be calculated.

4. **Radial Bursting force**

$Fr =(2\pi \times \sigma m \times Iph \times N) / \delta$ kg.

5. **Number of supports to be provided in winding (Flat conductor)**

$Ns= (Dmi\ x\sqrt{12}x\sqrt{\sigma m})/(bi \times \sqrt{E})$

Where, $E=1.13x10^6$ kg/cm^2.

6. **Number of supports to be provided in winding (Round conductor)**

$Ns=(8x\ Dmi \times \sqrt{\sigma m}) / (di \times \sqrt{\pi E})$
σm as derived from item 3 above.

7. **Calculation of internal axial compression**

$Fc=(-)\ (34Sn)/\ (ez \times hw)$ kg.

Note: 1/3 Fc is acting on outer winding.
2/3 Fc is acting on the inner winding
(-) Indicates that force is acting towards the centre.

8. **Calculation of Axial imbalance force due to tapping within the windings**

$Fa=(a/2) \times (NIsc)^2x10^{-7}$kg.

Note 1 : If tapping is divided into two groups between the centre and the end of the windings, the force will be reduced to 1/4th of the figure obtained by the above formula.

Note 2 : If the compensating gap is provided in the untapped winding, the force will be half of that calculated above.

Note 3 : For multi-layer single coil design and other modes of Ampere-turn balancing actual unbalance Ampere-turns can be determined by residual Ampere-turn diagram.

9. **Calculation of Maximum compressive pressure in the radial spacers**

$Pi=(Fa+2/3Fc)/Ai$ kg/cm^2

$Po=(Fa+1/3Fc)/Ao$ kg/cm^2

Note: The value calculated should not exceed 300kg/cm^2 for normal Calendered press boards and 500kg/cm^2 for pre-compressed press boards.

10. **Calculation of tensile stress in the tie rods**

$Pt=(Fa - 1/3Fc)/(Nt \times At)$ kg/cm^2.
Fa as derived from item - 8 above & Fc as derived from item - 7 above.
Note: The value calculated should be less than 2500kg/cm^2 for Mild steel tie rods.

11. Calculation of Resistance to Collapse

(Applicable only to disc winding using rectangular conductor)

$F(Crit)=\{1.5E(Iph)^2x\ (m)\ /\ bo\ x\ Dmo\ x\ \delta^2\ x\ 10^8\}\ +\ \{(450xAox\delta xb^3)\ /\ Iph\}\ t$, Where:

E =Modulus of Elasticity of conductor in kg/cm^2

m =Number of turns x number of Parallel Conductors per coil

Iph =Rated phase current in A.

bo = Thickness of outer winding conductor in cm

Dmo =Mean diameter of outer winding in cm.

δ = Current density in A/mm^2

Ao =Total supported area of the outer radial spacer in cm^2.

12. Calculation of most highly Stressed Coil: (Applicable for tapped winding only)

$fa=(0.733\ Q\ x\ Fr\ x\ \log_{10}(2aNc+1)\ t$, where:

Q =Turns per coil adjacent to tapped out of coil, expressed as fraction of total turns in the limb.

Fr =Radial force as derived from item - 4 above.

A = Per unit number of turns out of circuit.

Nc = Number of coils per limb.

13. Calculation of 'W' i.e. mechanical loading per centimeter of periphery

$Wl = (fa)/(\pi xDm)\ kg/cm$, Where :

Fa = Value as derived from item-12 above in kg.

Dm = Mean diameter of tapped winding in cm.

Add 25% extra for the concentration of force and assume W = 1.25Wl.

$\sigma max = (WxL^2xY)\ /\ (12xIo)\ kg/cm^2$, where :

L =Span in cm = $\{(\pi xDm\ /\ ns)\ x\ bs\}$

ns =Number of spacers.

bs = Width of spacer in cm

Y = Maximum distance from the neutral axis for conductor in cm i.e. axial height of the winding across the neutral axis divided by 2.

Io =Moment of inertia of the coil i.e. $bd^3/12$

b =Radial depth of coil in cm.

d =Axial height of coil in cm

The maximum permissible value for σmax is $1250kg/cm^2$.

14. Calculation of bending stress on clamping rings: The stress on circular rings is as below:

$\sigma max=\{(6\pi\ x\ F\ x\ D)\ /(8\ b\ x\ t^2x\ n^2)\}\ t/cm^2$, where :

F =Total axial force (Fa-1/3Fc) in t.

Fa =Value as derived from item - 8 above.

Fc = Value as derived from item - 7 above.

D = Diameter of ring in cm.

b =Width of ring in cm.

t =Thickness of ring in cm.

n =Number of jacking points.

The maximum permissible value for max is 1100kg/cm if a circular Perma wood ring is used.

Annexure-3

CAPITALISATION OF TRANSFORMER LOSSES

The following formula shall be used for the purpose of calculating the present worth of the transformer after taking into account the capitalization of its losses.

$$K=D\ \{(1+i)^n-1\}\ /\ i(1+i)^n$$

Where

K = Present worth of transformer in Rupees.

D = Annual cost of combined no-load and load losses in Rupees.

i = rate of compound interest on unit price of transformer @ 12% per annum.

n = Life of transformer

Substituting the value of D, which is:

$$D= \{(I+F^2C)\ x365x24xT\}/1000$$

Where,

I =Maximum No-load loss in watt.

C =Maximum Load - loss in watt

F =Load factor

T =Tariff in Rupees

Assuming values of n as 50 years, F as 50% and T as Rupees **4.25** per kWh, the value of K is,

$$K =37.23(I+0.25C)\{(1+0.12)^{50}-1\}/0.12(1+0.12)^{50}$$
$$=\mathbf{309}(I+0.25C).$$

Annexure-4

Overall Dimensions of the Autotransformer

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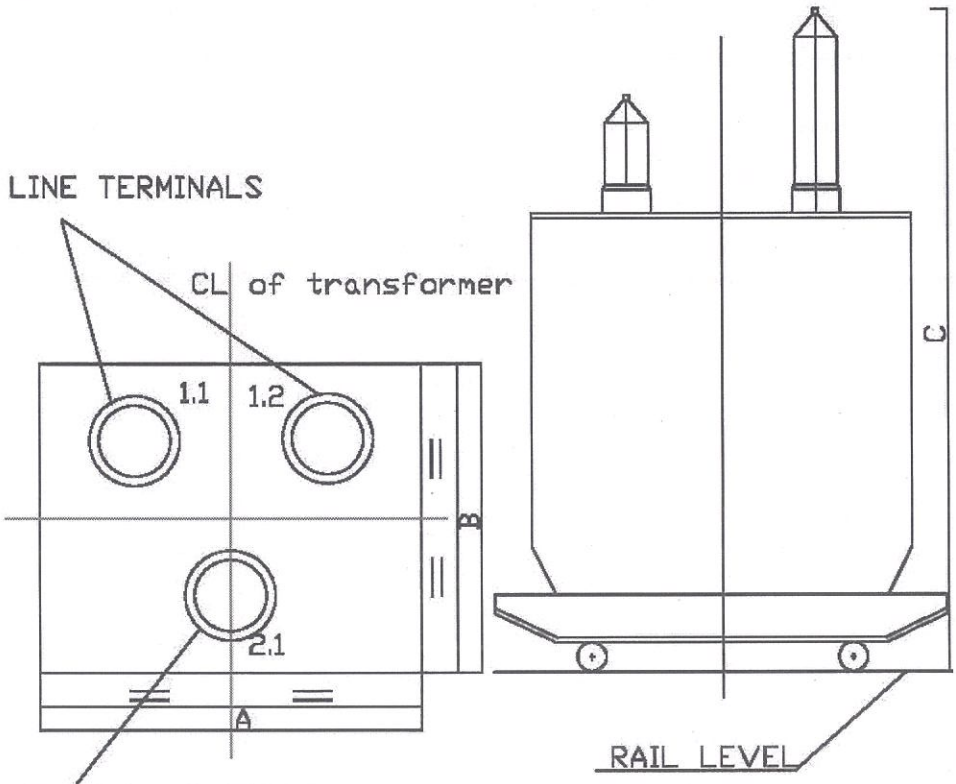


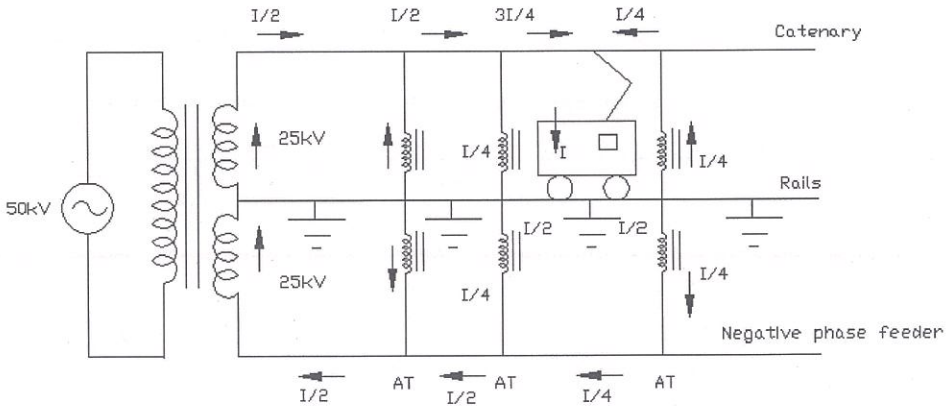
REF	DIMENSIONS IN MM		
	8MVA	12.3MVA	16.5MVA
A	4000	4500	5000
B	3000	3500	4000
C	4000	4500	4800

NOTE: THE ABOVE DIMENSIONS ARE FOR THE OVERALL DIMENSIONS INCLUDING RADIATORS MOUNTED ON THE TANK

OVERALL DIMENSIONS OF 8, 12.3 & 16.5 MVA , 55/27.5KV AUTOTRANSFORMER

Annexure-5

Principle of 'AT' feeding System



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