भारत सरकार - रेल मंत्रालय
अनुसंधान अभिकल्प और मानक संगठन
मानक नगर, लखनऊ- 226 011

Telephone: 2465763 (O).
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Fax : 91-0522-2465763
E-mail:psti.ti@rdso.railnet.gov.in

संख्या/No. RDSO-TI0LKO(PSI)/19/2020-O/o PED/TI/RDSO **दिनांक/Date: As signed.**

1.	M/s Meiden T&D (India) Limited, SEZ, Menakuru, SPSR Nellore District, Naidupeta Andhra Pradesh – 524126	gagandeep.tandon@meiden.in
2.	M/s Toshiba Transmission & Distribution Systems (India) limited, 1104, Surya Kiran building, 19, K. G. Marg, Cannaught Place, New Delhi-110001	rajib.chaudhary@toshiba-ttdi.com
3.	M/s Hitachi Energy India Limited Power Transformer Factory, Maneja Works Vadodara, Gujarat - 390013, India	sukhamnder.singh@hitachienergy.com, shailendra.p.sing@hitachienergy.com
4.	M/s CG Power and Industrial Solutions Ltd., Power Transformer Division T-3 29, 31-32 New Industrial Area, Mandideep Raisen, Madhya Pradesh - 462046, India,	akhilesh.gupta@cgglobal.com, nidhi.tiwary@@cgglobal.com,
5.	M/s Kanohar Electricals Limited, Rithani, Delhi Road, Meerut-250103	jagbir.singh@kanohar.com
6.	M/s Bharat Heavy Electricals Limited, P. O. BHEL, Jhansi (UP)-284129	rodbhellko@hotmail.com
7.	M/s Siemens Limited, Plot No.-78, JIL Jagatjit Industrial limited, Shaheed RIPON, Katyal marg sector, Gurugram Haryana -122015	debraj.choudhary@siemens.com
8.	M/s Vishvas Power Engg. Services Pvt. Ltd., Plot No. K-5, Five Star Industrial Area MIDC, Butibori, Nagpur Nagpur, Maharashtra - 441122, India	vishvaspowercmc@gmail.com
9.	M/s High – Volt Electricals Pvt. Limited, J-46 /J-47, MIDC Tarapur Industrial Area, Boisar, Distt. Palghar, Maharashtra – 401506	viraldesai@highvolt.in
10.	M /s TMC Transformers India Private Limited, Sur.No.26 1/2, Part B, Village Khandiwada (ASOJ), Vadodara-Halol Highway VADODARA,Gujarat - 391510	tkmohan@tmc-india.com
11.	M/s Shree Abirami Enggineering Works Private Limited, SAEW Unit-2, Survey No 22/1 & 22/2, Sriperumbudur Kodambakkam High Road, Kanchipuram, Tamil Nadu -602105,	md@abiramiengg.com
12.	M/s Technical Associates Limited, B-7 Eldeco Sidcul Industrial Park Sitarganj U.S. Nagar Uttarakhand Sitarganj, Uttarakhand - 262405, India	eproc@techasso.com
13.	M/s Transformers & Rectifiers India Limited, Survey No. 427 P/3-4 and 431 P/1-2, Sarkhej- Bavla Highway, Village Moraiya, Taluka Sanand, Dist. Ahmedabad Gujarat - 382213, India	Siddharth.dixit@transformerindia.com

विषय/Sub: Standard of Transformer Oil to be used in Traction Transformers of Indian Railways.

संदर्भ/Ref: (i) This office letters of even no. dated 02.12.2024 & 13.12.2024.
(ii) Core letter no. CORE-HQ0ELEC(MP)/4/2022-O/o CAO/CORE/PRYJJ dated 14.11.2024.

*****

Vide letters referred above, it was advised to refer the Standard of Transformer Oil to be used in Traction Transformers as 'Type A of IEC: 60296', appearing in the **CLW vendor directory** with **item ID**: **2100653**. Accordingly, the vendors appearing in the CLW Vendor Directory against this item, are to be referred for the sources of Transformer Oil.

2. Further, following A&C slips of the respective specifications of the Transformers w.r.t. change in standard of Inhibited Mineral Insulating Oil, are also enclosed herewith, for reference.

SN	Specification No.	Description of Specification	A&C Slip No.
i.	TI/SPC/PSI/AUTOTR/1200	Specification for 8 MVA, 12.5MVA & 16.5MVA 55kV/27.5kV Autotransformer	A&C slip No. 01
ii.	TI/SPC/PSI/TRNPWR/4200	Specification for 21.6MVA & 38/53/63MVA Single Phase Dual LV Winding Traction Power Transformer	A&C slip No. 01
iii.	TI/SPC/PSI/TRNPWR/ 5200	Specification for 54MVA & 60/84/100MVA Scott	A&C slip No. 02

	with A&C slip No. 01	Connected Traction Power Transformer	
iv.	TI/SPC/PSI/TRNPWR/3201	Specification for 13.5/18.9 MVA, 21.6/30.24 MVA, 30/42MVA & 40/56 MVA Single Phase Traction Power Transformer	A&C slip No. 01
v.	TI/SPC/PSI/AUTOTR/0091	Specification for 50/75/150 MVA, ONAN/ONAF/ OFAF, 220/ 132 kV, 3-Phase Oil Immersed Type Auto Transformer.	A&C slip No. 01
vi.	TI/SPC/PSI/CT/0210	Specification for Current Transformers for Railway AC Traction Substation	A&C slip No. 01
vii.	TI/SPC/PSI/PT/0210	Specification For 220kV or 132kV or 110kV or 66kV or 25kV Potential Transformer	A&C slip No. 01
viii.	ETI/PSI/15	Specification For 5kVA, 10kVA, 25kVA & 50kVA Auxiliary Transformer.	A&C slip No. 01
ix.	ETI/PSI/15A with A&C slip No. 01	Specification For 100kVA Auxiliary Transformer.	A&C slip No. 02

2. This is for your information and further necessary action at your end, please.

This is issued with the approval of the Competent Authority (PED/TI).

Digitally Signed by
Jitendra Kumar
Date: 30-12-2024 17:42:21
Reason: Approved

(Jitendra Kumar)
Director/TI-3
For Director General (TI)

संलग्नक: As stated above.

Copy to:

The Principal Chief Electrical Engineer,

- **i.** Central Railway, Statin Building, Mumbai CST – 400 001.
- **ii.** Eastern Railway, Fairlie Place, Kilkata-700 001.
- **iii.** East Central Railway, Hajipur-844 101.
- **iv.** East Coast Railway, hubaneshwar-751 023.
- **v.** Northern Railway, Baroda House, New Delhi - 110 001.
- **vi.** North Central Railway, Prayagraj-211 015.
- **vii.** North Eastern Railway, Gorakhpur-273 012.
- **viii.** North Frontier Railway, Mailgaon - 781 011.
- **ix.** North Western Railway, Jaipur – 302 017.
- **x.** Southern Railway, Park Town, Chennai- 600 003.
- **xi.** South Central Railway, Railnilayam, Secunderabad-500 371.
- **xii.** South Eastern Railway, Garden Reach, Kilkata-700 043.
- **xiii.** South East Central, Railway, ilaspur-495 004.
- **xiv.** South West Railway, DRM's Office, Hubli-580 028.
- **xv.** Western Railway, Churchgate, Mumbai-400 020.
- **xvi.** West Central Railway, Jabalpur- 482 001.
- **xvii.** Konkan Railway, Belapur Bhavan, Sectir-11, CBD Belapur, Navi Mumbai 400614.

2. Chief Administrative Officer, CORE, Prayagraj-211001, e-mail: ceehq.core@gmail.com

3439394/2024/O/o PED/TI/RDSO

Addendum & Corrigendum Slip No. 01 to the RDSO's Technical Specification No. TI/SPC/PSI/TRNPWR/4200 (02/2021) for 21.6 MVA & 38/53/63 MVA Single Phase Dual LV Traction Power Transformer.

*****

1. Standard of Insulating Oil mentioned as "IS 335:2018 (Type-II)" at Para No. 4.1-2 and 6.2.1.1 is replaced with "IEC: 60296 (Type A)".

2. First sentence of the Para No. 3.6 mentioned as "The transformer shall be supplied with new Inhibited Mineral Insulating Oil conforming to IS: 335:2018 (Type-II) and the additional requirements stipulated under clause 6.3.8.9" is replaced with "The transformer shall be supplied with new Inhibited Mineral Insulating Oil conforming to IEC: 60296 (Type-A).

3. Last sentence of the Para No. 3.6 mentioned as "For the sources of Insulating Oil, refer RDSO Vendor Directory available on RDSO website" is replaced with "For the sources of Insulating Oil, refer CLW Vendor Directory (item ID: 2100653) available on IREPS website."

4. Existing description of Para No. 6.3.8.9, Sub Para 6.3.8.9.1 & 6.3.8.9.2 are deleted and read as below:

   "Insulating Oil
   Inhibited Mineral Insulating Oil as per IEC: 60296 (Type-A) shall be used"

******

Dhruv 30.12.2024	30/12/24	Kumar 30/12/24
(Dhruv Maurya)	(Ramesh Kumar Pal)	(Jitendra Kumar)
JE/TI	ADE/TI-3	DTI-3

File No.RDSO-TI0LKO(PSI)/30/2020-O/o PED/TI/RDSO
Government of India,
Ministry of Railways
Research Designs & Standards Organisation,
Manak Nagar, Lucknow- 226 011
Telephone: 2465763 (O).
42805(Off.)
Fax : 91-0522-2465763
E-mail:dti.psi.rdso@gmail.com

Date: 03.02.2021

To,

1. The Principal Chief Electrical Engineer,
   - (i) Central Railway, Station Building, Mumbai CST – 400 001.
   - (ii) Eastern Railway, Fairlie Place, Kolkata-700 001.
   - (iii) East Central Railway, Hajipur-844 101.
   - (iv) East Coast Railway, Bhubaneshwar-751 023.
   - (v) Northern Railway, Baroda House, New Delhi - 110 001.
   - (vi) North Central Railway, Allahabad-211 015.
   - (vii) North Eastern Railway, Gorakhpur-273 012.
   - (viii) North Frontier Railway, Mailgaon - 781 011.
   - (ix) North Western Railway, Jaipur – 302 017.
   - (x) Southern Railway, Park Town, Chennai- 600 003.
   - (xi) South Central Railway, Railnilayam, Secunderabad-500 371.
   - (xii) South Eastern Railway, Garden Reach, Kolkata-700 043.
   - (xiii) South East Central, Railway, Bilaspur-495 004.
   - (xiv) South West Railway, DRM's Office, Hubli-580 028.
   - (xv) Western Railway, Churchgate, Mumbai-400 020.
   - (xvi) West Central Railway, Jabalpur- 482 001.
   - (xvii) Konkan Railway, Belapur Bhavan, Sector-11, CBD Belapur, Navi Mumbai 400614.

2. Chief Administrative Officer, CORE Allahanbad-211001, e mail: ceehq.core@gmail.com

Sub: Specification of Traction Power Transformers of 2X25kV system.

The specification of the Traction Power Transformer & Autotransformer for application in 2X25kV System has been approved by this office and details of these are as below:

SN	Specification no.	Description
1.	TI/SPC/PSI/ TRNPWR/5200	Specification for a) 54MVA, ONAN 220kV/2X(2X27)kV Scott Connected Traction Power Transformer b) 60/84/100MVA, ONAN/ONAF/OFAF, 220kV/2X55kV or 132/2X55kV or 110/2X55kV or 66/2X55kV Scott Connected Traction Power Transformer
2.	TI/SPC/PSI/ TRNPWR/4200	Specification for a) 21.6MVA 220kV/2X27kV or 132kV/2X27kV or 110 kV/2X27kV or 66kV/2X27kV, Single Phase Dual LV Traction Power Transformer. b) 38/53/63MVA, ONAN/ONAF/OFAF 220kV/2X27.5kV or 132kV/ 2X27.5kV or 110kV/2X27.5kV or 66kV/2X27.5kV, Single Phase Dual LV Traction Power Transformer
3.	TI/SPC/PSI/ AUTOTR/1200	Specification for 8MVA, 12.3MVA & 16.5MVA, ONAN, 55kV/27.5kV Autotransformer

2. The approved copy of the said specifications has been uploaded on the railsaver (www.railsaver.gov.in) for reference of Zonal Railways.

3. This is for your information please and is issued with approval of the competent authority.

03/02/21

(Gyan Prakash Katiyar)
Director TI-3
For Director General (TI)

Encl: NIL.

Copy to: ED/EEM, Railway Board – For kind information please.

कर्षण संस्थापन निदेशालय
TRACTION INSTALLATION DIRECTORATE

सत्यमेव जयते

भारत सरकार, रेल मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION FOR 21.6MVA & 38/53/63MVA Single Phase Dual LV Traction Power Transformer Specification No. TI/SPC/PSI/TRNPWR/4200

This specification supersedes the specification no. ETI/PSI/123 (09/93) with A &C slips no. 2

ISSUED BY

TRACTION INSTALLATION DIRECTORATE
RESEARCH DESIGNS AND STANDARDS ORGANISATION
(MINISTRY OF RAILWAYS)
MANAK NAGAR, LUCKNOW-226 011

Technical specification for

(a) 21.6MVA 220kV/2X27kV or 132kV/2X27kV or 110 kV/2X27kV or 66kV/2X27kV, Single Phase Dual LV Traction Power Transformer.

(b) 38/53/63MVA, 220kV/2X27.5kV or 132kV/2X27.5kV or 110 kV/2X27.5kV or 66kV/2X27.5kV, Single Phase Dual LV Traction Power Transformer

Specification No. TI/SPC/PSI/TRNPWR/4200

Amendment number	Amendment /Revision	Total pages (including annexure)	Date of issue
0	• Specification no. ETI/PSI/123 (09/93) with A &C slips no.1 & 02 revised. • Rating of 38/53/63MVA included.	60	02.02.2021
	Prepared by	Checked by	Approved by
Signature			
Date	02.02.2021	02.02.21	2/2/21
Designation	SSE/TR	Dir TI-III	EDI TI

INDEX

1.0 Scope:

1.1 This specification supersedes the specification no. ETI/PSI/123(09/93) with A &C slips no. 1 & 2.

1.2 This specification applies to the 21.6MVA, ONAN, 220kV/2X27kV or 132kV/2X27kV or 110 kV/2X27kV or 66kV/2X27kV & 38/53/63MVA ONAN/ONAF/OFAF, 220kV/2X27.5kV or 132/2X27.5kV or 110/2X27.5kV or 66/2X27.5kV , Single Phase Dual LV Traction Power Transformer for Autotransformer (AT) feeding system for installation in Indian Railway's Traction Sub-Stations, which may be manned or unattended type.

1.3 It is to be noted that "The make in India Policy of government of India shall be applicable."

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 dated 18.01.2021 (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 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, catenary wire and feeder wire is steeped 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 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 in 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 drop in feeder circuit.
(b) Large spacing between traction sub-stations.
(c) Less interference to 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 is 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 third remains as stand by. Thus two single phase transformers which feed the OHE constitute an open-delta connection (alternatively, referred as V-connection) on

the three phase transmission network. The Scott-connected transformer and V-connected single phase transformers are effective in reducing voltage imbalance caused by the traction loads on the transmission network of the Electricity Board. The spacing between adjacent sub-station is normally between 70 to 100 km.

1.6.1.4 In case of V Connected and 54MVA Scott Connected Transformers, One outer side terminal of the secondary windings of traction transformer is connected to the catenary, the other outer side terminal being 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 case of 60/84/100MVA Scott Connected Transformer, there are one M phase and one T phase secondary and these are connected to autotransformer of which 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 in 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 wrong phase coupling of power supply, a dead zone known as 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) as stand by. 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 condition) and two paralleling interrupters. In case of fault in the OHE, the corresponding feeder circuit breaker of the TSS trips to isolates it.

1.6.1.7 A figure showing the principle of AT feeding system is placed at Annexure-6.

1.6.2 PROTECTION SYSTEM

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

a. Differential protection.
b. IDMT over current protection on HV & LV sides.
c. Instantaneous over-current protection on 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 a number of vertical dropper wires, usually at regular intervals (the contact wire and catenary wire together being referred as 'catenary' or 'catenary wire'.

b. A feeder wire of standard all Aluminium Conductor (size 19/3.99mm) of 240 mm^2 section.

1.6.4 Traction Power Transformer – General Data

The Traction Power Transformer is either single phase of 21.6 MVA (ONAN) rating or Scott-Connected of 54MVA (ONAN) rating.

1.6.5 Nature of Traction Load on the OHE System

1.6.5.1 Traction load is of frequently and rapidly varying nature and may fluctuate between no load and over loads. The TSS equipment is subject to earth faults/short circuits caused by failure of insulation, snapping of OHE touching the earth, wire dropped by bird connecting the OHE to earth/overline structure and miscreant activity. On an average number of faults/short circuits per month is about 40, but in exceptional cases the number could be 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 operation of the distance, delta-I and instantaneous over current 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 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)

1.6.5.4.1 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.

1.6.5.4.2 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 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 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.

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 30^0C, 45^0C and 85^0C. The oil level indicator shall be so designed and mounting that the oil level is clearly visible to an operator standing on the ground. Oil level gauge shall also have the provision of the low and high fluid level alarms.

1.7.3 **Silica gel breather:** Conventional type silica gel breather or self-dehydrating type silica gel breather to be provided.

(a) Conventional type: It shall be complete with oil seal and connecting pipes. The connecting pipes shall be secured properly. The container of the silica gel breather shall be of transparent flexi glass or similar material suitable for outdoor application. Orange Silica Gel (round balls 2 to 5mm) with quantity of two DTO-8 silica gel connecting with flanged mounting two pipes control through two different valves as per DIN:42567 & IS:3401 to be provided.

(b) Self-Dehydrating type: The breather shall be able to automatically dehydrate the own silica gel 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. Control box degree of protection shall be at least IP55. The type pest 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 input supply of 230V AC, 50 Hz. The silica gel type, quantity and valve shall be as mentioned in (a) above.

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. Shroud Pressure relief Device will be used and have provision of discharge of oil from PRD to safe place by closed pipeline. This avoids hazards of fire and it is safe to persons working near Transformer & it is environmental friendly.

(b) Smart PRD: Along with the conventional features, the smart PRD shall be capable of continuously indicating the pressure in main tank through 4-20mA analog communication. The PRD shall have provision of digital communication through Modbus or similar protocol. This shall be suitable for integration with SCADA if required. Also, PRD should be capable of giving soft alarm in 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 of 50mm size and suitably baffled to reduce aereation of oil. The valves shall be flanged to seat 40 mm adopter threaded to thread size P 1 - 1/2 for connection to oil filtration plant.

1.7.6 **Drain valve:** It shall be of size 80 mm 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 magnetic switch or micro switch type, electrically independent and wired up to the marshaling 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 analog output. The Buchholz relay shall have provision of digital communication through Modbus or similar protocol. This shall be suitable for integration with SCADA if 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. The OTI shall have a local /remote indication (in control panel) for oil temperature.

1.7.10 **Winding temperature indicator (WTI):** It shall have one alarm contact, one trip contact, two contacts for FAN operations and two contacts for pump operation, none of the contacts being earthed. The contacts shall be electrically independent. The WTI shall have a local /remote indication (in control panel) for winding temperature.

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

1.7.12 **Fibre Optic Winding Hot Spot Temperature Monitor:** Fibre optical winding hot spot temperature monitor to be provided with the transformer windings, connected in addition to the winding temperature indicator in parallel to measure transformer winding hot spots in real time and activate control of the cooling system. The Fibre to be given high strength casing through jacketing and Fibre Optic shall be governed by IEC-60076-2 (Ed.3.0). The specification and other requirements of this system have to be as per details given in the Annexure-1.

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

1.7.14 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.

1.7.15 (i) The manufacturers of Part, Fittings and Accessories for the Transformer shall be mentioned in the SOGP, BOM & QAP and these documents shall be got approved by RDSO. During prototype test, the accessories will be tested & performance monitored either by functional testing or by Test Certificate (TC) verification of the accessory as categorised below:

SN	Name of the accessory	Category
1.	Motorised off Circuit tap changer	Functional testing
2.	Bucholz relay	TC Verification
3.	Pressure Relief Device	TC Verification

4.	Magnetic Oil level Gauge	TC Verification
5.	Bushing Current Transformer	TC Verification
6.	Silica gel Breather	TC Verification
7.	Wheel Valve, Double Flanged valve	TC Verification
8.	Analogue Type Temperature Indicators	TC Verification
9.	Terminal Connectors	TC Verification
10.	Radiators	TC Verification
11.	Fire Optic Winding Hot Spot Temperature Monitor	TC Verification

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

(iii) In case manufacturers desire to change a particular make of accessory, prior approval of RDSO would be required on SOGP, Bill of Material (BOM) and Quality Assurance Plan (QAP) on the basis of functional testing or TC verification as categorized in above table.

(iv) The Traction Power Transformer manufacturer shall be responsible for availability of compatible accessories for the equipment approved.

(v) In case of Transformer manufacturer change in the make of OCTC for approved design of transformer, the routine testing of the transformer also shall be witnessed by RDSO.

(vi) After the successful functional testing of tap changer by RDSO, make of the manufacturer of Tap Changer shall be communicated by RDSO to the all the approved/ in process manufacturer of transformer for their reference.

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, which 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 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.

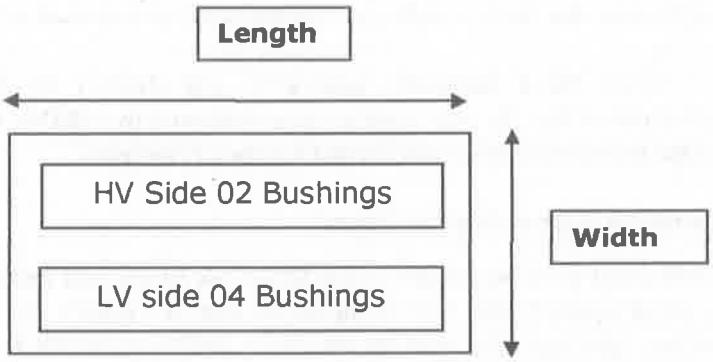
2.3 The AC electric locomotives are fitted, for conversion of AC to DC, with Single Phase Bridge connected silicon rectifiers with smoothing reactor for feeding the DC Traction motors. The rectifiers introduce harmonic currents in the 25kV power Supply system. On few of the

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%

3. 0 **Design and Constructional Features**

3.1 **Overall Dimensions:** The overall dimensions of the transformer with all parts/fittings shall be kept as low as possible, and in any case shall not exceed the values given below; Refer as Annexure-2



MVA	kV	Dimensions (mm)	
		Length	**Width**
21.6MVA	220/2X27kV	8000	6500
	132,110,66kV/2X27kV	7000	6000
38/53/63MVA	220/2X27.5kV	8500	7500
	132,110,66kV/2X27.5kV	8000	7000
Height of the top most point of primary bushing terminal		7500 mm	
Height of the topmost point of secondary bushing terminal		5500 mm	

3.2 **TRANSFORMER TANK**

3.2.1 The tank for the transformer shall be of bell type construction with flanges on the outside and shall have a flat top .The flanges of the upper and lower tanks shall be jointed by bolts, nuts and suitable plain/spring/beveled washers. A suitable gasket and metallic stoppers shall be provided between the flanges of upper and lower tank so as 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 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 lifting of the transformer filled with oil by means of lifting jacks.

3.2.4 The tank shall be fitted with an under carriage and mounted on four for 21.6MVA and eight for 38/53/63MVA bi-directional swiveling type flanged rollers for being rolled on 1676 mm (5' 6") gauge track on which it shall also rest in the final position. The rollers shall be provided with 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 at least five inspection covers of suitable size on the tank to enable inspection of the lower portions of bushings and the leads as well as various connections of the motorised off - circuit tap – changer.

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 leak proof. 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 supports shall be provided on the tank for fixing of Aluminum ladder for ease of maintenance at site. A suitable ladder of Aluminium shall be provided on the tank for ease of maintenance. Removable aluminum ladder shall be a part of transformer supply.

3.2.9 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 An Oil Drain Valve of 80mm Dia and 04 number Nitrogen Injection Valve of 25mm Dia (02 on each on HV & LV side) shall be provided on the Transformer Tank for the connection of NIFPES, if required in future.

3.3 MARSHALLING BOX & RTCC PANEL

3.3.1 MARSHALLING BOX

3.3.1.1 A Vermin proof, weather proof and well ventilated marshalling box made of steel sheet of thickness not less than 2 mm, strengthened with adequate stiffeners, shall be provided on the left hand side of the transformer tank as viewed from the secondary terminals side. It shall have a hinged door with provision for pad locking. The door opening outward horizontally.

3.3.1.2 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.

3.3.1.3 The marshalling box shall house the winding and oil temperature indicators, Contactors & MCB of cooling fan and terminal board. 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.

3.3.1.4 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.

3.3.1.5 All cables from the Cooling fans, 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 armored, stranded copper conductor confirming to IEC:60502-1. The cables shall be adequately insulated for heat from the tank surface and the sun.

3.3.1.6 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.

3.3.1.7 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 marshaling box door.

3.3.2 Remote Tap Changer Control (RTCC) Panel

3.3.2.1 A Vermin proof, weather proof and well ventilated RTCC Panel made of steel sheet of thickness not less than 2 mm, strengthened with adequate stiffeners, shall be provided for providing in the control room of the substation.

3.3.2.2 The RTCC panel shall house actuating switch for electrical raise/lower control of tap changer, tap position indicator, signal lamps for "Tap changer in progress", and all other auxiliary devices for remote electrical control of the OCTC.

3.3.2.3 RTCC panel shall also house the Digital Display of OTI & WTI and indications/control & pump of Fans (ONAF /OFAF mode) as mentioned in Para 3.12.

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 principal tapping with primary winding excited 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 preferably of boltless design to avoid the possibility of local heating. Indian transformer manufacturers shall use core material as per above specification with BIS certification.

3.4.2 The laminations for the core shall be free from waves, deformations 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 Yoke/core clamping bolts shall have adequate threaded length beyond the face of the nuts for tightening at a later stage, if need arises. Each of the core clamping bolts and the core-clamping framework shall be insulated from the core laminations and tested after completion of the core assembly to ensure that they withstand a voltage of 2 kV r.m.s. with respect to core for a duration of 60 seconds.

3.4.6 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.

3.4.7 Manufacturer shall, preferably have the core cutting facility in their works and proper monitoring and quality control to avoid any mixing with defective /second grade materials.

3.5 WINDINGS

3.5.1 The type of the winding is to be decided by the transformer manufacturer after ensuring that the all the parameters mentioned in the specification are fulfilled with the decided type of winding. The primary and secondary windings shall be uniformly insulated. All the four terminals of the two secondary windings shall be brought out separately through 52kV OIP condenser bushings.

3.5.2 The windings shall be made of continuous electrolytic copper conductor, paper insulated to class - A insulation 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.

3.5.3 Normally, no joint 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 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 conductor should be mentioned in the SOGP. Whenever manufacturer desires to change the size from type tested design, type testing of the transformer including short circuit test shall be repeated.

3.5.5 A separate tapped winding shall be provided on the secondary winding for 21.6MVA and on the primary winding for 38/53/63MVA connection of the off - circuit tap – changer. The tapped winding shall be distributed in multi-sections in order to reduce the imbalance in ampere turns to the minimum at any tap position.

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

Item		Secondary	Primary			
1.	Highest voltage for equipment Um, kV	52	72.5	123	145	245
3.2	Rated short duration power frequency withstand voltage, kV	95	140	230	275	395
4.	Ra3.ted lightning impulse withstand voltage, kV peak	250	325	550	650	950

3.5.7 The windings shall be so designed that the transfer of lightning switching surges from primary to secondary windings and vice-versa is kept to the minimum level.

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

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

3.5.10 During short circuits, the stresses actually 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.

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

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

3.5.13 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 such devices.

3.5.14 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 dash pots or any other suitable device, so as to maintain a constant pressure and obviate the need for any retightening in between successive periodical overhauls.

3.5.15 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.

3.5.16 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.

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

3.5.18 In order 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.

3.5.19 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.

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

3.5.21 The vertical locking strips and radial spacers shall be made of pre-compressed pressboard conforming to grade PSP: 3052 of DIN: 7733.

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

3.5.23 Leads from the windings to the terminals, from the tap switch, to the tapings of the secondary windings or to the tapings of the primary windings and other interconnections shall be properly supported and secured.

3.5.24 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 conforming to IS: 335:2018 (Type-II) and the additional requirements stipulated under clause 6.3.8.9. In addition 10% extra oil by volume shall be supplied in non-returnable steel drums. The characteristics of the insulating oil before energisation of the new transformer and during its maintenance and supervision in service shall conform to IS: 1866. For the sources of Insulating Oil, refer RDSO Vendor Directory available on RDSO website.

3.7 **Bushings and Terminal Connectors**

3.7.1 Both the 245kV/145kV/123kV/110kV/72.5kV side and 52kV side bushings shall conform to IS: 2099. On the primary side, sealed draw lead type Oil Impregnated Paper (OIP) condenser bushings shall be used. On the secondary side, sealed draw rod/ solid stem type OIP condenser bushings shall be used. The dimensions of the bushings shall conform to IS: 12676.

3.7.2 The temperature rise of any part of the bushing shall not exceed 40 ^{0} C over an ambient temperature of 50^{0} C while carrying the rated current continuously.

3.7.3 The porcelain housing of 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 so as to avoid accumulation of dust and pollutants and to permit easy cleaning.

3.7.4 The 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 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:

SN	Item	Secondary	Primary			
1.	Highest system voltage of Bushing to be used Um, kV	52	72.5	123	145	245
2.	Rated short duration wet power frequency withstand voltage, kV	95	140	230	275	460
3.	Rated lightning impulse withstand voltage, kV peak	250	325	550	650	1050

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

SN	Item	Secondary	Primary			
1.	Highest system voltage of Bushing to be used Um, kV	52	72.5	123	145	245
2.	Arcing horn gap setting variable between, mm	150 and 300	250 and 500	500 and 900	500 and 900	1200 and 1500

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 bushings shall not lead to its deterioration/ breakage.

3.7.9 The condenser 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 over load condition of ONAN rating with 200% over loading.

1. Primary side: Rigid type terminal connector to suit 28.62mm overall dia, ACSR Conductor (Zebra), size 54/7/3.18 mm and shall match with the size of bushing stud on the other side, shall be as per the firm's drawing approved by RDSO.

2. Secondary side: Expansion type terminal connector to suit 50mm overall diameter Aluminium Tubular Bus or rigid type terminal connector to suit 38.25 mm Dia AAC 'Bull' Conductor 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 bolt, nuts, spring and flat washers. The fasteners shall conform to clause 3.12 of this specification.

3.7.12 For the sources of Bushings Please refer Annexure-7.

3.8 **Bushing Type Current Transformers**

3.8.1 The 52 kV and 72.5/123/145/245kVside bushings shall be so arranged as to accommodate bushing type current transformers (BCTs) for the biased differential protection of the transformer. The BCTs shall conform to IS: 2705 and meet with the stipulations in clause 5.1(20) 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 one of the bushings of the left hand side (as viewed from the secondary terminals side) secondary winding (which feed the catenary and would carry a higher current in service as compared to the other secondary windings which feeds the feeder) 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 upto 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) 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 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	72.5	123	145	245
Minimum clearance, mm	500	700	1100	1300	1900

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 Motorised Off Circuit Tap changer

3.10.1 General requirements for OCTC

3.10.1.1 The transformer shall be fitted with a motor operated rotary type tap- changer to cater for the voltage range specified in clause 5.1(13) of this specification. The motor drive unit shall be installed in a weather and corrosion proof, adequately ventilated cubicle made of steel sheet not less than 2 mm thick or Aluminium material not less than 4mm thick with adequate stiffeners to prevent deformation during transit and handling. The cubicle shall have a sloping roof. The top of the cubicle shall be at a height of about 1.5 m from the rail level. The cubicle shall be so positioned that the hinge of the operating handle - for manual operation - is at a height of about 1.1 m from the rail level.

3.10.1.2 Local OCTC control cabinet shall be mounted on the tank in accessible position. It should be adequately ventilated and provided with metal clad space heater, controlled by an associated thermostat and switch to prevent condensation of moisture in the cubicle.

3.10.1.3 All wiring in the cubicle 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.

3.10.1.4 Suitable legend and schematic diagram plates made of stainless steel or anodised aluminium with black lettering and lines shall be fixed on the inside surface of the cubicle door.

3.10.1.5 A tap position indicator shall be provided to indicate the tap position which shall be clearly visible to an operator standing on the ground.

3.10.1.6 Operating mechanism for off load tap changer shall be designed to go through one step of tap changer per command. Subsequent tap changes shall be initiated only by a new or repeat command.

3.10.1.7 Limit switches shall be provided to prevent overrunning of the mechanism and shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop shall be provided to prevent over-running of the mechanism under any condition.

3.10.1.8 A five digit non-resettable type counter shall be fitted to the tap changing equipment to indicate the number of operations completed.

3.10.1.9 Tap Changer shall be 110V DC Motor operated as well as remote operation and external handle for manual hand operation.

3.10.1.10 The tap- changer motor shall be suitable for operation off 110 V DC from a battery. The voltage at the battery terminals may vary between 110% and 85% of the normal value. The voltage at the tap- changer motor terminals is likely to be less than 85% of the normal value of 110 V DC due to voltage drop in control cable.

3.10.1.11 It shall not be possible for any two controls to be in operation at the same time.

3.10.1.12 Once the tap changing operation has been initiated and the power supply goes off, OCTC should not stay in between and has to complete the Tap change event once the power supply is restored.

3.10.1.13 The tap - changer shall be provided with suitable interlocking arrangement to prevent its operation (including manual tap changing) when either one or both circuit breakers on the primary as well as on the secondary sides of the transformer is/are in closed condition.

3.10.1.14 The variation of taps shall be in in steps of 5% each to give rated secondary voltage for variation in primary voltage of + 10% to -15%. The principle tap shall be on tap no. 3. There shall be 2 Taps for higher input voltage and 3 taps for lower input voltage variation as detailed below:

(a) For 21.6MVA Transformer: (Tap changer on secondary side) The tap changer shall be of 52kV voltage class with a continuous current of 800A and a short circuit current withstand capability of 8kA for 5seconds.

(b) For 38/53/36MVA transformer: (Tap changer on primary side)

Nominal Voltage	Tap 1	Tap2	Tap3	Tap4	Tap5	Tap6
kV	kV	kV	kV	kV	kV	kV
220	242	231	220	209	198	187
132	145	138	132	125	118.8	112.2
110	121	115.5	110	104.5	99	93.5
66	72.6	69.3	66	62.7	59.4	56.1

Rated and Short Circuit Current of the tap changer shall be as below:

Nominal Voltage	Voltage Class	Rated Current	Short Circuit Current for 2 seconds
kV	kV	I	kA
220	245	400	04
132	145	800	08
110	123	800	08
66	72.5	1250	12.5

3.10.2 OCTC Control of Transformers

3.10.2.1 The tap - changer and its control circuit shall be designed for operation from the remote control centre (RCC) by the traction power controller (TPC) as well as from the tap changer cubicle and RTCC panel. It shall be provided with necessary interface for its remote control through SCADA. The control feature shall provide the following:

3.10.2.2 Local Electrical Control

a. Local – Remote selector switch shall be provided in the local tap changer control cabinet. It shall control the tap changers as follows:

(i) When the selector switch is in the local position, it shall be possible to operate the 'raise-lower' commands locally. Remote control of the raise-lower functions shall be prevented.

(ii) When the selector switch is in remote position, the local operation of raise lower switches shall be in- operative. Remote control of the raise/lower function shall be possible from the Remote Tap Changer Control Panel (RTCC).

b. A 'raise –lower' control switch/push button shall be provided in the local tap changer control cabinet. This switch shall be operative only when 'local remote' selector switch is in 'local' position.

c. An OFF-ON switch shall be provided in the local tap changer control cabinet of the transformer. The tap changer shall be in- operative in the OFF position of the switch.

3.10.2.3 Manual Control

The cranking device for manual operation of the tap changer gear shall be removable and suitable for operation by a man standing at ground level. The mechanism shall be complete with the following:

a. Mechanical tap position indicators shall be clearly visible from near the transformer.
b. A mechanical operation counter.
c. Mechanical stops to prevent over cranking of the mechanism beyond the extreme tap positions.
d. The manual control considered as back to the motor operated load tap changer control shall be interlocked with the motor to block motor start- up during manual operation. The manual operating mechanism shall be labeled to show the direction of operation for raising/lowering.

3.11 **Cooling Equipment**

3.11.1 The transformer shall be designed for ONAN (for 21.6MVA) & ONAN/ONAF/OFAF for 38/53/63MVA type of cooling.

3.11.2 The radiators shall consist of a pressed steel plate assembly formed into elliptical oil channels (as per 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 5.1(14) 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 3.14 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 minimum 200 micron. The shade of paint shall be gray as shade 631 of IS: 5.

3.11.3 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 at 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 use of headers, isolating valves of size 80mm shall be used between tank and headers.

3.11.4 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.

3.11.5 Each Transformer with ONAF rating shall be provided with two completely independent groups of cooler fan banks, each of 50% capacity having 25% additional fans in each group as stand by (Subject to minimum of one cooler fan per group). Fans and blowers

for air blast cooling shall be mounted so as to ensure that no damage to radiators can arise from vibration of the fans.

3.11.6 Cooler System shall be provided such that both groups of fans shall start independently at different temperatures. The control circuit shall also enable switching/changeover of designation of one group of fan to another so that the groups can be interchanged. The standby fans shall be switched on automatically in case of failure of equivalent cooler fans in that group of coolers respectively.

3.11.7 Air blower shall be suitable to start direct on line. Air blower shall be designated so that they operate with a minimum of noise or humming. It shall be possible to remove the blower complete with motor without disturbing or dismantling the cooler structure frame work.

3.11.8 Blades shall be suitably painted for outdoor use. For fans, painted wire mesh guards, with mesh not greater than 25mm shall be provided to prevent accidental contact with blades. Fans mounted shall be provided with outside guards against birdage. Guards shall be provided over all moving shafts and couplings.

3.11.9 Manufacturer shall specify the loading capacity of transformer in case of failure of one or more fans. Provision should be made to avoid hunting of fans.

3.11.10 For OFAF rating the cooling system shall in addition contain electric motor driven oil pump having 100% stand by capacity. Stand by fan and electric motor driver oil pump shall come into operation automatically in the event of failure of any fan or oil pump in the bank.

3.11.11 The oil circuit of all cooler banks shall be provided with oil flow indicators, shut off valves lifting lugs top and bottom oil filtering valves, air release plugs, drain valve and thermometer pockets fitted with captive screw cap on the inlet/outlet branches of each separately mounted cooler bank

3.11.12 Cooling fans for each unit shall be housed in fan box to prevent ingress of rain water. Each fan shall be suitably protected by galvanized wire mesh guard.

3.11.13 Centrifugal oil pump shall be used. Measures shall be taken to prevent mal-operation of Buchholz relay when all oil pumps are simultaneously put into service. The pump shall be so designed that pump impeller will not restrict the natural circulation of oil, when the pump is not in use/ operation.

3.11.14 Cooling fan and oil pump motors with 'F' class insulation shall be suitable for operation on 230 volt, single phase, 50 cycle power supply with variation in supply voltage and frequency.

3.11.15 An oil flow indicator with alarm contacts shall be provided in each oil pump circuit to indicate flow of oil in the normal direction and to actuate an alarm if the flow of oil is stopped or is in reverse direction.

3.11.16 The coolers and its accessories shall preferably be hot dip galvanized or corrosion resistant paint should be applied to it.

3.12 CONTROL OF COOLER OPERATION

3.12.1 Cooler units shall be suitable for operation with a 240Volts, Single Phase, 50Hz power supply.

3.12.2 The cooler fans shall come into service through contact of winding temperature indicator at predetermined temperature of transformer winding. The temperature

setting for operation of fan and oil pump shall be adjustable over a reasonable range. Hunting of the transformer cooling equipment shall be avoided by providing suitable range settings. Separate winding temperature indicator with necessary contacts shall be provided and housed in local control kiosk for control of pumps and fans.

3.12.3 Suitable manual control facility for cooler fans and oil pumps shall also be furnished.

3.12.4 For control of cooler fans and oil pumps separate weather and vermin proof control cubicle shall be furnished and installed near the transformer.

3.12.5 Control equipment for fan motors and oil pump shall be mounted in a marshaling box adjacent to the transformer and shall include necessary electrically operated contactor and with control gear of suitable design both for starting and stopping the motors & pump manually and also automatically from the contacts of the Winding Temperature indicating device. Overload and other necessary protections shall be provided as per requirement. A no volt relay shall also be fitted. MCB shall be provided for the main supply. The temperature of the transformer winding at which the fan and oil pump will come into service shall be indicated along with the range of adjustments available in the system.

3.12.6 The cooling equipment shall have provision for visual/alarm indication for the following in the control equipment on the transformer remote tap changer control panel (RTCC) to be supplied by the firm.

i) The Auto/Manual position of the selector switch for the cooling equipment.
ii) That the first set of contacts of the winding temperature indicator has closed.
iii) That the second set of contacts of the winding temperature indicator has closed.
iv) Fans of first group 'ON' indication.
v) Fans of second group 'ON' indication.
vi) Standby fan in first group 'ON' indication.
vii) Standby fan in second group 'ON' indication.
viii) Electric motor driver oil pumps 'ON' indication.
ix) Stand by Electric motor driver oil pump 'ON' indication

3.13 Fasteners

All fasteners of 12 mm diameter and less exposed to 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 04Cr17Ni12Mo2 or equivalent/better.

3.14 Painting

3.14.1 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.

3.14.2 All steel surfaces exposed to weather shall be properly descaled/grit blasted. The epoxy and polyurethane protective paints as per ISO/EN 12944 have to be provided for proper protection against corrosive and coastal environments and give life of approx. 12-15 years. All the external surfaces of the Transformer shall be given first coat of epoxy zinc rich (having minimum 83% metallic 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 minimum 200

micron. The shade of paint shall be gray as shade 631 of IS: 5. Same paints have to be applied at damaged surfaces, if any, at site during erection /commissioning of the transformer. One final coat of polyurethane paint has to be applied to ensure proper smoothness and finish.

3.14.3 For panels like marshalling Box, OCTC drive mechanism box and RTCC panels Powder Coating painting of minimum 80 micron thickness is to be done. The shade of paint shall be shade 631 of IS: 5 for the marshalling Box, OCTC drive mechanism box and shade 216 of IS: 5 for the RTCC Panel.

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.	IS:335	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:2099	Bushing for alternating voltages above 1000Volts.
9.	IS:2705	Current Transformer
10.	IS:2927	Brazing Alloys
11.	IS:3024	Electrical Steel Sheets (Oriented)
12.	IS:3637	Gas Operated Relays.
13.	IS:3639	Fittings and accessories for Power Transformers.
14.	IS:4253 (Pt. II)	Cork and Rubber
15.	IS:5561	Electrical Power connectors.
16.	IS:5621	Hollow Insulators for use in Electrical Equipments.
17.	IS:13234	Guide for Short Circuit Calculations in 3 phase ac system
18.	IS:6209	Methods for Partial Discharge measurement.
19.	IS:6600	Guide for loading of Oil Immersed Transformers.
20.	IS:8468	On - Load Tap changers.
21.	IS:10028	Code of Practice for selection, installation and maintenance of Transformers.
22.	IS:10593	Method of evaluating the analysis of gases in oil filled electrical equipment in service.
23.	IS:12676	Oil impregnated paper Insulated Condenser Bushing- Dimensions and requirements.
24.	IEC:60137	Bushings for alternating voltages above 1000Volts.
25.	IEC:60185	Current Transformer
26.	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**

5.1 **Particulars for 21.6MVA**

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 version. The rating plate shall be of Stainless steel or anodized Aluminium material only. The rating and general data of the transformer shall be as follows:

SN	Rated primary voltage, Un, kV		66	110	132	220
1.	Highest system voltage, Um, kV		72.5	123	145	245
2.	Short - circuit apparent power at the Transformer Location (MVA)		3,500	6,000	10,000	20,000
3.	Rated Power,(MVA)		21.6 MVA (Each secondary winding shall have a rated power of 10.8 MVA)			
4.	Rated current at principal tapping (A)	Primary	327.3	196.4	163.6	98.2
		Secondary	400			
5.	Maximum permissible losses at rated voltage, current and at the principal tapping, kW	No Load	11.5	11.5	11.5	13.0
		Load	95.0	95.0	95.0	95.0
6.	Type		ONAN cooled , single phase, step down Power Transformer, double limb wound, core -type for outdoor installation.			
7.	Windings		One primary winding and two secondary windings, uniformly insulated shall be provided. The terminals of the secondary winding shall be brought out separately, for cascade connection externally.			
8.	Rated secondary voltage (at no - load), kV		2X27kV			
9.	Rated frequency, Hz		50 +/-3%			
10.	Percentage Impedance voltages, LV1/Primary winding & LV2/Primary winding at 10.8 MVA base at principal tapping		%Z = (11 to 13)%			
11.	Non - cumulative over load 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.			
12.	Polarity		Subtractive			
13.	Tappings (Off – Circuit)		A separate tapped winding on each secondary winding to give rated secondary voltage for variation in primary voltage of + 10% to -15% , in steps of 5% each.			
14.	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 5.1.1(11) (temperature measured by resistance method). b) Top oil: 40 °C (temperature rise measured by thermometer). c) Current carrying parts in air: 40 °C (temperature rise measured by thermometer). 2. The winding hot - spot temperature under the rated and overload conditions shall not exceed 115° C (please refer the temperature rise test para)
15.	Ability to withstand short circuit, sec.	Thermal ability : 3s Dynamic ability : 0.25 second
16.	Flux density at rated voltage and frequency at principal tapping	Shall not exceed 1.7 tesla.
17.	Current density in the windings at rated current	Shall preferably not exceed 2.5 A/mm^2
18.	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 occur at sufficient interval of time apart such that the temperature rise limits, both of Oil and Winding do not exceed the values specified in clause 5.1.1(14) of this specification .The interval of time between two successive non-cumulative overloads shall not be less than 3 hours.

19. Bushings:

SN	Item	Secondary	Primary			
1.	Type	OIP condenser	OIP condenser			
2.	Highest voltage for equipment Um, kV	52	72.5	123	145	245
3.	Rated current, A	800	800	800	800	800
4.	Minimum creepage distance in air , mm	1300	1813	3075	3625	6125

20. Bushing Type current Transformers for differential protection of transformer

SN	Item	Secondary	Primary			
1.	Highest voltage for equipment Um, kV	52	72.5	123	145	245
2.	CT Ratio	800/5	660/5	400/5	330/5	200/5
3.	Frequency, Hz	50+/-3%				
4.	Class of accuracy as per IS:2705 (Part IV)	PS				
5.	Minimum knee -point emf , V	175	175	150	150	150
6.	Maximum excitation current at knee - point voltage , A	0.25	0.75	0.75	0.75	0.75
7.	Maximum resistance of the secondary winding , ohm	0.5	0.5	0.25	0.25	0.25

5.2 **Particulars for 38/53/63MVA**

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 version. The rating plate shall be of Stainless steel or anodized Aluminium material only. The rating and general data of the transformer shall be as follows:

SN	Rated primary voltage Un, kV		66	110	132	220
1.	Highest system voltage Um, kV		72.5	123	145	245
2.	Short - circuit apparent power at the Transformer Location (MVA)		3,500	6,000	10,000	20,000
3.	Rated Power,(MVA)		38/53/63 MVA (Each secondary winding shall have a rated power of 19/26.5/31.5 MVA)			
4.	Rated current at principal tapping & at 38MVA (A)	Primary {38*1000/(kV)}	575.7	345.45	287.8	172.27
		Secondary {19*1000/(27.5)}	690 for each secondary winding			
5.	Maximum permissible losses at rated voltage, current and at the principal tapping at 38MVA, kW	No Load	28	28	28	28
		Load	113	113	113	113
6.	Type		ONAN/ONAF/OFAF cooled , single phase, step down Power Transformer, double limb wound, core -type for outdoor installation.			
7.	Windings		Primary winding shall be Single Phase Traction Power Transformer. Two secondary windings of 27.5kV each shall be provided. The primary and secondary windings shall be uniformly insulated.			
8.	Rated secondary voltage (at no - load), kV		2X27.5kV			
9.	Rated frequency, Hz		50 +/-3%			
10.	Percentage Impedance voltages, LV1/Primary winding & LV2/Primary winding at 19MVA base at principal tapping		%Z = (11 to 13)%			
11.	Non - cumulative over load 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 (ONAN). 2. 200% rated load for 5 min (ONAN).			
12.	Polarity		Subtractive			
13.	Tappings (Off – Circuit)		A separate tapped winding on primary winding to give rated secondary voltage for variation in primary voltage of + 10% to -15% , in steps of 5% each.			
14.	Temperature rise		1. The temperature rise over an ambient temperature of 500C both at rated and overload conditions shall not exceed the value indicated below: a) Winding: 50 0C at rated load, and 60 0C for overloads as specified in Clause 5.1.1(11)			

		(temperature measured by resistance method). b) Top oil: 45 0C (temperature rise measured by thermometer). c) Current carrying parts in air: 40 0C (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 the temperature rise test para)
15.	Ability to withstand short circuit, sec.	Thermal ability : 3 s Dynamic ability : 0.25 s
16.	Flux density at rated voltage and frequency at principal tapping	Shall not exceed 1.7 tesla.
17.	Current density in the windings at rated current	Shall preferably not exceed 2.5 A/mm^2 @ 38MVA Base
18.	Acoustic sound level when energized at rated voltage and at no-load	Not more than 75 dB at a distance of one meter @ 38MVA Base.

Note: Non-cumulative power load means overload which occur at sufficient interval of time apart such that the temperature rise limits, both of Oil and Winding do not exceed the values specified in clause 5.1.1(14) of this specification .The interval of time between two successive non-cumulative overloads shall not be less than 3 hours.

19. Bushings:

SN	Item	Secondary	Primary			
1.	Type	OIP condenser	OIP condenser			
2.	Highest voltage for equipment Um, kV	52	72.5	123	145	245
3.	Rated current, A	2000	1250	800	800	800
4.	Minimum creepage distance in air , mm	1300	1813	3075	3625	6125

20. Bushing Type current Transformers for differential protection of transformer

SN	Item	Secondary	Primary			
1.	Highest voltage for equipment Um, kV	52	72.5	123	145	245
2.	CT Ratio	2000/5	1200/5	700/5	600/5	350/5
3.	Frequency, Hz	50+/-3%				
4.	Class of accuracy as per IS:2705 (Part IV)	PS				
5.	Minimum knee -point emf , V	175	175	150	150	150
6.	Maximum excitation current at knee - point voltage , A	0.25	0.75	0.75	0.75	0.75
7.	Maximum resistance of the secondary winding , ohm	0.5	0.5	0.25	0.25	0.25

6.0 **Testing of Transformer**

6.1 General

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

6.1.2 Prior to 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. 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 so as 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 at 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 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 manufacture shall carry out these tests on each and every unit during the process of manufacture 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 'Pressure test' at 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. Insulation test for core bolts.
5. Test for pressure relief device.
6. 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 IS: 335, type-II (Para 6.3.8.9 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 permanent deflection of flat plates after release of vacuum shall not exceed the values specified below:

Horizontal length of flat plate	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, radiator and conservator 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.

6.2.1.4 Insulation test for core bolts: This test shall be done as described in Clause 3.4.5 of this specification.

6.2.1.5 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.

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

6.2.2 During the prototype approval, at following manufacturing stages the tests may be witnessed by the representative of the purchaser /DG (TI), RDSO, Lucknow at the works of the manufacturer.

6.2.2.1 Motorised off Circuit Tap Changer
6.2.2.2 Transformer Tank
6.2.2.3 Transformer CORE.
6.2.2.4 Transformer winding Assembly

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

6.2.2.1 A. Motorised off Circuit tap changer: Following tests shall be conducted

(i) Visual and dimensions check: Visual and dimensions check of the complete Motor Drive unit (MDU) of the Off Circuit tap Changer shall be carried out as per the approved drawings and requirements mentioned in the clause no. 3.10 of this specification.

(ii) Mechanical Endurance test: The off circuit tap changer shall be fully assembled and subjected for 1000 operations without any failures. An operation shall comprise moving the tap changer from one tap position to the next higher or lower tap position.

At the minimum voltage of 93.5V DC : 250 operations.
At the maximum voltage of 121V DC : 250 operations.
At the rated voltage of 110V DC : 500 operations.

(iii) Contact resistance Measurement: Contact resistance at every tap position shall be measured before and after endurance test. Contact resistance shall be less than 2 milli ohm.

(iv) Operation check of the tap changer with drive mechanism: The Off circuits tap changer (OCTC) and the respective Drive mechanism shall be checked for 2 complete cycle of operation - The operation shall be smooth without any abnormal sound.

(v) HV Test on auxiliary Circuit. All auxiliary circuits shall be subjected to a separate source AC withstand test of 2kV for 1 minute between all live terminals and the frame/earth. - Equipment should withstand the test.

(vi) Pressure test:

- For in tank type tap changer: Pressure test on top head cover shall be conducted at 12PSI for six hour.
- For out tank type tap changer: Pressure test of oil compartment shall be conducted at 12psi for six hour.

At the end of the test no pressure drop/leakage shall be observed.

(vii) It shall be verified that once the tap changing operation has been initiated and the power supply (110V DC) goes off, OCTC should not stay in between and has to complete the Tap change event once the power supply is restored.

(viii) Manual Operation: Five complete raise and lower operation shall be verified with manual handle.

(ix) Type tests reports of the tap changer of the type tests as per IEC: 60214/IS: 8468 shall be submitted (Clause no. 6.3.8.1 of this specification).

6.2.2.2 Transformer Tank: following tests shall be conducted:

(i) The pressure test and vacuum test shall be done as per the 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.

6.2.2.3 Transformer CORE.

(i) 2 kV r. m. s. withstand voltage between Core clamping bolts and core laminations for duration of 60 seconds.

(ii) Stack height, Diameter and window dimensions as per the approved drawings.

(iii) The manufacturer test certificate of the CORE material shall be submitted.

6.2.2.4 Transformer Winding Assembly: Following measurements/inspection shall be conducted on HV, LV & Regulating windings.

(i) Thickness of the bare and insulated conductor.

(ii) Width and Thickness of the conductor. The ratio of width to thickness of copper conductor used for winding shall not exceed 5:1.

(iii) Number and location of Probes for Fiber Optic Temperature Measurement. The Transformer manufacturer should submit the details that the probes are located in the hottest point of the winding.

6.2.3 The requirement of the functional testing by RDSO for OCTC may be waived off subject to the following:

(i) Earlier RDSO has witnessed the item at the works of manufacturer and manufacturer submits a declaration that the design of manufactured unit is identical to that, which has been witnessed by RDSO.

(ii) The transformer manufacturer has witnessed the unit as per the tests/formats mentioned in the specification.

6.2.4 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 so as 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 at 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 the tap changer on the lowest tap position 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 tests shall be undertaken at transformer on ONAN, ONAF and OFAF ratings for 38/53/63MVA and ONAN mode for 21.6MVA. 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.
2. 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)
3. The ambient temperature shall be measured using alcohol in glass thermometers or by thermocouple or by electronic thermometers.
4. The winding temperature shall be determined by the resistance method only.
5. The temperature of the top oil shall be measured by an alcohol in glass thermometer placed in an oil- filled thermometer pocket.
6. 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).
7. 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.
8. The FOS shall be operational during temperature tests and be demonstrated during these tests. During probe verification, the hottest probes for each phase shall be identified, and temperature data for all probes recorded and reported in the test report.

6.3.1.3 The test shall be carried out as described below:

6.3.1.3.1 **100% load (For ONAN, ONAF & OFAF Ratings)**

1. A quantum of power equal to the sum of the measured losses viz. No- load loss and load losses measured at lowest tap position, 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 1^0C 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 shall commence as soon as possible after switching off. The first reading of the resistance shall be taken before the expiry of 90 s from the instant of switching off and the first ten readings shall be taken at intervals of 15 s apart. Thereafter, another ten readings shall be taken at intervals of 30 s 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, the top and bottom radiator header oils shall also be recorded at half - hourly intervals through out the test starting from the instant power supply is switched on to commence the test till it is switched off.
7. The WTI, OTI and FOS 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 power supply is switched off, the readings of OTI and WTI shall be recorded at intervals of 1 min and of FOS at interval of 30 seconds apart for 30 min.

6.3.1.3.2 **150% load (For ONAN rating only)**

1. After completion of the test at 100 % load, the transformer shall be fed with power, which shall be a value so as 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 minute. At the end of the 15 minute 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 (For ONAN rating only)**

1. After completion of the test at 150 % load, the transformer shall be fed with power, which shall be a value so as 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 a period of 5 min. At the end of the 5 min 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, WTI and FOS shall also be recorded at the time of switching on 200% load as well as at the time of switching off the power supply.

6.3.1.6 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.

6.3.1.7 The temperature rise of the oil, windings and current carrying parts in air under both the overloads 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 5.1 (14) of this specification. The winding hot - spot temperature under the overload conditions shall not exceed 115^0 C

6.3.1.8 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 same as the calculated value of the hot - spot temperature of the winding.

6.3.1.9 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 terminals of the primary and secondary windings shall be tested with the following voltages:

1.	Highest voltage for equipment, Um, kV	52	72.5	123	145	245
2.	Lightning impulse withstand voltage, kV peak	250	325	550	650	950

6.3.3 TEST WITH LIGHTNING IMPULSE, CHOPPED ON THE TAIL

This test shall be done 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 at 21.6MVA or 38MVA (as transformer) in accordance with IS: 2026 (Part I) with the following schedule:

6.3.4.2 Prior to 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 and between the windings.
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:
    1) Separate - source voltage withstand test.
    2) Induced over-voltage withstand test.

9. Recording of recurrent surge oscillogram (RSO) at the highest, lowest and principal tapping.
10. Frequency response analysis (FRA) of the transformer.

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

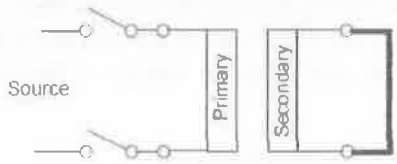


Fig: Single line diagram for the PRE-SET Method

In this method the secondary of the transformer are short circuited previously and Circuit Breaker at primary side is closed to apply a shot. Since, in this transformer there are two secondary winding, inner terminals of the two secondary windings should be connected in series during the short circuit test.

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 at the highest tap (+10%).
2nd shot	Asymmetrical current at the highest tap (+10%).
3rd shot	Asymmetrical current at the principal tap.
4th shot	Symmetrical current at the principal tap.
5th shot	Symmetrical current at the lowest tap (-15%).
6th shot	Asymmetrical current at the lowest tap (-15%).
7th shot	Symmetrical current at the lowest tap (-15%).

6.3.4.5 The duration of each shot shall be 0.25s.

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 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 short circuit and this can be kept as reference for 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 acoustic sound level of the transformer, energised at rated voltage and frequency shall be carried out either as per Indian Electrical & Electronics Manufacturers Association (IEEMA) or as per National Electrical Manufacturers Association (NEMA) procedure.

6.3.6 Measurement of Partial Discharge Quantity

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 **Motorised OCTC**

6.3.8.1.1 Following tests shall be carried out thereon in accordance with relevant IEC: 60214/ IS: 8468.

6.3.8.1.2 Test for temperature rise of contacts: The test shall be carried out at rated current mentioned in para 3.10.1.15. The temperature rise shall not exceed the limit specified in IEC: 60214 or IS: 8468.

6.3.8.1.3 **Mechanical Endurance Test**: With the tap-changer in oil, 100 operations shall be done manually and 10,000 operations shall be done with the motor drive unit. An operation shall comprise moving the tap-changer from one tap position to the next higher or lower tap position. All the taps of the tap- changer i.e. maximum position tap to the minimum position tap shall be covered during the test. While testing with the motor drive unit the D.C. voltage for the motor drive unit shall be adjusted to the values indicated below, and the number of operations at each value of voltage shall be as indicated against each.

1. At the minimum DC voltage of 93.5 V DC — 2500 operations
2. At the maximum DC voltage of 121 V DC — 2500 operations
3. At the rated DC voltage of 110 V DC — 5,000 operations.

6.3.8.1.4 **Milli- Volt Test:** The test shall be done both before and after the mechanical endurance test to assess the condition of the contacts. The variation in the milli- volt drop values shall be not more than 20%.

6.3.8.1.5 **Short Circuit Current Test**: The test shall be done in accordance with IS: 8468 with short –circuit current and duration mentioned in para 3.10.1.14.

6.3.8.1.6 **Dielectric Tests**: The tests shall be done in accordance with IS: 8468.

6.3.8.1.7 **Auxiliary Circuits Insulation Tests**: Auxiliary circuits including the motor and other auxiliary equipment shall be tested in accordance with IS: 8468.

6.3.8.2 **Condenser Bushings**

6.3.8.2.1 The type tests shall be carried out in accordance with IS: 5621 on 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.

6.3.8.2.2 The type tests shall be carried out in accordance with IS: 2099 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 other fixing device.
10. Measurement of partial discharge quantity.

6.3.8.3 **Bushing type Current Transformers**

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

6.3.8.4 **Buchholz Relay**

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

6.3.8.5 **Terminal Connectors**

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

6.3.8.6 **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 vibration test and there shall be no variation.

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

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

6.3.8.7 **Pressure Relief Device**

The following tests shall be conducted on the prototype of 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.

6.3.8.8 **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.

6.3.8.9 **Insulating Oil**

6.3.8.9.1 The Inhibited Mineral Insulating Oil as per Type –II Transformer Oil of IS: 335:2018 shall be used.

6.3.8.9.2 Also, following parameters are required to be maintained and ensured in the Inhibited Mineral Insulating Oil in addition to the technical requirements laid down in IS:335 (2018).

SN	Parameter	Requirements
1.	Lowest Cold Start Energizing Temperature (LCSET)	0°C
2.	Flash point	Min, 140 °C
3.	Presence of Oxidation Inhibiter (DBPC-2, 6 ditertiary-butyl-para-cresol)	Range (0.25 to 0.30) %
4.	Oxidation Stability: (a) Total Acidity (Neutralisation value after oxidation) (b) Total sludge after oxidation	 Max, 0.2 mg KOH/g Max, 0.05%

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. Polarity test.
9. Voltage ratio test.
10. Dielectric tests comprising:
    1) Separate- source voltage withstand test.
    2) Induced over voltage withstand test.
11. Recording of recurrent surge oscillogram (RSO).
12. Tests on motorised off circuit tap- changer.
13. Measurement of capacitance and tan-delta values of transformer windings
14. 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 finish 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.

6.4.3 Measurement of No – Load Current: Measurement of no- load current referred to the primary side shall be done at:

1. 90%, 100% and 110% of the rated voltage at the principal tapping, and
2. The appropriate tap voltage at the maximum and minimum tap positions.

6.4.4 Measurement of No- Load Loss: Measurement of no- load loss referred to the primary side shall be done at:

1. 90 %, 100% and 110% of the rated voltage at the principal tapping, and
2. The appropriate tap voltage at the maximum and minimum tap positions.

6.4.5 Measurement of Resistance of Windings: The resistance of the windings shall be measured at all tapings and computed at 75^0 C.

6.4.6 Measurement of Percentage Impedance Voltages: The percentage impedance voltages at principal, maximum and minimum tap positions shall be measured at rated current and at ambient temperature and computed at 75^0 C.

6.4.7 Measurement of Load Loss: Load losses at rated current shall be measured at principal, maximum and minimum tap positions at ambient temperature and computed at 75^0.

6.4.8 Polarity test: The polarity (subtractive) and marking of the terminals for the polarity shall be verified.

6.4.9 Voltage Ratio Test: Voltage ratio shall be measured at all tap positions.

6.4.10 Dielectric Tests

6.4.10.1 Induced Over Voltage Withstand Test: The test shall be done by applying the test voltage across the entire secondary winding as per IS: 2026(Part III).

6.4.10.2 Separate-Source Voltage Withstand Test: The test voltage to be applied shall be as under:

1.	Highest voltage for equipment Um, kV	52	72.5	123	145	245
2.	Rated short duration power frequency withstand voltage, kV	95	140	230	275	395

6.4.11 Recording of Recurrent Surge Oscillogram (RSO): The oscillograms shall be taken at the maximum, minimum and principal tapings.

6.4.12 Tests on OCTC: The tests shall be conducted in accordance with IS: 8468 or IEC: 60214.

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

6.4.14 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) measured at minimum tap position (corrected to 75^0C) exceeds the value defined in Clause 6.3.1.3.1(1), or if the no-load loss/ load loss at the principal tapping 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 what so ever 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 prior to 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 order is more than 10 nos. In case order is less than 10 nos. 2 copies of 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 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 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.

9.2 The transformer shall be dispatched with its core and windings along with the tap-changer assembly in the transformer tank filled with oil and the space above the oil filled with pure dry air or inert gas like nitrogen at a pressure slightly above atmospheric pressure. However, if there are limitations on account of weight, the tank shall be filled with nitrogen/dry air under pressure and the oil for the first filling shall be supplied separately in steel drums. In case the tank is filled with inert gas/dry 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 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/check list in each crate containing the following particulars:

Crate	Description of item/	Approx. gross weight in	Approx. outside

No.	component in the crate	kgf	dimensions in mm

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

9.8 The transformer shall be erected and commissioned by the Purchaser. The successful tenderer/manufacturer shall invariably make available at 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 site in a damaged condition and in the opinion of the Railway's Engineer at 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 prior to 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 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 at the option of the Purchaser. Manufacturer shall pay to the Purchaser value thereof at the contract price or in the absence of such price at a price decided by the Purchaser and such other expenditure and damages as may arise by reason 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, so as 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 successful tenderer/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 ~~his offer:~~ 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-4.
    1) Asymmetrical short-circuit current.
    2) Hoop stress in primary and secondary windings.
    3) Compressive pressure in the radial spacers.
    4) Internal axial compressive force.
    5) Axial imbalance force.
    6) Radial bursting force.
    7) Resistance to collapse.
    8) Bending stress on clamping ring and densified wood.
    9) 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.

11.2 The manufacturer shall submit to DG(TI), RDSO, Lucknow for approval the following detailed dimensioned drawings as per Indian Railways standard in sizes of 210mm x 297mm or any integral multiples thereof:-

1. Outline 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 primary and secondary 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 dash-pot/ 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 off-circuit tap-changer assembly with salient technical parameters.
8. Tap-changer cubicle layout.
9. Schematic diagram for driving of motorized off-circuit ap-changer from remote control centre by telecommand and corresponding telesignalling.
10. Name and rating plate of motorized off-circuit tap-changer.
11. General arrangement of marshaling box & RTCC indicating protection control equipment.
12. Wring diagram of marshalling box.
13. Schematic diagram of protection and control circuits in marshalling box with cable schedule.
14. Legend plate showing protection and control circuits for fitment in the marshalling box.
15. OIP Condenser Bushing for primary side including cross-sectional view, shed profile and salient electrical and mechanical characteristics.
16. OIP condenser bushing for secondary side including cross-sectional view shed profile and salient electrical and mechanical characteristics.
17. Dimensional drawing, V-I characteristic and rating plate for bushing types current transformers.
18. Rigid type terminal connector for primary side bushing terminal.
19. Expansion type terminal connector for secondary side bushing terminal.
20. Rating plate diagram of connections, both in English and Hindi versions.
21. Details of radiators.
22. Details of breather.
23. External cables run with cable schedule.
24. Any other drawings considered necessary by the manufacture and/ or purchaser.

11.3 After approval, six copies of each of the approved drawings shall be supplied to each consignee(s). Besides, after final approval, one copy of drawings in hard as well as in soft shall be submitted to DG, RDSO, Lucknow.

14.0 Clause wise conformity, deviations etc.

14.1 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 deviate there from together with detailed remarks/justification. If there are no deviations, a 'NIL' statement shall be attached.

14.2 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.

15.0 CAPITALISATION OF TRANSFORMER LOSSES

The capitalized valve of transformer losses shall be as low as possible and commensurate with optimum no-load and load the losses. The capitalized value shall be computed as detailed at Annexure -5 and furnished with offer. Capitalized value calculated, as per Annexure-5 shall be added to the unit cost of the transformer for taking into consideration the cost of losses during its service life.

Annexure-1

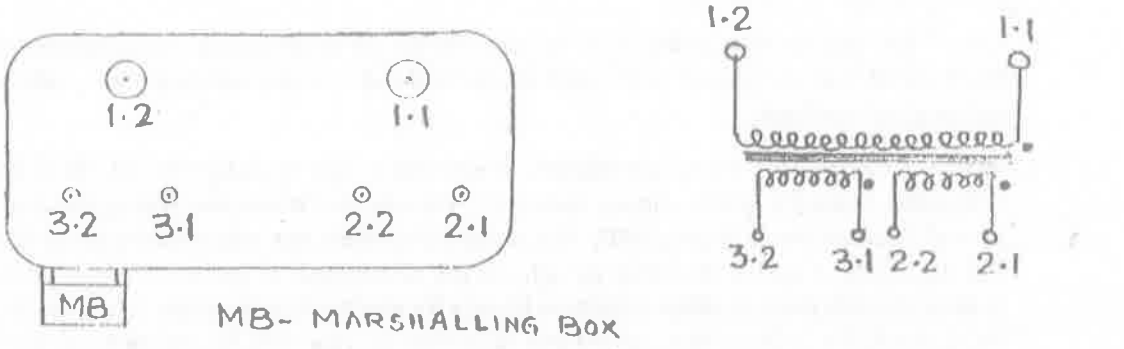
Specification for Fiber Optic Temperature Measurement system

1. Fibre optic based temperature measurement of Oil and windings shall be done using Fiber Optic sensors meeting following broad criteria.
2. System shall be of proven technology. The temperature sensing tip of the fiber optic shall is ruggedized. The probes shall be directly installed in each winding of power transformer to measure the winding hot spot and at the top oil temperature. There shall be at least 5 probes inside the transformer.
3. Out of the 5probes one probe shall be used for top oil temperature measurement and the balance 4 will be placed in the each LV, HV and Tap Changer winding (One probe per winding), of one limb.
4. Probes shall be able to be completely immersed in hot transformer oil. They shall withstand exposure to hot vapour during the transformer insulation drying process, as part of Vacuum Phase Drying (VPD). The probes shall meet the requirement to eliminate the possibility of partial discharge in high electric stress areas in the transformer. Probes shall preferably have certified Weidman testing for electrical parameters as per ASTM D-3426 and ASTM D-149 that is current (no more than 10 year old). Test results and studies to be submitted by the transformer manufacturer along with the first unit of a certain type of traction power transformer.
5. Temperature range of the system should be up to +200°C without any need of recalibration. Probes must connect to the tank wall plate with threaded connectors containing a Viton O-ring to prevent against oil leakage.
6. Probes shall be of material inert to mineral and ester oils, multiple jacketed (Kevlar preferred), perforated outer jacket to allow complete oil filling and mechanical strength.
7. System should include analog outputs for each measurement channel. Temperature resolution of the analog outputs shall be ±0.1°C and precision of +/- 0.5°C and the system shall offer user programmable temperature alarm outputs with 8 relays. The cooling system (fans) should be operated through these relays. The temperature settings for the relays shall be made as per the end-user request.
8. All inputs and outputs of the system shall meet the requirements of surge test of IEEE C37.90.1-2002 in which a 4000 V surge is applied to all the inputs and outputs without permanent damage to the instrument. The system should electronically store testing records of components and allow for on board diagnostics and instructions, including a signal strength reading to verify integrity of fiber optic connections. System should contain a battery for date/time stamp of data readings. The system should comply with IEC61850 protocol, along with DNP3.0, Modbus, TCP/IP and ASCII.
9. The transformer manufacturer should submit details showing that the probes are located in the hottest point of the winding, while submitting drawings for approval. The manufacturer are free to use more than 4 probes if design so required.
10. The controller shall be housed in cooler cubicle or in a separate enclosure having ingress protection IP 56.
11. Temperature Rise Test Measurements shall be made with the fiber Optic Thermometers.

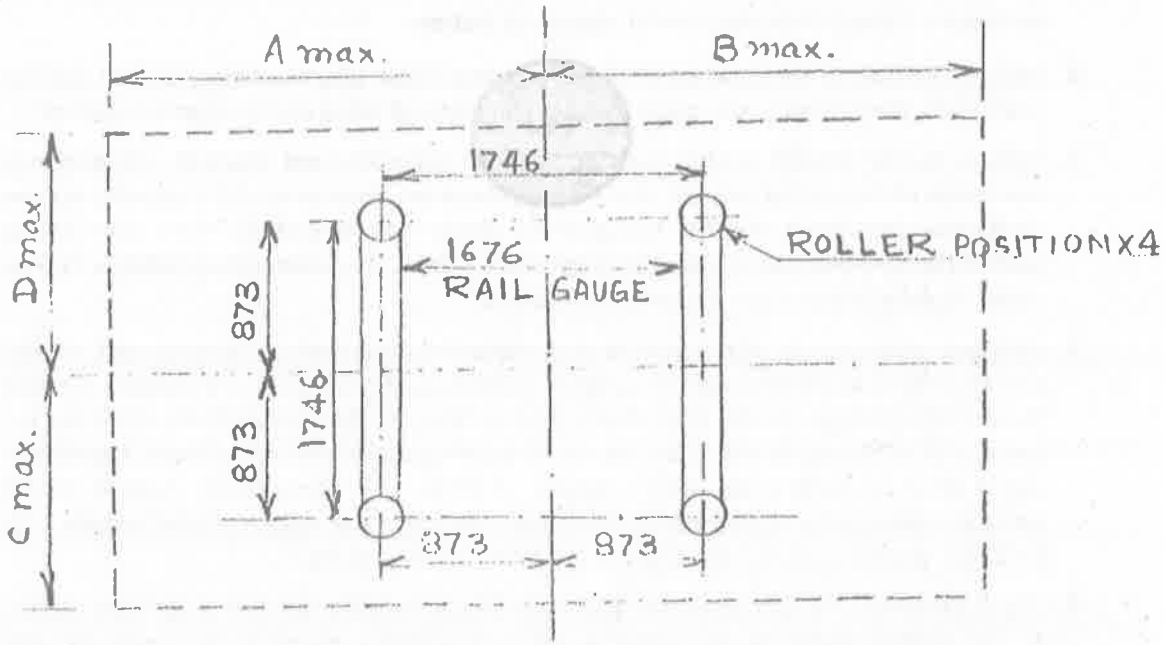
    The equipment shall be operational during temperature tests and be demonstrated during these tests. During probe verification, the hottest probes for each phase shall be Identified, and temperature data for all probes recorded and reported in the test report

Annexure-2

Overall dimensions and Terminal arrangement of Single Phase Transformer For 2X25kV System



TERMINAL ARRANGEMENT



MVA	kV	Dimensions (mm)			
		A	B	C	D
21.6MVA	220/2X27.5kV	4000	4000	3250	3250
	132,110,66kV/2X27.5kV kV	3500	3500	3000	3000
38/53/63MVA	220/2X27.5kV	4250	4250	3575	3575
	132,110,66kV/2X27.5kV	4000	4000	3500	3500
Height of the top most point of primary bushing terminal		7500 mm			
Height of the topmost point of secondary bushing terminal		5500 mm			

Annexure-3

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 manufacturer		
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 iv) Appropriate Voltage at -15% tap v) Appropriate Voltage at +10% tap	 A A A A A	
13.	Power factor of no-load current at Rated Voltage and rated frequency	A	
14.	Value of the inrush current at rated voltage on primary side, the secondary side being open circuited.	A	

15.	Losses: (i) No-Load loss at rated frequency and at: (1) 90% rated voltage at the principle tapping (2) rated voltage at the principle tapping (3) 110% rated voltage at the principle tapping (4) Appropriate Voltage at -15% tap (5) Appropriate Voltage at +10% tap (ii) Load loss (at 75 ^{0}C) with rated current and frequency: (1)Principle tapping (2)-15% tapping (3)+10% tapping (iii) Total Losses at rated current and frequency: (1) Principle tapping (2)-15% tapping (3)+10% tapping	 kW kW kW kW kW kW kW kW kW kW kW	
16.	Resistance voltages (at 75^{0}C) at rated current and Principal tapping i) Primary ii) Secondary (furnish with each secondary winding separately)	 % %	
17.	Reactance voltages (at 75^{0}C) at rated current and frequency at Principal tapping (corresponding to Zt, Zf and Zn)	 %	
18.	Impedance voltage (at 75 ^{0}C) at rated current and frequency: (1)Principle tapping (2)-15% tapping (3)+10% tapping	%Zt, %Zf, %Zn % % %	
19.	Resistance (at 75 ^{0}C) of primary winding at: (1)Principle tapping (2)-15% tapping (3)+10% tapping	 Ω Ω Ω	
20.	Resistance (at 75 ^{0}C) of each secondary winding at	Ω	
21.	Reactance of winding: i) Primary at: 1) Principle tapping 2) -15% tapping 3) +10% tapping ii) Each Secondary	 H H H H	
22.	Regulation (at 75 ^{0}C) with rated current and at power factor of: (1)Unity (2)0.8 lagging	 % %	
23.	Efficiencies: i) Efficiency (at 75 ^{0}C) at unity power factor at 1) 100% Load 2) 75% Load 3) 50% Load 4) 25% Load ii) Efficiency (at 75 ^{0}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 occur	 % % % % % % % % %	

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.	 ^{0}C ^{0}C ^{0}C	
27.	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 2)150% rated current for 15 min. 3)200% rated current for 5 min.	 ^{0}C ^{0}C ^{0}C ^{0}C ^{0}C ^{0}C	
28.	Details of core: i) Type of core ii) Flux density at principal tapping at rated voltage and frequency. iii) Flux density at principal tapping 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 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. x) Core bolt Insulation withstand voltage xi)Core bolt insulation flashover voltage	 Tesla Tesla mm VA/kg VA/kg VA/kg VA/kg VA/kg VA/kg kVrms kVrms	
29.	Details of windings: i)Type of winding: 1) Primary 2) Secondary 3) Number of turns of primary winding 4) Number of turns of secondary Winding 5) Number of parallel paths in primary winding 6) Number of parallel paths in secondary winding 7) Is interleaving/intershielding of the winding adopted to ensure better impulse voltage distribution in primary winding? 8) Is inter leaving/interhielding of the winding adopted to ensure better impulse voltage distribution in secondary winding?	 Yes/No Yes/No	

	9) Is the insulation of end turns of primary winding reinforced?	Yes/No	
	10) Is the insulation of end turns of secondary winding reinforced?	Yes/No	
	ii) Mode of connection (i.e. in series or in parallel) of the portions of the primary and secondary windings on the two limbs of the core, if applicable:		
	1) Primary		
	2) Secondary		
	iii) Dimensions of the copper conductor used in the winding:		
	1) Primary	mmxmm	
	2) Secondary	mmxmm	
	3) Tapped secondary	mmxmm	
	iv)Current density at rated current:		
	1)Primary	A/mm^2	
	2)Secondary	A/mm^2	
	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) Primary winding	kV peak	
	b) Secondary winding	kV peak	
	2)Lightening impulse chopped on tail withstand voltage:		
	a) Primary winding	kV peak	
	b) Secondary winding	kV peak	
	3)Separate source power frequency withstand voltage:		
	a) Primary winding	kV	
	b) Secondary winding	kV	
	4)Induced overvoltage withstand value	kV	
	viii) Minimum flashover distance to earth in oil of :		
	1) Secondary winding to core	mm	
	2) Primary winding to yoke	mm	
	3) Primary winding to tank	mm	
	ix) Material used for coil clamping rings and specification thereof		
	x) Can either end of each secondary (25kV) winding be connected directly to earth?	Yes/No	
	xi) Magnitude of axial precompressive force on the windings:		
	a) Primary	T	
	b) Secondary	T	
	xii) Calculated maximum axial thrust in the windings due to dead short at the terminals:		
	a) Primary	T	
	b) Secondary	T	
	xiii)Calculated short circuit forces:		
	1) Hoop stress in primary winding	kgf/cm^2	
	2) Hoop stress in secondary winding	kgf/cm^2	
	3) Compressive pressure in the radial spacers	kgf/cm^2	
	4) Internal axial compressive force	kgf	
	5) Axial imbalance force	kgf	
	6) Resistance to collapse	kgf	
	7) Bending stress on clamping ring	kgf/cm^2	
	8) Radial bursting force	kgf	
	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.	Nm	
30	Motorized off-circuit tap-changer i) Name of the manufacturer ii) Country of origin iii) Type designation iv) Governing specification v) Is a separate tapped winding provided on each secondary vi) Number of tappings: 1) Plus tappings 2) Minus tappings vii) Percentage variation of voltages on different tappings viii) Minimum contact pressure between moving and stationary contacts ix) Maximum rated through current x) Voltage class xi) Rated voltage of control circuit xii) Tap changer motor particulars : 1) Make and type 2) Rated voltage 3) Rated current 4) Rated power 5) Speed 6) Class of insulation	 Yes/No % kg A kV V(DC) V (DC) kW rpm	
31.	Bushings: **i) Primary side:** 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) Secondary side:** 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	
32.	Bushing type current transformers: **i) Primary side:** 1) Name of the manufacturer 2) Governing specification		

	3) Transformation ratio 4) Accuracy Class 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°C 10) Short time thermal current and duration **ii) Secondary side:** 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°C 10) Short time thermal current and duration	 A VA mA V Ω kA, sec A VA mA V Ω kA, sec	
33.	Insulating oil: i) Governing specification ii) Source of supply		
34.	Type of transformer tank		
35.	Details of radiators: i) Make and type ii) Type of mounting iii) Overall dimensions (LxWxH)	 mmxmmxmm	
36.	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	
37.	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 value of contacts.	 A kV	
38	Details of oil temperature indicator: i) Make and type ii) Governing specification iii) Number of contacts provided iv) Rated current of contacts v) Dielectric withstand value of contacts	 A KV	
39.	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	 mm A	

	vi)Dielectric withstand value of contacts	kV	
40.	Details of pressure relief device: i) Make and type ii) Governing specification iii) Does it rest itself?	 Yes/No	
41.	Bimetallic terminal connectors: **i)Primary side:** 1.Source of supply 2.Governing specification 3.Type 4.Rated current 5.Temprature rise over an ambient temperature of 45^0 C while carrying rated current 6.Short time current and duration **ii)Secondary side:** 1.Source of supply 2.Governing specification 3.Type 4.Rated current 5.Temperature rise over an ambient temperature of 45^0 C while carrying rated current 6.Short time current and duration	 A ^{0} C kA, sec. A ^{0} C kA, sec	
42.	Make of NIFPEF System		
43.	Make of FOS system		
44.	Acoustic sound level at a distance of 1 m, when energised at rated voltage and rated frequency without load.	dB	
45	Partial discharge value at 1.5 Um/$\sqrt{3}$ kV rms	pC	
46	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 largest package x) Crane lift (excluding slings) for untanking core and coils xi) Crane lift (excluding slings) for removal or primary side bushings. xii) Dimensions of the complete transformer including all parts, fittings and accessories: 1) Overall length 2) Overall breadth 3) From rail level to the topmost point xiii) Minimum thickness of steel plate/ sheet used: 1) Bell tank 2) Tank bottom 3) Conservator 4) Radiator	 kg kg kg kg kg L kg kg kg Kg mm mm mm mm mm mm mm mm mm	

	5) Marshalling box. 6) Tap changer cubicle. xiv) Overall shipping dimensions of the largest package (LxBxH) xv) Mode of transportation of transformer unit (filled with Oil/nitrogen gas)	mm mm mm x mm x mm	
B.	**Other Particulars**		
47.	Is the transformer tank fitted with lifting pads? If yes what is the numbers of pads?	Yes/No	
48.	What is the number of inspection covers provided?	Nos.	
49.	Are conduits/trays provided for cable run?	Yes/No	
50.	Is the core electrically connected with the tank?	Yes/No	
51.	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	
52.	Is the core construction without core bolts?	Yes/No	
53.	Are the core bolts grounded, and if so how?	Yes/No	
54.	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	
55.	What is the number of radial spacers used in the: i) Primary windings ii) Secondary windings.		
56.	What is the number of joints provided in the : i) Primary windings ii) Secondary windings.		
57.	Are the spacers/blocks/angle rings of pre-compressed press boards? If no, indicate the material with specification.	Yes/No	
58.	Are arrangements made for ensuring automatic constant pressure on the coils? If no give the reasons.	Yes/No	
59.	Are the closed slots provided on the outer most winding for locking the vertical strips? If no give the reasons	Yes/No	
60.	What is the periodicity for tightening of the coil clamping arrangement	Years	
61.	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	
62.	What is the over flux withstand capability of the transformer (max. permissible limit of flux density)?	Tesla	
63.	Are windings pre-shrunk?	Yes/No	
64.	Have the details of 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	
65.	Are arcing horns provided for primary and secondary bushings?	Yes/No.	
66.	Is a test tap provided in each of the primary side and secondary side bushings?	Yes/No	
67.	Is the porcelain housing of the bushings of single piece construction?	Yes/No	
68.	Is the shed profile of the porcelain of the bushing free from under ribs but has a lip?	Yes/No	
69.	Is the bushing type current transformer of low reactance type?	Yes/No	
70.	Is clause by Clause" Statement of compliance" attached?	Yes/No	

71.	Is "Statement of deviation" if any attached?	Yes/No	
72.	Does the tap changer have snap action? If not, give reasons.	Yes/No	
73.	Is the tap changer of the rotary type or the sliding type?	Rotary/ sliding	
74.	Is the Buchholz relay provided with two shut-off valves, one on either side?	Yes/No	
75.	Is separate conservator tank and buchholz relay provided for tap changing equipment?	Yes/No	
76.	Are fasteners of 12 mm diameter and less exposed to atmosphere of stainless steel to grade 04 Cr 17 Ni 12 Mo to IS 1570 Part-V or equivalent/better?	Yes/No	
77.	Are the fasteners of more than 12 mm diameter exposed to atmosphere of stainless steel or MS hot dip galvanized?	Stainless steel/hot dip galvanized	
78.	Are test certificates for tests as per clause 6.3 attached?	Yes/No	
79.	Are all the calculations required as per clause 12.3.1 attached?	Yes/No	
80.	Are all the drawings required as per clause 12.3.2 attached?	Yes/No	
81.	Is adequate space provided in the marshalling box for housing the wiring and components /equipment?	Yes/No	
82.	Is warranty as per clause 10.0?	Yes/No	
83.	Is the list of spares furnished or not?	Yes/No.	

Annexure-4

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 circuit, in the winding.
bi=Thickness of inside winding conductor in cm.
Dmi=Mean diameter of inside winding in cm.
di=Diameter of 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 the 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 tapppings placed within the body of the outer winding.

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

$Isc=k\sqrt{2}(Iph/e)A.$

$k\sqrt{2}$ 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
$k\sqrt{2}$=	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 $k\sqrt{2}$ 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√2)²/(2.55)

k√2 as derived from item 1 above.
The figure so calculated shall be less than 1250kg/cm².

Note: The value of (Iph²xRdc)/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 =(2π x σm x Iph x N) / δ kg.

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

Ns= (Dmi x√12x√σm)/(bi x √E)

Where,E=1.13x10⁶ kg/cm².

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

Ns=(8x Dmi x √σm) / (di x √πE)
σm as derived from item 3 above.

7. **Calculation of internal axial compression**

Fc=(-) (34Sn)/ (ez x hw) kg.

Note: 1/3 Fc is acting on outer winding.
2/3 Fc is acting on 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) x (NIsc)²x10⁻⁷kg.

Note 1 : If tapping are 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/cm²

Po=(Fa+1/3Fc)/Ao kg/cm²

Note: Value calculated should not exceed 300kg/cm² for normal calandered press boards and 500kg/cm² for precompressed press boards.

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

Pt=(Fa - 1/3Fc)/(Nt x At) kg/cm².
Fa as derived from item - 8 above & Fc as derived from item - 7 above.
Note: The value calculated should be less than 2500kg/cm² 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 δ² x 10⁸} + {(450xAoxδxb³) / Iph} t, Where: .
E =Modulus of Elasticity of conductor in kg/cm².

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)/(πxDm) 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 concentration of force and assume W = 1.25Wl.

σmax = (WxL^{2}xY) / (12xIo) kg/cm^2, where :
L =Span in cm = {(πxDm / ns) x bs}
ns =Number of spacers .
bs = Width of spacer in cm
Y = Maximum distance from 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

Maximum permissible value for σmax is 1250kg/cm^2.

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

σmax={(6π x F x D) /(8 b x t^{2}x 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.

Maximum permissible value for max is 1100kg/cm, if circular permawood ring is used.

Annexure-5

CAPITALISATION OF TRANSFORMER LOSSES

Following formula shall be used for the purpose of calculating the present worth of the transformer after taking in account 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 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

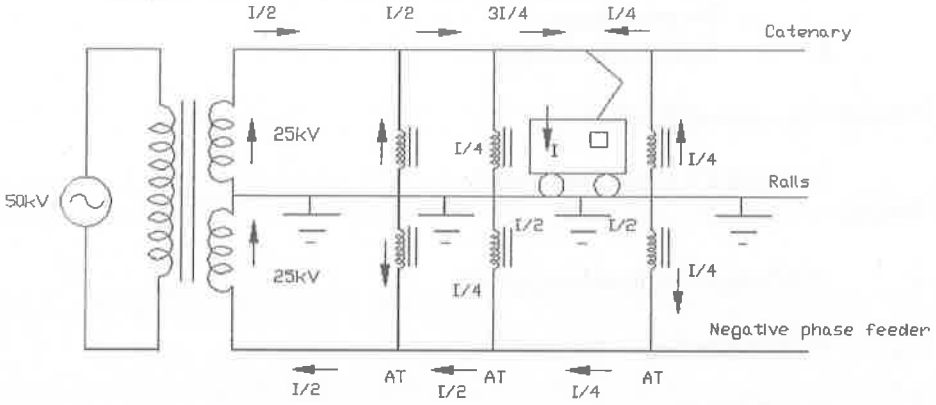
T =Tariff in Rupees

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-6

Principle of 'AT' feeding System



Annexure-7

Policy Regarding the Sources of Bushings

This office vide letter no. File No.RDSO-TI0LKO(PSI)/22/2020-O/o PED/TI/RDSO dated 26.10.2020 has circulated the policy regarding the sources of Bushings, same is reproduced as below:

a. Traction Power Transformer manufactures are free to propose any make of the Bushing and the make of the bushing shall be mentioned in the SOGP/QAP/BOM of Traction Power Transformer. Transformer Manufacturer shall be fully responsible to use the Bushings which have already been type tested by RDSO as per the standard mentioned in the specification of Traction Power Transformer.

b. If a new manufacturer (i.e. of which name is not mentioned in the approved SOGP/QAP/BOM) of Bushing is proposed by the Transformer Manufacturer, RDSO shall conduct the type testing on the Bushing as per the standards mention in the specification of Traction Power Transformer on the request of the Traction Power Transformer Manufacturer and after the successful testing, revised SOGP/QAP/BOM of the transformer manufacturer may be approved by RDSO, after inclusion of the make of type tested Bushing.

c. It is also clarified that, if for 'A' make Transformer, the Bushing of 'X' make of 'V' voltage and 'I' current rating has been type tested by RDSO, it is not required to type test again if another transformer manufacturer say 'B' proposes the 'X' make bushing of same voltage & current rating. For this, the make of type tested Bushing shall be communicated by RDSO to all the approved/in process transformer manufacture and Zonal Railways for their reference.

d. It shall be responsibility of the Traction Power Transformer manufacturer to ensure the functionality of the Bushing which is being supplied with Traction Power Transformer.

e. If any Zonal Railway requires indenting the OIP bushing, the standard of the Bushing mentioned in the specification of Power Transformer shall be referred and any Bushing manufacturer shall be able to participate. The type test shall be conducted by RDSO, if already not done on the OIP bushing of same manufacturer of same rating. If already type testing has been done, only routine testing of the bushing as mentioned in the standard of the bushing shall suffice as acceptance criteria.

f. The make of the Bushings which are type tested by RDSO at present is enclosed below for ready reference.

SN	Item description	Make
1.	245kV OIP Condenser Bushing for Main Transformer	M/s Cromption Greaves Limited, A3-MIDC Ambad, Nashik - 422010
2.	52kV 800A OIP Condenser Bushing 8MVA Autotransformer	M/s GE T & D India Limited ,46, Sipcot Industrial Complex, Zuzuwadi,Village – Hosur- 635126
3.	52kV 2000A OIP Condenser Bushing for Main Traction Power Transformer	(i) M/s GE T & D India Limited ,46, Sipcot Industrial Complex, Zuzuwadi, Village – Hosur- 635126 (ii) M/s Transformers and Electricals Kerala Ltd., Post Angamally Dist. - Ernakulam, Kerala-683 573

		(iii) M/s YASH High Voltage Insulators Pvt. Ltd., 84/1B Khakhariya, Bh. General Motors, Halol-Champaner Road, Tal.-Savli, Dist. Vadodara-391510 (iv) M/s Bharat Heavy Electricals Ltd., Transformer Engineering Deparatment ,Bhopal (MP) – 462 022
4.	52kV 3150A OIP Condenser Bushing for Main Traction Power Transformer	(i) M/s Crompton Greaves Ltd., D-2 MIDC, Waluj, Aurangabad-431136 (ii) M/s GE T & D India Limited ,46, Sipcot Industrial Complex, Zuzuwadi,Village – Hosur-635126 (iii) M/s Transformers and Electricals Kerala Ltd., Post Angamally Dist. - Ernakulam, Kerala- 683 573 (iv) M/s YASH High Voltage Insulators Pvt. Ltd., 84/1B Khakhariya, Bh. General Motors, Halol-Champaner Road, Tal.-Savli, Dist. Vadodara-391510
5.	145 kV OIP Condenser Bushing for Main Traction Power Transformer	(i) M/s GE T & D India Limited ,46, Sipcot Industrial Complex, Zuzuwadi, Village – Hosur- 635126 (ii) M/s Transformers and Electricals Kerala Ltd., Post Angamally Dist. - Ernakulam, Kerala-683573 (iii) M/s YASH High Voltage Insulators Pvt. Ltd., 84/1B Khakhariya, Bh. General Motors, Halol-Champaner Road, Tal.-Savli, Dist. Vadodara-391510 (iv) M/s Bharat Heavy Electricals Ltd., Transformer Engineering Deparatment ,Bhopal (MP) – 462 022 (v) M/s Cromption Greaves Limited, A3-MIDC Ambad, Nashik - 422010