सत्यमेव जयते

STANDARD SPECIFICATIONS AND TECHNICAL PARAMETERS FOR TRANSFORMERS AND REACTORS (66 kV & ABOVE VOLTAGE CLASS)







GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY

APRIL 2021

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

सेवा में,
As per attached List

विषय: Amendment No. 1 to "Standard Specifications and technical Parameters for Transformers and Reactors (66 kV & above voltage class)"-reg.

As you are aware that "Standard Specifications and technical Parameters for Transformers and Reactors (66 kV & above voltage class)" duly approved by Hon`ble Minister of Power and New and Renewable Energy was circulated by this office vide letter dated 29.04.2021 to all the concerned utilities. Further, the document also empowers the committee under Chairmanship of Member (Power System) with representation from stakeholders (IEEMA, EPTA, CPRI, POWERGRID, NTPC, NHPC, Two STUs) as members and CE (PSETD) as Member Secretary of the committee to carry out updation of the document every two years and any amendment, if there is an urgency. Clause No. 7 of Chapter 2 of the above mentioned document mandates the requirement of Dynamic Short Circuit Test for Transformers.

Representation has been received from multiple organizations citing that presently none of the Transformer manufacturer has got their design of 765 kV class and 500 MVA, 400 kV class transformer tested for dynamic short circuit withstand capability and process of getting the design tested would take approximately 15-18 months and only after successful testing subsequent units can be manufactured which will further take few months depending upon availability of material and capacity in the works. Manufacturers are in no position to deliver the transformer of tested design within next 24 Months. This scenario could delay the completion schedule of many transmission projects, specially associated with the evacuation of renewable generation.

To deliberate the issue of DSC requirement for the above mentioned transformers, a meeting of the committee under Chairmanship of Member (Power System) was held on 28.08.2021. After detailed deliberations

following amendment in clause 7 of Chapter 2 of "Standard Specification and Technical Parameters for Transformers and Reactors (66 kV and above)" was finalized:

Existing Provision	Amended Provision
7.0 DYNAMIC SHORT CIRCUIT TEST REQUIREMENT AND VALIDITY The transformer, the design of which is similar to the offered transformer, should have been successfully tested for short circuit withstand capability as per IS 2026 Part-5 in line with the requirement of CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations. **The criteria for similar transformer is specified in Annexure-J.** The relevant Test Report/certificate shall be enclosed along with bid. Further, design review of offered transformer shall be carried out based on the design of reference transformer, which has already been subjected to Short circuit tests in lieu of repetition of Short circuit tests. In case, manufacturer has not conducted short circuit test earlier, the same shall be carried out on offered transformer. A format (forms part of Annexure-J) filled with data of a typical sample case has been prepared for reference and guidance of utility to compare a Short Circuit tested transformer with the offered transformer in order to verify the similarity criteria as per Annexure J.	**7.0 DYNAMIC SHORT CIRCUIT TEST REQUIREMENT AND VALIDITY** The transformer the design of which is similar to the offered transformer, should have been successfully tested for short circuit withstand capability as per IS 2026 Part-5 within last 5 years. **The criteria for similar transformer is specified in Annexure-J**. The relevant Test Report/certificate shall be enclosed along with bid. Further, design review of offered transformer shall be carried out based on the design of reference transformer, which has already been subjected to Short circuit tests in lieu of repetition of Short circuit tests. In case, manufacturer has not conducted short circuit test earlier, the same shall be carried out on offered transformer. However, considering the fact that dynamic short circuit tested design is not available for 765 kV voltage class Auto Transformer & 500 MVA, 400 kV voltage class Auto Transformer and testing of these transformers would require some more time, the above requirement of Dynamic short circuit (DSC) withstand test for these transformers shall be applicable for the projects for which bid invitation date is after **31st August 2023**. For these transformers, theoretical evaluation of the ability to withstand the dynamic effects of short circuit, based on calculation and consideration of the design characteristics and manufacturing practices, shall be carried out as per IS 2026-5/IEC 60076-5. A format (forms part of Annexure-J) filled with data of a typical sample case

	has been prepared for reference and guidance of utility to compare a Short Circuit tested transformer with the offered transformer in order to verify the similarity criteria as per Annexure J

Further, queries have been received in this office on applicability of subject document for the projects awarded before issuance of the document. In this regard, it is clarified that the subject document was issued in April 2021 and shall be applicable for projects which were awarded after the issuance of the document. Similarly, another document “Standard Technical Specification of transformers for Solar Park Pooling Station” was issued in June 2021 and shall be applicable for projects, which were awarded after the issuance of the document.

भवदीय/ Regards

Signature Not Verified

Digitally signed by AKSHAY DUBEY

Date: 2021.09.10 10:53:49 IST

(अक्षय दुबे / Akshay Dubey)

उप निदेशक / Deputy Director

आलोक कुमार, भा.प्र.से.
सचिव
भारत सरकार
Alok Kumar, I.A.S.
Secretary
Government of India

सत्यमेव जयते

Ministry of Power
Shram Shakti Bhawan
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FOREWORD

The complexity of Indian Power System has increased manifold with formation of one of the largest single Synchronous grid in the world. In present scenario, the major assets of a power system would play an important role not only in terms of investment but also in terms of availability and reliability of the system.Transformers and reactors as compensating device are the vital & essential assets in Power delivery system. Reliability and availability of such assets play important role in uninterrupted power supply and smooth operation of a power system.

The "Standard specifications and technical parameters for transformer and reactors (66 kV and above voltage class)" is a much awaited technical document thoroughly updated in line with national and international best practices for the benefit of all stakeholders involved. The manual has specifically been prepared keeping in view the domestic as well as international requirement by incorporation of best design practices, quality control and testing requirements.

The uniform practice across the utilities in the country would place all manufacturers at a level playing field and benefit indigenous manufacturers, reinforcing the vision of **Aatma-Nirbhar Bharat**. It would provide a further fillip to '**Make in India**' initiative. This initiative would simplify the procurement process, bringing in faster delivery, overall efficiency, quality and productivity in the entire value chain of transformer / reactor procurement & operation.

I thank members of the Committee and all contributors including officers of Central Electricity Authority (CEA) for their sincere efforts & invaluable contribution in bringing out this document. Since the consultation with large number of stake holders has already been held, I would urge for adoption of this standard specifications by the utilities and manufacturers across the country in true spirit in order to achieve the ultimate objective of cost effective uninterrupted (24x7) quality power to all consumers and smooth operation of the Power System.

Feedback from the users for improvement of the document is welcome.

(Alok Kumar)

RIGHT TO INFORMATION

स्वच्छ भारत
एक कदम स्वच्छता की ओर

प्रकाश मस्के
अध्यक्ष तथा पदेन सचिव भारत सरकार
Prakash Mhaske
Chairperson & Ex-officio Secretary
to the Government of India

सत्यमेव जयते

केन्द्रीय विद्युत प्राधिकरण
विद्युत मंत्रालय
सेवा भवन, आर, के, पुरम
नई दिल्ली–110066
Central Electricity Authority
Ministry of Power
Sewa Bhawan, R. K. Puram
New Delhi-110066

MESSAGE

The transformer and reactor are vital and expensive assets in Power delivery Chain. The generation capacity addition and increase in demand for energy will require enhancement in transformation capacity as well as reactive compensation. Reliability and availability of such important assets plays an important role in achieving the ultimate objective of delivery of uninterrupted (24x7) Quality power to all consumer at affordable rate and smooth operation of a power system.

Keeping above objectives in mind, Ministry of Power had constituted a committee for the standardization of technical specification of transformer & reactor incorporating the best practices & state-of-art technology which is the need of hour to ensure quality, reliability and long & trouble-free service.

I thank Members of the Committee, the Officers of CEA and all contributors for their invaluable input and sincere effort in bringing out the document on "Standard Specifications and Technical Parameters for Transformers and Reactors (66 kV & above voltage class)". This initiative would support the ambitious goal of "Local to Global" of Government of India (GoI) under "Make in India" (MII) program and would enhance the overall efficiency, quality and productivity in the entire value chain of transformer / reactor procurement & operation. The objective of this document is to formulate a standard document bringing out critical parameters of transformer and reactors which affects the quality, reliability, efficiency and cost of such assets.

I am sure that this document would benefit all the utilities and manufacturers across the country and adoption of this guideline in true spirit would achieve the ultimate objective of "One Nation One Specification" in the overall interest of Power system.

(Prakash Mhaske)

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सत्यमेव जयते

भारत सरकार
GOVERNMENT OF INDIA
केन्द्रीय विद्युत प्राधिकरण
CENTRAL ELECTRICITY AUTHORITY
विद्युत मंत्रालय
MINISTRY OF POWER
सेवा भवन, रामकृष्ण पुरम्
SEWA BHAWAN, RAMAKRISHNA PURAM

नई दिल्ली-110066, दिनांक :
New Delhi-110066, Dated

FOREWORD

The phenomenal growth of Indian Power transmission system has resulted in the formation of one of the largest Single Synchronous Grids (One Nation One Grid) in the world. The transmission system establishes the vital link between the generating source and the distribution system, connected to the ultimate consumers. In coming years, huge generation capacity addition including large scale integration of generation from renewable sources, increase in demand for energy, expansion of electricity market and power exchange between India & neighbouring countries would further require commensurate expansion & strengthening of the associated Transmission & Distribution network including enhancement in transformation capacity as well as reactive compensation.

Transformers and reactors are vital and expensive assets in power system. Emphasis needs to be laid on improved design, quality control during manufacturing, use of right components/accessories, proper Operation & Maintenance of such vital assets for trouble free service during its expected service life of about 35 years. The failure of such vital equipment can have a significant economic impact due to high cost, long lead time in procurement, manufacturing and installation. The standardization of technical specification of transformer & reactor incorporating the best design practices & state-of-art technology is the need of the hour as there is no uniform practice across the utilities in the Country.

The standardization of ratings & technical parameters, fixation of losses eliminating the need for capitalization of losses, provision of tertiary and OLTC, use of RIP/RIS/OIP bushings and their ratings & dimensions, details of BCT, use of CTC, digitalization and integration with BCU & SCADA system for control & monitoring of OLTC & cooler system, the similarity criteria with reference to Short Circuit testing of transformer, design review, improvement in basic Manufacturing & testing facility at manufacturer's works, MQP, inspection & testing, the key issues relating to transportation, handling, loading-unloading, Erection, Testing and commissioning, stringent measures to stop leakage of oil, introduction of Virtual inspection & testing as an alternative to conventional practice, standardization of foundation for interchangeability of different makes, roles & responsibilities of utility & manufacturer during the warranty period, condition assessment / monitoring etc. are some of the important aspects, which affects the quality, reliability, efficiency and cost of such assets, have been addressed in the document with clarity.

My sincere gratitude & thanks to members of the committee and all contributors including officers from CEA. I would like to express my sincere gratitude to Mr. Prakash Mhaske, Chairperson, CEA for his support and guidance in accomplishment of the task. I thank Mr. S.D. Dubey, Ex-Chairperson, CEA and Mr. K.K. Arya, Ex-Member (Hydro), CEA under whose guidance this exercise was initiated. My special thanks to IEEMA for the initiative and to my colleagues Mr. Sanjay Srivastav, Ex. Chief Engineer (HE&TD), Mr. A.K.Rajput, Chief Engineer (RT&I), Mr. Y.K.Swarnkar, Director (PSETD), Mr. Bhanwar Singh Meena, Mr. Faraz, Ms. Bhaavya Pandey, Mr. Karan Sareen and Mr. Apoorv Goyal from CEA; Mr. J Santosh from CPRI; Mr. Gunjan Agarwal, Mr. Richik Manas Das, Mr. Amandeep from Powergrid; Mr. Subhash Thakur, Mr. Mohd. Wasif, & Mr. Kaushik Das from NTPC; Mr. Rajesh Sharma, Mr. A. Tiwari & Mr. Niraj Singh from NHPC; Mr. P.K. Pattanaik from OPTCL, Mr. Loveleen Singh from DTL; Mr. Pramode Tupe & Mr. Sanjay Patki from Tata Power; Mr. Y.V.Joshi (Ex-GETCO); Mr. S.K. Mahajan, Mr. S.K.Gupta, Mr.R.K. Singh & Mr. A.Deota from BHEL; Mr. Gautam Mazumdar from CGL; Mr. Vikrant Joshi & Ms. Elizabeth Johonson from GE; Mr Jayasenen & Mr. Rakesh Patil from Siemens; Ms. Tanvi Srivastava & Mr. Tarun Garg from Hitachi ABB; Mr. Santanu Lahiri from Toshiba; Mr. S.P. Pathak from SJVNL; Mr. J.Pande & Mr. Uttam Kumar from IEEMA; Mr. Nirav Patel from Yash High Voltage and special invitees Mr. P. Ramchandran (Ex-ABB), Mr. M. Vijaykumaran (Ex-GE) and Mr. V.K. Lakhiani (Ex-BHEL) for their invaluable contribution, support and co-operation all through.

The process of standardisation would simplify the procurement process, bring faster delivery and would place all manufacturers at a level playing field. I am sure that the document would be useful to all stakeholders and adoption of this standard specifications of Transformer & reactor in true spirit would bring uniform practice across the utilities in the country and would achieve ultimate goal of quality, reliability & trouble free service of such vital assets in power delivery chain, which will be in overall interest of the Power System.



(S.K.Ray Mohapatra)

Chief Engineer (PSE&TD)

File No. 10/24/2016-PG
Government of India
Ministry of Power
Shram Shakti Bhawan, Rafi Marg,
New Delhi – 110001

Dated: 16th April, 2021

To,

Chairperson,CEA,
Sewa Bhawan, R.K Puram,
Sector-1, New Delhi - 110066

Kind Attn.: Sh. S.K Ray Mohapatra, Chief Engineer (PSETD)

Subject: Constitution of Standardization committee for preparation of Power Transformer Standardization manual-reg.

Sir,

I am directed to refer to CEA's letter dated 31.12.2020 and email dated 08.03.2021 on the subject cited above, forwarding therewith the report/document titled "Standard Specifications and Technical Parameters for Transformers and Reactors (66kV & above voltage class)" and to say that the subject document after incorporating the clause of 'Amendment Process' has been accepted.

2. CEA is advised to issue the document with all concerned Stakeholders and request them to adopt these standards.

3. This issues with the approval of Hon'ble Minister of State (Independent Charge) for Power & New Renewable Energy.

Yours faithfully,

(Sanjeev Jain)
Under Secretary to the Govt. of India

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Chapter-1

Introduction

CHAPTER -1

INTRODUCTION

The phenomenal growth of Indian Power transmission system has resulted in the formation of One Nation One Grid, one of the largest single synchronous Grids in the world. The transmission system establishes the vital link between the generating source and the distribution system connected to the ultimate consumer. A Robust, Reliable and Optimally Planned transmission network would facilitate in achieving ultimate objective of cost effective delivery of power and providing 24x7 Quality Power for All consumers at affordable rate. In coming years, huge generation capacity addition including large scale integration of generation from renewable sources, expansion of electricity market and exchange of Power between India & neighboring countries would further require commensurate expansion & strengthening of the associated Transmission & Distribution network. The complexity of Indian Power System has increased manifold over the years. With operation of multiple agencies (State Utilities, Central Utilities, and Private players) in power sector, high availability & reliable operation assumes tremendous importance in present scenario. In such a scenario, the major assets of a power system would play an important role not only in terms of investment but also in terms of availability and reliability of the system.

The transformer and reactor are vital and expensive assets in a power system. The increase in demand for energy will require enhancement in transformation capacity as well as reactive compensation requirement. Reliability and availability of such important assets plays an important role in the smooth operation of a power system. Emphasis needs to be laid on improved design, quality control during manufacturing, use of right components/accessories, maintenance and safety during operation of such vital assets. Generally, due to poor quality of raw material, workmanship, and manufacturing techniques or due to normal and abnormal stresses of the system during the operation (like frequent system faults, over loading, environmental effect, unexpected continuous operating voltage and over voltage stresses), and poor maintenance practice, transformers/reactors fail much before their expected life span (expected life span of about 35 years). The failure of such vital equipment can have significant economic impact due to high cost, long lead time in procurement, manufacturing and installation. Long repair time is a matter of concern in many cases of failure of transformer/reactor. Restoration of transformer/reactor takes about 3 to 6 months after major repair at manufacturer's works depending on the type of repair and procurement of

a new one requires 6-10 months depending on the voltage class of transformer/reactor.

There is no uniform practice across the utilities in the Country as far as the technical specification of transformer/reactor is concerned. At present, same rating/class of transformers/reactors are being designed differently even for the same user. Even for same specifications, manufacturer review design for successive tenders considering prevailing market condition. This results in unnecessary increase in design & manufacturing cycle time, cost, human efforts & inventories. In view of above there was need to address this issue and develop a standard/common design & engineering specification for transformer & reactor incorporating the best practices of various utilities, latest technological development and future trends, which would be followed by utilities & manufacturers across the Country. The objective of this initiative is to formulate a standard document bringing out critical technical parameters of transformer and reactors which affects the quality, reliability, efficiency and cost of such assets.

This standardization process shall have following advantages:

- The procurement process will be simplified and delivery time would be reduced resulting in early completion of project
- Due to standard design, frequent design reviews can be avoided
- Standard ratings and standard civil foundation block would facilitate interchangeability of different make of transformer / reactor
- Standard fittings and accessories
- Lesser requirement of inventories

Keeping in view above objective, Ministry of Power vide order no. 10/24/2016-PG dated 20.08.16, had constituted a committee under the Chairmanship of Member (Power System), CEA, with the following composition:

1. Member (Power System), CEA -- Chairman
2. CMD, PGCIL
3. Director (Trans), MoP
4. A representative from GETCO
5. A representative from RRVPN
6. A representative from HVPN
7. A representative from BHEL
8. A representative from IEEMA
9. Chief Engineer, CEA (Convenor)

The Terms of Reference of the Committee are as under:

a) To adopt country wide standard designs of Power transformers for each class ratings and performance parameter wise (including losses);
b) To reduce lead time, human efforts & errors during the transformer procurement process by adopting standard losses and detailed guaranteed technical particular (GTP) format;
c) To adopt specifications and application guides for various fittings and accessories for the selection and maintenance of transformer components;
d) To follow the Guidelines for preparation and checking of standard contract drawings preferred cooler and OLTC control schemes;
e) To adopt standard Manufacturing Quality Plan (MQP) for manufacturing, testing and packing of transformers to define and ensure quality for reliability;
f) To enhance the overall efficiency, quality and productivity in the entire value chain of transformer procurement and operation;
g) To achieve interchangeability of transformers of different make, procured by different utilities – by standardizing the losses, lay out and foundation plan of transformers; and
h) To achieve shorter deliveries of power transformers for timely and speedier completion of projects.

Several rounds of meetings were held in CEA with stake holders, utilities and manufacturers of transformer, reactor & their accessories for standardization of Technical Specification so that both utilities and manufacturers across the Country are benefitted and follow a uniform practice. **Although the terms of reference was focused exclusively for transformer, but the standardization process has been extended to cover the specification for the reactor of 220kV and above voltage system as well.**

This document/guidelines shall be applicable to new transformers/reactors of 66 kV and above voltage class. The document does not cover transformers suitable for Static Var Compensator (SVC), Static Compensator (STATCOM), traction transformers, welding transformers, testing transformers, mining transformers, furnace transformers and inverter transformer for Renewable generators.

This document covers only technical aspects pertaining to manufacturing, transportation, erection, testing, commissioning and condition monitoring of transformer/reactor. The commercial aspects, contractual terms, scope of works for OEM/contractor etc. may be defined by the utility as per its requirement and practice.

Some important points considered while preparing this document are as under:

1. The purpose of this document is: (a) to standardize the ratings; (b) bring uniformity in the design by fixing major technical parameters including maximum permissible losses, eliminating the need for capitalisation of losses; (c) facilitate physical inter-changeability of different makes by standardizing the common mounting arrangement/foundation plan; (d) improve manufacturing facility, reliability & quality of supply of Transformer/Reactor from all manufacturers; (e) achieve cost effective production & faster delivery; and (f) adoption of Condition Based Maintenance (CBM) practices across the utilities in the country to assess the health of assets.

2. Attempt has been made to standardize and restrict the number of ratings of Power Transformers and Reactors at different voltage levels so that the manufacturers shall have to design and manufacturer fewer ratings resulting in requirement of less inventory of components and faster delivery. In the process the focus will be on quality of production which will be in overall interest of utilities, manufacturers and the system.

3. Following ratings of power/auto transformers, Generator Transformers and reactors have been standardized based on general practice and most commonly used ratings in India.

POWER/ AUTO TRANSFORMERS:

Sr. No.	MVA Rating	Line Voltage Rating	Phase	Type
1.	500 MVA	(765/√3)/(400/√3)/33 kV	Single Phase	Auto Transformer
2.	500 MVA	400/220/33 kV *400/230/33 kV	Three Phase	Auto Transformer
3.	315 MVA	400/220/33 kV *400/230/33 kV	Three Phase	Auto Transformer
4.	167 MVA	(400/√3)/(220/√3)/33 kV *(400/√3)/(230/√3)/33 kV	Single Phase	Auto Transformer
5.	105 MVA	(400/√3)/(220/√3)/33 kV *(400/√3)/(230/√3)/33 kV	Single Phase	Auto Transformer

6.	315 MVA	400/132/33 kV	Three Phase	Auto Transformer
7.	200 MVA	400/132/33 kV *400/110/33 kV	Three Phase	Auto Transformer
8.	200 MVA	220/132 kV *230/110 kV *220/110 kV	Three Phase	Auto Transformer
9.	160 MVA	220/132 kV *230/110 kV *220/110 kV	Three Phase	Auto Transformer
10.	160 MVA	220/66 kV	Three Phase	Power Transformer
11.	100MVA	220/33 kV *230/33 kV	Three Phase	Power Transformer
12.	80 MVA	132/33 kV *110/33 kV	Three Phase	Power Transformer
13.	50 MVA	132/33 kV *110/33 kV	Three Phase	Power Transformer
14.	31.5 MVA	132/33 kV *110/33 kV	Three Phase	Power Transformer
15.	31.5 MVA	66/11 kV	Three Phase	Power Transformer
16.	20 MVA	66/11kV	Three Phase	Power Transformer
17.	12.5 MVA	66/11kV	Three Phase	Power Transformer

* See para 5 below.

GENERATOR TRANSFORMERS (For thermal plants):

Sr. No.	MVA Rating	Line Voltage Rating	Phase	Type
1.	315 MVA	Generation Voltage/(800/√3)kV	Single	GT
2.	265 MVA	Generation Voltage/(800/√3)kV	Single	GT
3.	315 MVA	Generation Voltage/(420/√3)kV	Single	GT
4.	265 MVA	Generation Voltage/(420/√3)kV	Single	GT
5.	200 MVA	Generation Voltage/(420/√3)kV	Single	GT

SHUNT REACTORS:

Sr. No.	MVAR Rating	Voltage Rating	Phase
1.	110 MVAR	765/√3 kV	Single Phase

2.	80 MVAR	765/√3 kV	Single Phase
3.	125 MVAR	420 kV	Three Phase
4.	80 MVAR	420 kV	Three Phase
5.	63 MVAR	420 kV	Three Phase
6.	50 MVAR	420 kV	Three Phase
7.	50 MVAR	245 kV	Three Phase
8.	25 MVAR	245kV	Three Phase

Note: *Primary voltage rating for Generator Transformers (GTs) could not be standardized as it depends on generator parameters and system requirement. The MVA ratings of GTs for thermal plants have been standardized for different voltage class. The MVA rating for GTs for Hydro plant may be decided by the respective utility. Although some ratings of Generator Transformers (GTs) could not be included due to certain technical limitations, the utility may take the help of this document for such ratings of GTs as far as possible.*

In view of objectives and benefits highlighted in following paragraphs, utilities are advised to procure transformers and reactors of these ratings only as far as possible. The transformers/reactors of other ratings should be procured only under special circumstances, for example to match with the rating of existing transformer and for parallel operation.

4. The fixation of maximum permissible loss values for transformers (No-load loss, Load loss, I^2R loss and auxiliary loss) and reactors (I^2R loss and total loss) has been done in consultation with utilities and manufacturers. The method of calculation of losses has been given along with a typical example for verifying the guaranteed values and for measurement at manufacturer works so that all utilities across the country get transformer and reactor of similar quality and efficiency. Manufacturer shall be penalized if losses measured during Factory Acceptance Test (FAT)/Routine tests are within +2% tolerance on maximum specified values, beyond which transformer/reactor would be liable for rejection. However, no incentive would be given to manufacturer for maintaining the losses less than the specified values. It is proposed to review the loss figures periodically based on the feedback from utilities and the manufacturers.

5. Tamil Nadu has 230 kV and 110 kV system and Karnataka has 110kV system which is different from the other States in the Country. Keeping in view the requirement of these two States, it was decided that loss figures for 400/230/33kV, 400/110/33kV,

220(or 230)/110kV, 230/33kV & 110/33kV transformers shall be same as that of 400/220/33 kV, 400/132/33 kV, 220/132kV, 220/33kV & 132/33kV transformers of identical MVA ratings respectively. However, the parameters for Bushing Current Transformers (BCTs) for these ratings have not been specified, utility may select BCT parameters as per their requirement.

6. In general, the tertiary windings have been removed in case of 3 limbed transformers (i.e. up to 200 MVA, 220 kV class transformer) to eliminate the possible failure due to tertiary winding, improve reliability and reduce overall cost. Unless there is special requirement like loading the tertiary, utilities are advised to avoid tertiary winding in transformers up to above mentioned ratings. The tertiary winding shall be capable of withstanding mechanical & thermal stress due to short circuit on its terminals and suitable for continuous thermal rating of 5MVA.

7. Keeping in view the infrequent use of OLTC and no significant voltage control/variation is being achieved by such use at 400 kV and 765 kV levels, it has been decided to have tap less 765/400/33kV ICTs to start with in order to simplify the design, eliminate failure due to OLTC, reduce the overall cost of transformer and improve the reliability of transformers. Based on the experience & feedback of the manufacturers and utilities, further initiative can be taken to have tap less transformers for lower voltage class transformers depending on system operation requirement. Reduction in tap range in case of other voltage class transformer will definitely simplify the lead design & the tap changer as number of lead connections gets reduced. Since many utilities did not like to reduce the tap range considering the system operating condition, no action could be taken in that direction. However, utilities are advised to explore the possibility of reduction in the tap range in OLTC as indicated at Annexure-A depending on their requirement and system condition.

8. During discussion in Standing Committee meetings relating to failure of sub-station equipment, it has been observed that bushing is one of the major cause of failure of transformer and in many cases this has led to severe consequences like fire/burning of transformer/reactors and explosion. Hence RIP/RIS bushings have been specified at various voltage levels in place of conventional OIP bushings. RIS would have been a better/preferred alternative to OIP, but due to limited manufacturer in the world, both RIP & RIS options have been considered.

9. Emphasis has been given to Design Review, which is the most important task to be carried out before commencement of the manufacturing of transformer/reactor to ensure its quality. The design review may be carried out by the purchaser or a consultant appointed by the purchaser. Design Review carried out by one utility for a specific transformer of a particular make, can also be used by another utility for the same design with the consent of the manufacturer. The Guaranteed and other technical particulars submitted by the manufacturer to the purchaser/ utility, would be used for technical evaluation, design review and verification of similarity criteria with reference to the Short Circuit tested transformer.

10. The requirement of SC testing has been emphasized in line with the provision of CEA (Technical Standards for Construction of Electric Plants and Electric lines) Regulations and repetition of SC test within validity period is not required provided the similarity can be established with reference to the SC tested transformer.

11. Customer/Purchaser always wishes that transformer/reactor manufactured and delivered must perform trouble free service for its "Specified Design Life". It is always a challenge for supplier/manufacturer to keep consistency in material used & manufacturing process, which are main cause for variation in quality of transformer/reactor. Customer practically cannot monitor them and is not expected to do so. The change in sub-vendors and skilled manpower (in the factory) from time to time also require due diligence to control and maintain the consistency of manufacturing process. It is also equally very important that transformer/reactor is manufactured in a clean dust free environment with humidity control. Any compromise on this aspect will have adverse effect on expected design life of transformer/reactor, no matter how good is the workmanship and quality of material used. The manufacturers are expected to develop their manufacturing facility at par with the global practices/standards to improve quality and manufacturing processes for transformer and reactor. This would enhance export potential & international acceptability of product. **The broad list of facilities the manufacturers should have are provided in Annexure-G. In case the manufacturer(s) do not have such facilities, it is to be ensured that such facilities are in place/developed within a period of two (2) years of release of this document.**

12. Considering the experience of COVID-19 pandemic, virtual inspection and testing has been introduced as an alternative to conventional practice of physical presence of representative of utility at manufacturer's works during inspection & testing.

13. The manufacturers have different arrangement of jacking and different spacing between jacking pads. Hence, it was difficult to standardize the civil foundation drawing based on jacking pad locations/arrangement. Design of block foundation based on maximum weight of transformer/reactor for a particular MVA/MVAR rating along with specified no. of rails with standard gauge (1676mm) and provision of suitable size of portable metal plate for jacking have been suggested to facilitate the physical interchangeability of transformers/reactors of different make on same foundation block. Thus, the outage time of replacement of spare/new transformer or reactor of different makes would be minimized as it can be accommodated in the same space with no or minor modification in foundation. The design requirement of soak pit and oil collecting pit for transformer/reactor has been clearly specified so that foundation design takes into account such provision.

14. It is a fact that during initial 5 years of operation many transformers/ reactors have failed. Therefore, during deliberation, utilities were insisting for inclusion of extended warranty/defect liability period for transformer/reactor up to 5 years to ensure supply of quality product by manufacturer. Manufacturers were of the opinion that utilities also have a major role to play in long and trouble free service of such assets. Good maintenance practice and regular monitoring of health of assets is equally important. Successful operation of transformer/reactor depends on operating conditions and O&M practices being followed by the utility. The extended warrantee period beyond normal period of warranty would have implication on overall cost of transformer/reactor. All utilities may not like to bear the extra burden on account of extended warranty, rather such utility may prefer to maintain the health of their assets properly for a long & trouble free service. Being a commercial issue, utilities and manufacturer may mutually decide about extended warranty/defect liability period. Leakage of Oil from transformer / reactor is construed as a serious quality lapse on the part of the Original Equipment Manufacturer (OEM). No leakage of oil is expected during the operating life of the transformer / reactor and accordingly OEM should ensure design & construction of tank & other gasketted joints.

However, the responsibilities of manufacturer and utility have been highlighted clearly & briefly in the document.

In general, all necessary steps should be taken to ensure that proper condition assessment/monitoring and maintenance of transformer/reactor is carried out effectively for a long & trouble free service. The condition monitoring tests include measurement of Insulation Resistance (IR), capacitance & tan-delta for winding & bushing, magnetic balance, winding resistance, turns ratio, oil Break Down Voltage (BDV), Dissolved Gas Analysis (DGA), thermal scanning, and Sweep Frequency Response Analysis (SFRA) etc. The frequency of tests and threshold values of various diagnostic parameters has been given to assess the condition of transformer or reactor for reference and guidance of utility. The frequency of tests may be increased depending on the condition assessment of transformer/reactor. The Pre-commissioning test results and the results of various tests carried out subsequently at sites shall be recorded religiously by the utilities. The trend analysis shall be carried out to take further course of action. The utility may procure and employ diagnostic equipment like DGA, winding resistance meter, SFRA, capacitance and tan delta measuring units etc. as per CEA (Grid Standards) Regulations either for each substation or cluster of substations depending on their assessment or requirement.

15. The management of such vital assets, when they are in service/operation as well as when they have outlived their expected life/at the end-of-life, is a challenging task for all utilities in a reformed power sector. Residual Life Assessment (RLA) would play a vital role while taking appropriate decisions on "Run-Refurbish-Replace (3 R's)", investment and future planning of the entire power system.

    For the oil-filled transformers, particularly which are in service for more than 15 years, it is advisable that the residual life should be estimated by assessing the extent of degradation of solid cellulosic paper insulation through Furan content analysis of oil and degree of polymerization of paper insulation. This would help utilities in making optimum use of transformers / reactors and also taking timely decision regarding Run-Refurbish-Replacement of transformers / reactors. Transformer Assessment Indices (TAIs) method may be used to identify the transformers which most urgently need attention or intervention.

16. Though the document prescribes uninhibited or inhibited (preferable) mineral insulating oil, utilities may use Ester (synthetic/natural) fluid for Transformer/Reactor as per their requirement. New generation insulating oils may also be considered provided any National or International standard is available for such oil. Accordingly, the temperature rise of oil over ambient temperature may be modified.

17. The specifications for firefighting system have not been included. But, the utilities shall ensure that adequate fire protection system including soak pit/oil collecting pits, fire separation walls (wherever required) and water hydrant system etc. are provided in line with CEA (Measures Relating to Safety and Electric Supply) Regulations.

18. As per CEA (Technical Standard for construction of Electrical Plants and Electric Lines) Regulations, minimum one single phase spare transformer/reactor shall be provided for the substations/ switchyards where single phase units have been installed to form three phase banks.

DOCUMENT OUTLINE:

The following Chapters along with number of **Annexures (Annexure-A to W)** have been included in the document:

Chapter 1: Introduction

This Chapter broadly covers the objective of formulation of this document/standard specification for transformer & reactor and brief on various Chapters and Annexures.

Chapter 2: Technical Specifications for Transformers and Reactors

This Chapter broadly covers the technical specification including broad construction features for winding, core, tank, bushings, other fittings & accessories, performance parameters like hot spot temperature, suitability to withstand various over voltages (TOV, over voltage due to Lightning and switching operations), thermal & dynamic SC withstand capability, and requirement of SC testing, the maximum temperature rise of oil & winding, cooling & on load tap changing system and associated digital control integrated with BCU/ SCADA system and the information to be provided on rating & diagram plate etc.

Chapter 3: Design Review

The stages in Design Review and mode of design review have been highlighted. The method of calculation of weight of core, flux density, no load loss, load loss, weight of copper, and current density etc. along with typical example has been given to help the user to verify the corresponding Guaranteed values.

Chapter 4: Quality Assurance Program

This Chapter covers typical Manufacturer's Quality Program (MQP), Inspection and testing including Stage inspection, Factory Acceptance Tests, testing of fittings and accessories, Tank tests and pre-shipment checks at manufacturer's works etc.

Chapter 5: Transport, Erection, Testing and Commissioning

The key issues relating to transportation, handling, loading-unloading, Erection, Testing and commissioning; checks after receipt at site; storage at site; precautions during erection including oil filling; pre-commissioning checks/tests; and final commissioning checks before energization are covered in this Chapter.

Chapter 6: Condition Monitoring and Life Cycle Management

This Chapter briefly highlights about various maintenance practices, benefit of Condition Based Maintenance (CBM), on-line monitoring (measurement of Partial Discharge, On-line DGA, Hot spot monitoring, on-line dry out system, thermo-vision scanning etc.) and off-line monitoring (measurement of winding resistance, voltage ratio, magnetizing current, Polarization Index (PI), capacitance & Tan delta measurement, Short circuit impedance, oil parameters and Frequency Response Analysis etc.), Reliability Centered Maintenance (RCM) and Transformer Assessment Indices (TAIs) method as per CIGRE document (WG A2.49)..). The frequency of tests to be carried out using various diagnostic tools and acceptance norms/threshold values corresponding to various diagnostic parameters like capacitance & Tan delta values, contact resistance and PI etc. has been given to assess the condition of transformer or reactor for reference and guidance of utility to take further course of action. The frequency of tests may be increased depending on the condition assessment of transformer/reactor.

The purpose of various diagnostic tests for condition monitoring & health assessment and acceptance norms for various diagnostic parameters for transformers/reactors has been explained briefly in this Chapter.

The major technical parameters like BILs of winding & bushings, temperature rise, losses etc. of single phase & three phase transformer & reactors and technical parameters of Bushing Current Transformers have been included as **Annexure– A & B respectively**. The insulation level of terminal bushings has been considered as one step higher than corresponding winding insulation level.

Annexure-C (Guaranteed and other technical particulars) lists out various technical parameters including guaranteed parameters which are to be furnished by the manufacturer to the purchaser or utility.

A typical test plan and test procedures for Transformers/Reactors have been listed in **Annexure-D**.

A typical Manufacturer's Quality Plan (MQP) have been listed in **Annexure-E**.

Typical example for calculation of flux density, core quantity, no-load loss and weight of copper for the benefit of the utilities has been provided at **Annexure-F**

The broad list of facilities the manufacturer(s) should have at its works has been provided in **Annexure-G.**

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

The scope of design review is covered in **Annexure-I.**

Annexure-J specifies criteria with typical example to establish similarity of offered transformer with reference to the Short Circuit tested transformer.

The painting procedure, parameters of unused inhibited/uninhibited Insulating Oil are given in **Annexure – K, Annexure - L** respectively.

In **Annexure-M**, rating & dimensions for condenser bushings (inside the transformer / reactor including space for BCT) has been standardized for particular voltage and current rating so that bushings of different makes are interchangeable.

A typical connection arrangement for bringing spare unit into the circuit in case of failure/outage of one of the other healthy units has been included in **Annexure-N.**

Typical arrangement for neutral formation for single phase units is given in **Annexure – O.**

Annexure-P covers the aspects related to the physical interchangeability of transformers and reactors of different makes on same foundation block (designed based on maximum weight) using portable metal plate for jacking and the design requirement of soak pit and oil collecting pit for taking into account in foundation design for transformer/reactor.

The GA drawing specifically for Hydro Plants has been given at **Annexure-Q**.

The details of 1100 V grade power and control cable, Specification for Oil Storage Tank, Breakdown Voltage (BDV) test set, portable DGA kit for transformer oil, online insulating oil drying system, Oil sampling bottles, Oil Syringe and has been included in **Annexure-R, S, T & U & V** for the reference of the utility.

The list of applicable Codes/Standards/Regulations/Publications is given at **Annexure-W.**

There may be financial implication on the overall cost of transformer or reactor due to standardization of certain technical parameters, fixation of losses, inclusion of certain specific construction features and use of specific component & material etc. However, if the overall Life Cycle Cost (LCC) is taken into consideration, the benefit will ultimately outweigh the initial increase in cost.

Standardisation is a continuous process which ensures improvement over the existing technology and standard practices being followed. The much awaited technical document has been thoroughly updated in line with national and international best practices for the benefit of all stakeholders involved. The manual has specifically been prepared keeping in view the domestic as well as international requirement by incorporation of best design practices, Quality control and testing requirements. Hence **a committee under Chairmanship of Member (Power System) with representation from stakeholders (IEEMA, EPTA, CPRI, POWERGRID, NTPC, NHPC, Two STUs) and CE (PSETD) as Member Secretary would review the requirement of updation of the document in every two (2) years unless there is any urgency requiring modification.**

All utilities across the country are advised to follow this document/ guidelines in true spirit to achieve the ultimate goal of "One Nation One Specification".

Chapter-2

Technical Specifications for Transformers & Reactors



CHAPTER-2

TECHNICAL SPECIFICATIONS FOR TRANSFORMERS AND REACTORS

1.0 GENERAL

1.1 This chapter covers specification for design, engineering, manufacture, testing, delivery at site including all materials, accessories, unloading, handling, proper storage at site, erection, testing and commissioning of the Transformer, Shunt Reactor and Neutral Grounding Reactor (NGR) specified.

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

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

1.4 Components having identical rating shall be interchangeable.

2.0 SPECIFIC TECHNICAL REQUIREMENTS

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

3.0 GUARANTEED AND OTHER TECHNICAL PARTICULARS

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

4.0 STANDARD RATINGS OF TRANSFORMER AND REACTOR

Standard ratings of transformer and reactor have been provided in **Chapter-1: Introduction**. It is desirable that Transformers & Reactors of only these ratings are procured by utilities to have standard ratings across the country. The transformers/reactors of other ratings should be procured only under special circumstances, for example to match with the rating of existing transformer for parallel operation.

5.0 PERFORMANCE

5.1 Transformer

5.1.1 The power and auto transformers shall be **used for bi-directional flow of rated power**. The generator transformer would step up the generation voltage to specified voltage for power evacuation. Generator Transformer should be suitable for back charging from HV side and shall be used to step down the voltage for feeding loads through unit transformer. The major technical parameters of single phase and three phase transformer units are defined at **Annexure – A.**

5.1.2 Transformers shall be capable of operating under natural cooled condition up to the specified load. The forced cooling equipment, wherever specified, shall come into operation by pre-set contacts of winding temperature indicator and the transformer shall operate in forced cooling mode initially as ONAF (or ONAF1, as specified) up to specified load and then as OFAF (ONAF2 or ODAF or ODWF, as specified). Generator transformer with unit coolers shall operate at OFAF/ODAF cooling. **The Cooling system shall be so designed that the transformer shall be able to operate at full load for at least ten (10) minutes in the event of total failure of power supply to cooling fans and oil pumps without the calculated winding hot spot temperature exceeding 140 deg C. If the Transformer is fitted with two cooler banks, each capable of dissipating 50 per cent of the loss at continuous maximum rating, it shall be capable of operating for 20 minutes at full load /continuous maximum rating in the event of failure of the oil circulating pump or fans/blowers associated with one cooler bank without the calculated winding hot spot temperature exceeding 140 deg C. The contractor shall submit supporting calculations for the above and the same shall be reviewed during design review**.

5.1.3 The transformer shall be **free from any Electrostatic Charging Tendency** (ECT) under all operating conditions and maximum oil

velocity shall be such that it does not lead to static discharges inside the transformer while all coolers are in operation.

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

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

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

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

5.1.8 The transformer and all its accessories including bushing/built in CTs etc. shall be designed to withstand the thermal and mechanical effects of any external short circuit to earth and of short circuits at the terminals of any winding without damage. **The transformer shall be designed to withstand the thermal stress due to short circuit for a duration of 2 seconds** and the same shall be verified during design review. However, **generator transformer and associated auxiliary transformer shall be designed to withstand the thermal stress due to short circuit for a duration of 3 seconds**.

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

765kV system	- 63 kA for 1 sec (sym, rms, 3 phase fault)
400kV system	- 63 kA for 1 sec (sym, rms, 3 phase fault)
220kV system	- 50 kA for 1 sec (sym, rms, 3 phase fault)
132kV system	- 40 kA for 1 sec (sym, rms, 3 phase fault)
66kV system	- 31.5 kA for 1 sec (sym, rms, 3 phase fault)

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

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

Mechanical strength of the transformer shall be such that it can withstand 3-phase and 1- phase through fault with rated voltage applied to HV and/or IV terminals of transformer. The short circuit shall alternatively be considered to be applied to each of the HV, IV and tertiary (LV) transformer terminals as applicable. The tertiary terminals shall be considered not connected to system source. For short circuit on the tertiary terminals, the in-feed from both HV & IV system shall be limited by the transformer self-impedance only and the rated voltage of HV and IV terminals shall be considered.

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

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

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

5.1.12 **The air core reactance of HV winding of transformer of 400 kV and above voltage class shall not be less than 20%.** External or internal reactors shall not be used to achieve the specified HV/IV, HV/LV and IV/LV impedances.

5.2 Tertiary Windings (if applicable as per Annexure - A)

The tertiary windings shall be suitable for connection of reactors or capacitors which would be subjected to frequent switching and shall be suitable for connection to LT Transformer for auxiliary supply. All the windings shall be capable of withstanding the stresses which may be caused by such switching. **The tertiary winding shall be designed to withstand mechanical and thermal stresses due to dead short circuit on its terminals and for 1/3rd of the MVA capacity of the transformer although the cooling for continuous thermal rating of the tertiary winding shall be for 5MVA capacity. Tertiary, if not loaded, i.e. not connected to reactor, capacitor or LT transformer etc., its terminals shall be insulated to avoid any accidental short circuiting.**

5.3 Shunt Reactor and Neutral Grounding Reactor (NGR)

5.3.1 Shunt reactors will be connected to the transmission system for reactive compensation and shall be capable of controlling the over voltages occurring in the system.

5.3.2 The neutral grounding reactor is required for grounding of the neutral point of shunt reactor (for line reactor only) to limit the secondary arc current and the recovery voltage to a minimum value.

5.3.3 **765 kV shunt reactors shall be designed for switching surge overvoltage of 1.9 p.u. and temporary over voltage of the order of 1.4 p.u. for about 15 cycles followed by power frequency overvoltage upto 830 kVrms for about five minutes. The reactor shall withstand the stress due to above transient conditions which may cause additional current flow as a result of changed saturation characteristics/slope beyond 1.25 p.u. voltage.**

5.3.4 **420 kV and below shunt reactors shall be designed for switching surge overvoltage of 2.5 p.u. and temporary overvoltage of the order of 2.3 p.u. for few cycles followed by power frequency overvoltage upto 1.5 p.u. The reactor must withstand the stress due to above transient conditions which may cause additional current flow as a result of changed saturation characteristics/ slope beyond 1.5 p.u.**

5.3.5 **The thermal and cooling system shall be designed for maximum continuous operating voltage U_m (where U_m= 800/√3 kV for 765/√3 kV reactor; 420 kV for 420 kV reactor & 245 kV for 245 kV reactor).**

5.3.6 **In addition, the reactors shall be designed to withstand the following over-voltages repeatedly without risk of failure (w.r.t. Hotspot temperature of 140 ^oC & core saturation):**

1.05 U_m Continuous (for 765 kV & 420 kV reactor)
1.10 U_m Continuous (for 245 kV reactor)
1.50 U_m for 5 seconds
1.25 U_m for 1 minute

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

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

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

5.3.10 The magnetic circuit shall be designed such that the magnetic characteristic of reactor is linear upto voltage specified at **Annexure–A.**

5.4 Radio Interference and Noise Level

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

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

6.0 MAXIMUM LOSSES

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

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

3	Auxiliary Losses	Rs. 8,00,000/KW
Note: For a fraction of a kW, the penalty shall be applied on pro rata basis.		

7.0 DYNAMIC SHORT CIRCUIT TEST REQUIREMENT AND VALIDITY

The transformer, the design of which is similar to the offered transformer, should have been successfully tested for short circuit withstand capability as per IS 2026 Part-5 in line with the requirement of CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations. **The criteria for similar transformer is specified in Annexure-J.** The relevant Test Report/certificate shall be enclosed along with bid. Further, design review of offered transformer shall be carried out based on the design of reference transformer, which has already been subjected to Short circuit tests in lieu of repetition of Short circuit tests. In case, manufacturer has not conducted short circuit test earlier, the same shall be carried out on offered transformer.

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

8.0 TYPE TESTS REQUIREMENT AND VALIDITY

The offered transformer/reactor or the transformer/reactor, the design of which is similar to the offered transformer/reactor, should have been successfully type tested within last 5 years as on the last date of submission of bid. Manufacturer may use same or different approved make of Bushings, Tap changer and other accessories used in type tested or short circuit tested unit in their transformer/reactor. Further, **type test report of transformer/reactor shall only be acceptable provided the offered transformer/reactor has been manufactured from the same plant**.

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

9.0 DESIGN REVIEW

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

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

9.3 The design review shall be finalised before commencement of manufacturing activity and shall be conducted generally following the "CIGRE TB 529: Guidelines for conducting design reviews for power transformers". However, salient points on design review has been specified in **"Chapter-3: Design Review"**.

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

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

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

10.0 SERVICE CONDITION

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

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

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

11.0 CONSTRUCTION DETAILS

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

11.1 Tank & tank cover

11.1.1 The tank shall be of proven design of either **Bell type with bolted/ welded joint or conventional (preferable) with bolted/welded top cover. Bell type tank, if provided, shall have joint as close as possible to the bottom of the tank.**

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

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

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

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

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

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

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

11.1.8 Tank stiffeners shall be provided for general rigidity and welded to the tank continuously along its ends and sides (Intermittent welds will not be accepted). These shall be designed to prevent retention of water. Sharp edges on stiffeners should be avoided for better paint adhesion.

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

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

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

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

11.1.13 The tank cover shall be provided with pockets for oil and winding temperature indicators. The location of pockets (for OTI, WTI & RTDs including two spare pockets) shall be in the position where oil reaches maximum temperature. Further, it shall be possible to remove bulbs/probes of OTI/WTI/RTD without lowering the oil in the tank. The thermometer shall be fitted with a captive screw to prevent the ingress of water.

11.1.14 It should be possible to inspect Buchholz relay or Oil surge relay, standing on tank cover or suitable arrangement shall be made to access Buchholz relay safely.

11.1.15 The tank cover shall be designed to prevent retention of rain water Bushing turrets, covers of inspection openings, thermometer pockets etc. shall be designed to prevent ingress of water into or leakage of oil from the tank.

11.1.16 Minimum four symmetrically placed lifting lugs of adequate size shall be provided so that it will be possible to lift the complete transformer/reactor when filled with oil & without structural damage to any part of the transformer/reactor. The factor of safety at any lug shall not be less than 2. Suitable haulage holes shall also be provided.

11.1.17 **A minimum of four jacking pads (not fouling with rail, rollers or other accessories) shall be provided in accessible position** to enable the transformer complete with oil to be raised or lowered using hydraulic jacks. The location shall be such that it should not interfere with loading & unloading from trailer.

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

11.1.19 The tank shall be provided with suitable valves as specified in **Clause 20: Valves and Clause 28: "Fittings and accessories"** of this chapter. Location of valves shall be finalized during design review.

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

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

11.1.22 **Gas venting** : The transformer/reactor cover and generally the internal spaces of the transformer/reactor and all pipe connections shall be designed so as to provide efficient venting of any gas in any part of the transformer/reactor to the Buchholz relay. The space created under inspection /manhole covers shall be filled with suitable material to avoid inadvertent gas pockets. The Covers shall be vented at least at both longitudinal ends. The design for gas venting shall take into accounts the slopes of the plinth (if any) on which the transformer/reactor is being mounted.

11.2 Gasket for tank & cover

All gasketed joints shall be designed, manufactured and assembled to ensure long-term leak proof and maintenance free operation. **All gasketed joints shall preferably be O-ring and designed with gasket-in-groove arrangement.** If gasket/O-rings is compressible,

metallic stops/other suitable means shall be provided to prevent over-compression. All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. All matching flanges of gasket sealing joints should be machined (except curb joints). Gasket with intermediate stops are not acceptable. To the extent possible, the seamless gasket should be used for openings on tank/cover such as turrets, bushing, inspection covers etc. **All tank gaskets/O-rings used shall be of NBR (Acrylonitrile Butadiene Rubber)** suitable for temperature conditions expected to be encountered during operation. The gasket material and additives should be fully compatible with transformer insulating fluid/oil. The gasket should not contain oil soluble sulphur compounds. The properties of all the above gaskets/O-Rings shall comply with the requirements of type-IV rubber of IS-11149. Gaskets and O-rings shall be replaced every time whenever the joints are opened.

11.3 Foundation, Roller Assembly and Anti Earthquake Clamping Device

11.3.1 **Transformer shall be placed on foundation either directly or on roller assembly. Reactor shall be placed directly on concrete plinth foundation.**

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

11.3.3 **The rail track gauge shall be 1676 mm. Single Phase auto transformers of 765kV class and 3-Phase auto transformers of 400kV class shall have four (4) rails and other voltage class transformers shall have two (2) rails. However, Generator transformers of 765kV & 400kV class (single phase units) may have two (2)/three (3) rails.**

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

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

11.3.6 For foundation of separately mounted cooler bank of transformer/reactor, fixing of cooler support shall be through Anchor Fastener with chemical grouting and no pockets for bolting shall be provided.

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

11.3.8 All control cubicles shall be mounted at least one meter above Finished Ground Level (FGL) to take care of water logging during flooding. Suitable arrangement (ladder and platform) shall be provided for safe access to control cubicles.

11.4 Conservator

11.4.1 The conservator of main tank shall have **air cell type** constant oil pressure system to prevent oxidation and contamination of oil due to contact with moisture. Conservator shall be **fitted with magnetic oil level gauge with potential free high and low oil level alarm contacts and prismatic oil level gauge.**

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

11.4.3 Conservator tank shall have adequate capacity with highest and lowest visible-levels to meet the requirements of expansion of total cold oil volume in the transformer and cooling equipment from minimum ambient temperature to top oil temperature of 100 deg C. The capacity of the conservator tank shall be such that the transformer shall be able to carry the specified overload without overflowing of oil.

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

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

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

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

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

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

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

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

11.4.12 **Conservator Protection Relay (CPR)/Air cell puncture detection relay** shall be externally installed on the top of conservator to give alarm in the event of lowering of oil in the conservator due to puncture of air cell in service.

11.5 Piping works for conservator

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

11.5.2 The feed pipe to the transformer/reactor tank shall enter the cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the transformer/reactor side of the Buchholz relay, and straight for not less than three times that diameter

on the conservator side of the relay. **This pipe shall rise towards the oil conservator, through the Buchholz relay, at an angle of not less than 3 degrees**. The feed pipe diameter for the main conservator shall be not less than 80mm. The Gas-venting pipes shall be connected to the final rising pipe between the transformer/reactor and Buchholz relay as near as possible in an axial direction and preferably **not less than five times pipe diameters from the Buchholz relay**.

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

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

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

11.6 Dehydrating Silica gel Filter Breather

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

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

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

11.7 Pressure Relief Device (PRD)

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

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

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

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

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

11.8 Sudden Pressure Relay/ Rapid Pressure Rise Relay (for 220kV and above transformer/reactor)

One number of Sudden Pressure Relay/ Rapid Pressure Rise Relay with alarm or trip contact (Terminal connection plug & socket type arrangement) shall be provided on tank of transformer/reactor. Operating features and size shall be reviewed during design review. **Suitable canopy** shall be provided to prevent ingress of rain water.

Pressurised water ingress test for Terminal Box (routine tests) shall be conducted on Sudden Pressure Relay/ Rapid Pressure Rise Relay.

11.9 Buchholz Relay

Double float, reed type Buchholz relay complying with IS:3637 shall be connected through pipe between the oil conservator and the transformer/reactor tank with minimum distance of five times pipe diameters between them. Any gas evolved in the transformer/reactor shall be collected in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation and taking gas sample. A copper tube shall be connected from the gas collector to a valve located about 1200 mm above ground level to facilitate sampling while the transformer/reactor in service. **Suitable canopy** shall be provided to prevent ingress of rain water. It shall be provided **with two potential free contacts** (Plug & socket type arrangement), **one for alarm/trip on gas accumulation and the other for tripping on sudden rise of pressure.**

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

11.10 Oil Temperature Indicator (OTI)

The transformer/reactor shall be provided with a dial type thermometer of about **150mm diameter for top oil temperature indication with angular sweep of 270°. Range of temperature should be 0-150°C with accuracy of ±1.5% (or better) of full scale deflection**. The instruments should be capable of withstanding high voltage of 2.5kV AC rms, 50Hz for 1 minute. The terminal provided for auxiliary wiring should be Press-fit type.

The thermometer shall have adjustable, **potential free alarm and trip contacts** besides that required for control of cooling equipment (if any), maximum reading pointer and resetting device, switch testing knob & anti-vibration mounting grommets (for projection mounting). Type of switch (NO/NC) shall be heavy duty micro switch of 5A at 240V AC/DC. Adjustable range shall be 20-90% of full scale range. The instruments case should be weather proof with epoxy coating at all sides.

Instruments should meet **degree of protection of IP55** as per IS/IEC-60529. A temperature sensing bulb located in a thermometer pocket on tank cover should be provided to sense top oil. This shall be connected to the OTI instrument by means of flexible stainless steel armour to protect capillary tubing. Temperature indicator dials shall have linear gradations to clearly read at least every 2 deg C. The setting of alarm and tripping contacts shall be adjustable at site.

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

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

Temperature transducer with PT100 sensor

RTD shall be provided with PT100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The PT100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per IS 2848 or equivalent. The PT100 sensor may be placed in the pocket containing temperature sensing element. RTD shall include image coil for OTI system and shall provide dual output 4-20mA for SCADA system. The transducer shall be installed in the Individual Marshalling Box. Any special cable required for shielding purpose, for connection between PT100 temperature sensor and transducer, shall be in the scope of manufacturer. 4-20mA signal shall be wired to Digital RTCC panel/BCU for further transfer data to SCADA through IS/IEC 61850 compliant communications.

11.11 Winding Temperature Indicator (WTI)

The transformer/reactor shall be provided with a dial type hot spot indicator of **about 150mm diameter for measuring the hot spot temperature of each winding** [HV, IV & Tertiary (if applicable)]. It shall have **angular sweep of 270°. Range of temperature should be 0-150°C with accuracy of ±1.5% (or better) of full scale deflection**. The instruments should be capable of withstanding high voltage of 2.5kV AC rms, 50Hz for 1 minute. The terminal provided for auxiliary wiring should be Press-fit type.

The thermometer shall have adjustable, **potential free alarm, trip contacts** besides that required for control of cooling equipment, if any. Instrument should be provided with maximum reading pointer and resetting device, switch testing knob & anti-vibration mounting grommets (for projection mounting). Type of switch (NO/NC) shall be

heavy duty micro switch of 5A at 240V AC/DC. Adjustable range shall be 20-90% of full scale range. The instruments case should be weather proof and epoxy coating at all sides. Instruments should meet **degree of protection of IP55** as per IEC60529. A temperature sensing bulb located in a thermometer pocket on tank cover should be provided to sense top oil. This shall be connected to the WTI instrument by means of flexible stainless steel armour to protect capillary tubing. WTI shall have image coil and auxiliary CTs, if required to match the image coil mounted in local control box. The setting of alarm and tripping contacts shall be adjustable at site.

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

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

Temperature transducer with PT100 sensor for each winding

RTD shall be provided with PT100 temperature sensor having nominal resistance of 100 ohms at zero degree centigrade. The PT100 temperature sensor shall have three wire ungrounded system. The calibration shall be as per IS 2848 or equivalent. The PT100 sensor may be placed in the pocket containing temperature sensing element. RTD shall include image coil, Auxiliary CTs, if required to match the image coil, for WTI system and shall provide dual output 4-20mA for remote WTI and SCADA system individually. The transducer and Auxiliary CT shall be installed in the Individual Marshaling Box. Any special cable required for shielding purpose, for connection between PT100 temperature sensor and transducer, shall be in the scope of Contractor. 4-20mA signal shall be wired to Digital RTCC / BCU panel for further transfer data to SCADA through IS/IEC 61850 compliant communications.

11.12 Earthing Terminals

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

11.12.2 **Two earthing terminals** suitable for connection to **75 x 12 mm galvanised steel flat** shall also be provided **on each cooler, individual/common marshalling box and any other equipment mounted separately.** For the tank-mounted equipment like online drying/Online DGA/Optical Sensor Box etc., (if provided), double earthing shall be provided through the tank for which provision shall be made through tank and connected through two flexible insulated copper link.

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

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

11.13 Core

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

11.13.2 The design of the magnetic circuit shall be such as to avoid static discharges, development of short circuit paths within itself or to the earthed clamping structure and production of flux component at right angles to the plane of laminations which may cause local heating. The step-lap construction arrangement is preferred for better performance in respect of noise, no-load current and no-load loss.

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

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

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

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

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

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

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

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

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

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

11.13.13 **In addition to above following additional provisions for reactors shall be applicable:**

a) The **leg magnetic packets (cheeses)** shall be made from state of the art **low loss electrical steel CRGO** (conventional/regular grade or better). The "Cheeses" shall be designed to minimize losses and equalize the distribution of flux in the legs.

b) The **"cheeses**" shall be **bonded using high temperature epoxy resins** to assure that they will remain bonded in service at the

maximum temperatures that will occur in the magnetic circuit and for the full expected life. Vacuum impregnation is preferred. The contractor shall present data on the characteristics of the packets at the time of design review.

c) Material with high temperature withstand capability such as ceramic/ slate spacers shall be used to separate the packets. High temperature, mechanically stable material shall be used between the end packets and the top and bottom yokes. Special care shall be taken not to impede the cooling in these areas.

d) Means shall be provided to distribute the flux from the "cheeses" and the windings to the top and bottom yokes to prevent concentrations of flux with resulting high temperatures in the yokes.

e) The yokes shall be designed such that high temperatures resulting from unequal distribution of the flux in the yokes will not occur.

f) The spaces between "cheeses" will be designed so that high temperatures will not result due to fringing of flux at the oil gaps between them. The designer shall calculate the temperatures resulting from fringing.

g) The structural design shall be made so that pressure will be maintained to prevent loosening resulting from thermal expansion and contraction during all loading cycles.

h) The design shall be made in such a way that excessive vibration does not occur in the windings, structural supports of the windings and magnetic circuit and this will be subjected to design review.

i) The structure shall be designed to withstand the clamping and magnetic forces. The calculated magnetic forces will be furnished at the time of design review.

11.14 Windings

11.14.1 The manufacturer shall ensure that **windings of all transformers/reactors are made in clean, dust proof** (Cleanroom class ISO 9 or better as per ISO 14644-1), **humidity controlled environment with positive atmospheric pressure.**

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

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

11.14.3 The conductor shall be transposed at sufficient intervals in order to minimize eddy currents and to equalise the distribution of currents and temperature along the winding.

11.14.4 The conductor insulation shall be made from **high-density (at least 0.75 gm/cc) paper** having high mechanical strength. The characteristics for the paper will be reviewed at the time of design review.

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

11.14.6 Coil assembly and insulating spacers shall be so arranged as to ensure free circulation of oil and to reduce the hot spot of the winding.

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

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

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

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

11.14.11 All insulating materials and structures shall be protected from contamination and the effects of humidity during and after fabrication, and after receipt, by storing them in a separate, climate-controlled area. All blocks shall be installed such that the grain is oriented in the horizontal direction, perpendicular to the winding compressive forces.

Aspect ratio of selected conductor shall be chosen suitably based on manufacturer experience to result in stable winding under normal and abnormal service condition after assembly.

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

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

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

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

11.15 Current carrying connections

The mating faces of bolted connections shall be appropriately finished and prepared for achieving good long lasting, electrically stable and effective contacts. All lugs for crimping shall be of the correct size for the conductors. Connections shall be carefully designed to limit hot spots due to circulating eddy currents.

11.16 Winding terminations into bushings

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

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

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

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

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

12.0 PAINT SYSTEM AND PROCEDURES

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

13.0 INSULATING OIL

The insulating oil shall be **unused inhibited (Type A, High Grade) (should be preferred) or uninhibited Transformer Oil conforming to IEC-60396-2020 & all parameters specified at Annexure–L,** while tested at oil supplier's premises. The contractor shall furnish test certificates from the supplier against the acceptance norms as mentioned at Annexure–L, prior to despatch of oil from refinery to site. Under no circumstances, poor quality oil shall be filled into the transformer and thereafter be brought up to the specified parameter by circulation within the transformer. The Unused Insulating Oil parameters including parameters of oil used at manufacturer's works, processed oil, oil after filtration and settling are attached at Annexure–L. The oil test results shall form part of equipment test report.

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

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

13.1 Particles in the oil (For 400 kV and above transformer & reactor)

The particle analysis shall be carried out in an oil sample taken **before carrying out FAT at manufacturer's works and after completion of the oil filtration at site.** The procedure and interpretation shall be in accordance with the recommendation of CIGRE report WG-12.17- "Effect of particles on transformer dielectric strength". Particle limit as shown below shall be ensured by manufacturer, implying low contamination, as per CIGRE Brochure 157, Table 8. After filtration the oil is to be flushed and particle count to be measured.

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

14.0 CONNECTION ARRANGEMENT OF SPARE UNIT WITH OTHER SINGLE PHASE TRANSFORMER/REACTOR UNITS

Detail connection arrangement for bringing spare unit into service for replacement of one of the single phase transformer/reactor units of a three phase bank is enclosed at **Annexure-N.**

15.0 BUSHINGS

15.1 **For various voltage class of transformer/reactor, type of bushings shall be as follows:**

Voltage Rating	**Bushing Type**
145 kV, 245 kV and 420 kV bushings for 400 kV and below voltage class transformers and reactors	RIP/RIS
420 kV and 800 kV bushings for 765 kV Class transformer; 800 kV bushings in 765 kV Class reactor	OIP/RIP/RIS
Bushings of 36 kV and below	Solid porcelain or oil communicating type OIP (For high current requirement e.g. for GTs)
Bushings of other rating	OIP/RIP/RIS

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

15.2 Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition, substation layout and movement along with the spare transformer/reactor with bushing erected and provided with proper support from one foundation to another foundation within the substation area. The electrical and mechanical characteristics of bushings shall be in accordance with IS/IEC: 60137. All details of the bushing shall be submitted for approval and design review.

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

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

15.4 Porcelain used in bushing manufacture shall be homogenous, free from lamination, cavities and other flaws or imperfections that might affect the mechanical or dielectric quality and shall be thoroughly vitrified, tough and impervious to moisture.

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

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

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

15.8 **Polymer insulator** shall be seamless sheath of a silicone rubber compound. The housing & weather sheds should have **silicon content of minimum 30% by weight**. It should protect the bushing against environmental influences, external pollution and humidity. The interface between the housing and the core must be uniform and without voids. The strength of the bond shall be greater than the tearing

strength of the polymer. The manufacturer shall follow non-destructive technique (N.D.T.) to check the quality of jointing of the housing interface with the core. The technique being followed with detailed procedure and sampling shall be finalized during finalization of MQP. The weather sheds of the insulators shall be of alternate shed profile as per IS 16683-3/IEC 60815-3. The weather sheds shall be vulcanized to the sheath (extrusion process) or moulded as part of the sheath (injection moulding process) and free from imperfections. The vulcanization for extrusion process shall be at high temperature and for injection moulding shall be at high temperature & high pressure. Any seams/ burrs protruding axially along the insulator, resulting from the injection moulding process shall be removed completely without causing any damage to the housing. The track resistance of housing and shed material shall be class 1A4.5 according to IS 9947. The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. **The polymer insulator shall be capable of high pressure washing.**

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

15.10 The hollow silicone composite insulators shall comply with the requirements of IEC-61462 and the relevant parts of IEC-62217. The design of the composite insulators shall be tested and verified according to IEC-61462 (Type & Routine test).

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

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

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

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

15.15 Bushing shall be specially packed to avoid any damage during transit and suitable for long storage, with non-returnable packing wooden boxes with hinged type cover. Without any gap between wooden planks. Packing Box opening cover with nails/screws type packing

arrangement shall not be acceptable. Manufacturer shall submit drawing/ documents of packing for approval during detail engineering. Detail method for storage of bushing including accessories shall be brought out in the instruction manual.

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

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

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

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

16.0 LAYOUT ARRANGEMENT AND CONNECTION OF GENERATOR TRANSFORMER IN HYDRO POWER PLANTS:

Hydro Power Stations are remotely located in hills where space is always a constraint. Many power stations are underground and generator transformers are placed in underground caverns. The GTs installed in hydropower stations may deviate from standardized layout/architecture due to specific layout and space constraints faced in hydropower station.

For standardized layout of GTs at hydropower stations, tentative typical layout and dimensions of generator transformers used in hydropower station have been shown at **Annexure–Q.**

In Hydropower stations, connections of HV side of transformers with cable/ GIS/AIS can be either Oil to SF6 (in case of GIS), Oil to Oil (in case of XLPE cables) or Oil to Air (in case of AIS). HV terminations must have provision to accommodate these interfacings. These interfacing should be as per the provisions of relevant international standards (e.g.

IEC 62271-211 for direct connection of transformer to GIS or EN 50299 for specification of cable box of transformers and reactors).

16.1 Cable Box (if applicable):

Oil filled Cable box shall be designed to match with requirement of the corresponding generator transformer and for ease of access and termination of the cables by the installer. The manufacturer of the cable box shall take into account the total dynamic forces generated during short circuit. The cable box as well as bushings shall be capable of withstanding vacuum during evacuation process. The design of cable box shall be in accordance with EN-50299 and the limit/ scope of supply of cable manufacturer and the transformer manufacturer shall also be in line with EN-50299. The electrical clearances as per prevalent Standards shall be maintained inside the cable box. Transformer manufacturer shall coordinate with the cable manufacturer to resolve any interfacing issues. To avoid any interfacing problem at site, the fitting of dummy cable termination and cable box needs to be checked, preferably at transformer manufacturer's premise/works. The detailed scope of supply of transformer manufacturer and cable manufacturer as per EN-50299 has been shown at **Annexure-Q.**

16.2 Transformer – Connection to GIS:

Transformer connection enclosure shall be part of gas insulated metal enclosed switchgear and shall house one end of a completely immersed bushing fitted on a power transformer and main circuit end terminal of GIS. The transformer connection with GIS shall be designed in line with IEC 62271-211 and the limit/scope of supply of switchgear manufacturer and the transformer manufacturer shall also be in line with above IEC. The switchgear manufacturer shall supply connection between the enclosures of different phases as per requirement to limit the circulating current in the transformer tanks. The manufacturer of the connection enclosure shall take into account the total dynamic forces generated during short circuit and the enclosure as well as bushings shall be capable of withstanding vacuum during evacuation process. The Gas Insulated Switchgear manufacturer shall make necessary arrangement to limit the Very Fast Transient (VFT) ground potential rise which may occur during switching operation of disconnectors. The detailed scope of transformer manufacturer and GIS manufacturer as per IEC 62271-211 has been shown at **Annexure-Q**.

17.0 NEUTRAL FORMATION AND EARTHING ARRANGEMENT

17.1 For 3-Phase Unit

The neutral of the transformer/reactor shall be brought out through bushing. The neutral of the shunt reactor shall be grounded either directly or through a neutral grounding reactor (NGR) as the case may be. The neutral terminal of transformer/ reactor/NGR shall be brought to the ground level by a brass/tinned copper grounding bar, supported from the tank by using porcelain insulators. The end of the brass/tinned copper bar shall be brought to a convenient location at the bottom of the tank, for making connection (using bimetallic strip of adequate size) to grounding mat through separate earth pits using two (2) numbers 75 x 12 mm galvanised steel flats. Aluminium clamps & connectors of suitable size shall be provided for connection with neutral of the transformer/ reactor, surge arrester and the neutral grounding reactor (NGR).

17.2 For 1-Phase Unit

The neutral terminals of the single phase transformer/reactor unit shall be brought out through bushing and necessary interconnection have to be made to form 3-phase bank and common neutral bus. The neutrals of 1-phase transformers/reactors can be connected by overhead connection using common brass/tinned copper/Aluminum pipe/ACSR conductor grounding bus, supported on the tank and fire walls by using porcelain insulators. The flexible jumper (wherever required) shall be of twin conductor. The neutral formation shall be such that neutral terminal of single-phase spare unit can be disconnected from or connected with the other single phase units in case of failure/outage of any units. The end of the neutral bus shall be connected to grounding mat through separate earth pits.

Typical arrangements for neutral formation has been indicated in **Annexure-O.**

18.0 DELTA FORMATION (applicable for 1-Phase Transformer):

The tertiary winding terminals of the transformer shall be brought out through bushing. The delta formation of tertiary winding of single phase units of a three phase bank shall be done outside the transformer. IPS Aluminium tube of suitable size (e.g. 3" IPS) with heat shrinkable insulating sleeves or cables of suitable voltage class, bus post insulators, support structures, conductors, clamps & connectors of suitable size required for tertiary delta formation shall be provided. The insulation tape or sleeve (wherever used) shall be of **at least 52kV class for 33kV tertiary bus. The minimum phase to phase horizontal**

spacing for delta formation shall be 1.5 meter. Metal sheathed cables shall be avoided for delta formation. More details are given in **Annexure-N**

Delta Formation in case of single phase Generator Transformer:

The LV winding of Generator Transformers shall be brought out through bushing and LV side of single phase transformers shall be connected in delta using different configuration of Bus Duct, depending on the rated current of LV winding to form three phase bank. The Transformer and Bus duct manufacturer shall co-ordinate with each other for formation of delta on Low voltage side of Generator Transformer maintaining required spacing between phases and safety clearances.

19.0 COOLING EQUIPMENT AND ITS CONTROL

19.1 Radiator based cooling for Power/Auto transformer & Reactor

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

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

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

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

(a) Cooling Fans, Oil Pumps, Oil Flow Indicator (as applicable)
(b) Top and bottom shut off valve of at least 80mm size
(c) Drain Valve and sampling valve
(d) Top and bottom oil filling valves
(e) Air release plug at top
(f) Two grounding terminals suitable for termination of two (2) Nos. 75x12 mm galvanised steel flats.
(g) Thermometer pockets fitted with captive screw caps at cooler inlet and outlet.

(h) Lifting lugs

19.1.4 Each radiator bank shall be detachable and shall be provided with flanged inlet and outlet branches. Expansion joint (for separately/ ground mounted cooler banks) shall be provided on top and bottom cooler pipe connection.

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

19.1.6 **Cooling fans** shall **not be directly mounted on radiator**. The supporting frames for the cooling fans shall be fixed preferably on separate support or to the main tank in such a manner that the fan vibration does not affect the performance of the radiators and its valves. Fans shall be located so as to prevent ingress of rain water. Each fan shall be suitably protected by galvanised wire guard. The exhaust air flow from cooling fan shall not be directed towards the main tank in any case.

19.1.7 **Two (2) nos., 100% centrifugal or axial in line oil pumps**, if applicable, (out of which **one pump shall be standby)** shall be provided with each radiator bank. **Measures** shall be taken **to prevent mal-operation of Buchholz relay** when all oil pumps are simultaneously put into service. The pump shall be so designed that upon failure of power supply to the pump motor, the pump impeller will not limit the natural circulation of oil.

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

19.1.9 An oil flow indicator shall be provided for the confirmation of the oil flow direction. An **indication in the flow indicator and potential free contacts for remote alarm** shall be provided.

19.1.10 Valves shall be provided across the pump and oil flow indicator to avoid oil drain and long outage during maintenance / replacement of pump and oil flow indicator.

19.1.11 **Cooling fans and oil pump motors** shall be suitable for operation from 415 volts, three phase 50 Hz power supply and shall be of premium efficiency **class IE3 conforming to IS: 12615**. Each cooling fan and oil pump motors shall be provided with starter, thermal overload and short circuit protection. The motor winding insulation shall be conventional **class 'B' type**. Motors shall have hose proof enclosure equivalent to **IP: 55** as per IS/IEC 60034-5.

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

19.1.13 Air release device and oil plug shall be provided on oil pipe connections. Drain valves shall be provided in order that each section of pipe work can be drained independently.

19.1.14 Automatic operation control of fans/pumps shall be provided (with temperature change) from contacts of winding temperature indicator. The manufacturer shall recommend the setting of WTI for automatic changeover of cooler control over entire operating range depending on types of cooling system like ONAN/ONAF/OFAF (or ODAF) or ONAN/ONAF1/ONAF2. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.

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

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

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

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

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

the Cooler Control Cabinet shall have provision for shorting to avoid CT open circuit while it is not in use.

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

19.1.19 AC power for Cooler Control Circuitry shall be derived from the AC feeder. In case auxiliary power supply requirement for Cooler Control Mechanism is different than station auxiliary AC supply, then all necessary converters shall be provided.

19.2 Unit cooler arrangement for Generator Transformer in Thermal plants

19.2.1 Cooling system for generator transformers in thermal plants shall be designed with unit cooler arrangement. Design of cooling system shall satisfy the performance requirements.

19.2.2 **Total capacity** of unit coolers furnished for each transformer shall be **minimum 120% of actual requirements**.

19.2.3 For generator transformer in thermal plants cooling shall be affected by use of **minimum six (6) nos. of tank mounted detachable type unit coolers**. Capacity of each unit cooler shall be **limited to maximum of 20% of the total cooling requirements**. The coolers shall be tank mounted. The orientation of coolers shall be subject to Purchaser's approval.

19.2.4 Each Unit Cooler shall have its own cooling fans, oil pumps, oil flow indicator, shut off valves of at least 80 mm size at the top and bottom, lifting lugs, top and bottom oil filling valves, air release plug at the top, a drain and sampling valve and thermometer pocket fitted with captive screw cap on the inlet and outlet.

19.2.5 **A magnetic type oil flow indicator** shall be provided for the confirmation of the oil pump operating in a normal state. An indication shall be provided in the **flow indicator to indicate reverse flow** of oil/loss of oil flow.

19.2.6 Valves shall be provided across the pump and oil flow indicator to avoid oil drain and long outage during maintenance / replacement of pump and oil flow indicator.

19.2.7 **Cooling fans and oil pump motors** shall be suitable for operation from 415 volts, three phase 50 Hz power supply and shall be of **premium efficiency class IE3 conforming to IS: 12615**. Each cooling fan and oil pump motors shall be provided with starter, thermal overload and short circuit protection. The motor winding insulation shall be conventional **class 'B'** or better type. Motors shall have hose proof enclosure equivalent to **IP:55** as per IS:IEC:60034-5. The temperature rise of the motor shall be limited to 70 deg. C above ambient of 50 deg. & shall comply with IS:12615.

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

19.2.9 Expansion joint shall be provided on top and bottom cooler pipe connections as per requirement.

19.2.10 Air release device and oil plug shall be provided on oil pipe connections. Drain valves shall be provided in order that each section of pipe work can be drained independently.

19.2.11 Suitable manual control facility for unit cooler shall be provided.

19.2.12 The changeover to standby unit cooler bank oil pump in case of failure of any service unit cooler shall be automatic.

19.2.13 Selector switches and push buttons shall also be provided in the cooler control cabinet to disconnect the automatic control and start/stop the unit cooler manually.

19.2.14 **Cooler fans & oil pumps of all unit coolers** (except standby cooler) shall **operate continuously.** The starting of unit cooler shall be done **as soon the Circuit Breaker of HV/IV/LV** (as applicable) side is **switched on**. Provision shall be kept to start the coolers by WTI contact.

19.2.15 Once started the cooling shall remain in operation as long as the transformer is in service. **When the transformer is switched off the cooling shall continue to run for a further duration of 30 minutes.** This timer shall be at least adjustable from 15 to 60 minutes. Further, a one-week timer is required to check the healthiness of the complete cooling system on a routine basis for one hour at a time. Spurious operation should however be avoided by appropriate settings. All settings shall be adjustable

19.2.16 Adequate warning/ safety labels are required to indicate that the fans may start at any time.

19.2.17 If any one group(s) is out of service and isolated, this shall not affect the automatic starting of the other unit cooler.

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

a) Cooler Supply failure (main)
b) Cooler supply changeover
c) Cooler Supply failure (standby)
d) Control Supply failure
e) Cooler unit failure for each unit cooler
f) No oil flow/reverse oil flow for pumps
g) Thermal overload trip for each fan / pump

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

19.3 Transformer Cooling System for Generator Transformers in Hydro Plants:

19.3.1 Each transformer shall be equipped with a water/oil cooling system mounted on transformer tank complete with heat exchanger, oil circulating pump, motor and associated control gear, pipes, valves, flow indicators etc. designed to be connected to the common cooling water system. **Two complete sets of cooling units each of 100% capacity (one shall be standby), both with 20% margin with necessary pipe-fittings** and valves shall be furnished with each transformer. **Cooler tube shall be made of Cu-Ni (90-10%). Double wall type cooler tubes** shall be used so that in case of leakage of tube, water is not mixed with oil, and instead get collected in a container. The container shall be equipped with a drain valve and a leakage detector relay. Alarms shall be provided for leakage from the first layer of tube, so that defect is immediately attended.

19.3.2 Heat exchangers shall be designed for pressure and vacuum conditions specified for the tank and also keeping in view their relative location with respect to tank.

19.3.3 Cooler units shall be connected to the tank by machined steel flanges welded to the cooler units and to the tank provided with gaskets. Inlet and outlet of each cooler connection to tank shall be provided with indicating shut-off valves, which can be locked in either open or closed

position. A separate oil tight blank flange shall be provided for each tank connection for use when cooler unit is detached.

19.3.4 **A magnetic type oil flow indicator with alarm and trip contacts** for outflow of oil from pump shall be provided with each assembly to indicate normal operation and direction of oil flow. Valves shall be provided at the outlet of each cooler for regulating the flow of water. Motorised valves shall be provided on the water inlet side of each cooler so as to ensure automatic changeover of coolers. The outlet of each pump shall be interconnected, using necessary isolating valves, to ensure cross operation of coolers

19.3.5 In addition, necessary instrumentation like pressure gauge, flow indication and isolation valve, non-return valves etc. and following shall be provided with coolers:

a) Glycerine filled pressure gauges at oil and water inlet and outlet branches.
b) A suitable differential pressure gauge or equivalent suitable device fitted with electrical contacts to give an alarm in case of choking of coolers.
c) Suitable thermometers screwed into pockets for outlet & inlet oil and water branches of coolers.
d) Each pump shall be provided with a non-return valve on delivery side.
e) A water flow indicator with alarm and one potential free contact shall be installed in the discharge pipe of the heat exchanger. Necessary valves for replacement/maintenance of faulty components.

19.3.6 The necessary piping, fittings, all type of valves shall be provided for connecting each transformer to the cooler and oil pumps. The oil piping shall be provided with machined flanged joints. Drain valves/plugs shall be provided in order that each section of the pipe work can be drained independently.

19.3.7 Control equipment for oil circulating pump and motor to be mounted in a marshalling box to be supplied with each transformer shall include the necessary contactors with auto motor control. Provision for automatic/manual control equipment will be made in accordance with the following:

a) Locally from the control cabinet through operation of local control switch.

b) From remote UCB/centralized control room after selecting the remote operation from local panel.

c) Automatically through the auxiliary contact of starting relay. For this purpose, the selector switch shall be put on auto and the cooler shall start working when the starting relay is energized.

d) Changeover of cooler and pump from main to standby shall be achieved via control system logic (based on running period).

e) Change over in the event of any pump or heat exchanger not functioning.

f) Oil pumps shall stop minimum one hour after stoppage of unit.

19.3.8 Auxiliary contacts shall be provided to indicate the running of all the pumps. Overload and single-phase protection of all motors shall be provided. Transformer manufacturer shall specify the loading capacity of the transformers in case of lesser quantity or pressure of cooling water. Sufficient number of contacts for annunciation and alarms/trips for oil pump running status, pump running hour status, pump overload status, flow status and water leakage in coolers shall be provided on the initiating relay/device for indication/annunciation on respective marshalling box and SCADA.

20.0 VALVES

20.1 Type of valves shall be used for transformer/reactor as per following table. The location and size of valves for other application shall be finalised during design review. Utility may specify any other valve required for some other applications.

Sr. No.	Description of Valve	Type
1	Drain Valve	Gate
2	Filter valve	Gate
3	Sampling Valve	Globe
4	Radiator isolation valve	Butterfly
5	Buchholz relay isolation valve	Gate
6	Sudden pressure relay	Gate
7	OLTC- tank equalizing valve	Gate / Needle

8	OLTC Drain cum filling valve	Gate
9	Valve for vacuum application on Tank	Gate
10	Conservator Drain valve	Gate
11	Aircell equalizing valve	Gate/Globe/Ball
12	Valve for Conservator vacuum (top)	Gate
13	Filter valve for Cooler Bank (Header)	Gate
14	Cooler Bank isolation valve	Butterfly
15	Pump Isolation valve	Butterfly
16	Valve for N2 injection (NIFPS) (if specified by utility)	Gate
17	Valve for NIFPS Drain (if specified by utility)	Gate
18	Valve for UHF Sensors (applicable for 400kV and above voltage class Transformer only)	Gate

20.2 **All valves upto and including 50 mm shall be of gun metal or of cast steel. Larger valves may be of gun metal or may have cast iron bodies with gun metal fittings.** They shall be of full way type with internal screw and shall open when turned counter clock wise when facing the hand wheel.

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

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

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

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

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

20.8 After testing, inside surface of all cast iron valves coming in contact with oil shall be applied with one coat of oil resisting paint/varnish with two coats of red oxide zinc chromate primer followed by two coats of fully glossy finishing paint conforming to IS: 2932 and of a shade (Preferably red or yellow) distinct and different from that of main tank surface. Outside surface except gasket setting surface of butterfly valves shall be painted with two coats of red oxide zinc chromate conforming to IS: 2074 followed by two coats of fully glossy finishing paint.

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

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

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

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

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

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

21.0 CABLING

21.1 All interconnecting control and power cables emanating from various parts of transformer/reactor like turret CT, MBs, Fans, pumps, Buchholz, PRD etc. shall be routed through covered cable tray or GI conduit and shall be properly dressed. All cables shall be armoured type. Un-armoured cables (if provided) in any circuitry, shall be through GI conduit and no part shall be exposed. Cable terminations shall be through stud type TB and ring type lugs. Type tested cables from approved sources shall be provided. Both ends of all the wires (control & power) shall be provided with proper ferrule numbers for tracing and maintenance. Further, any special cables (if required) shall also be considered included in the scope. All cable accessories such as glands, lugs, cable tags/ numbers etc. as required shall be considered included in the scope of supply. **Typical technical specification for cables is attached at Annexure-R**. The cross section of "control cable" shall be **1.5 sq.mm (minimum)** except for **CT circuits** which should be **2.5 sq.mm (minimum)**.

21.2 Cabling of spare unit of transformer/reactor with isolator switching arrangement shall be in such a way that spare unit can be brought into service in case of failure/ outage of a healthy unit without physically shifting. All control, protection, indication signals of spare unit shall be brought to the Common Marshalling Box (CMB) of all the banks. From CMB all the control, protection and indication signals of R, Y, B and Spare units shall be transferred to Purchaser's Control panels/SCADA. Change-over of spare unit signals with faulty unit shall be done through Purchaser's C & R panels / SCADA level. Changeover of RTCC signals shall be carried out in CMB. Plug & socket arrangement shall be provided for quicker transition of faulty unit to spare unit to avoid interconnection errors.

22.0 TAP CHANGING EQUIPMENT

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

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

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

22.1.2 Arrangement shall be made for securing & pad locking the tap changer in any of the working positions & it shall **not be possible for setting**

or padlocking it in any intermediate position. An indicating device shall be provided to show the tap in use.

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

(a) A mechanical operation indicator.

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

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

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

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

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

22.1.5 Following signals to be provided:

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

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

22.2 On Load Tap Changing (OLTC) Equipment

22.2.1 Main OLTC Gear Mechanism

22.2.1.1 Single/ three phase transformer as specified in **Annexure-A** shall be provided with voltage control equipment of the tap changing type for varying its effective transformation ratio whilst the transformers are on load. The OLTC shall conform to IS 8468/IEC 60214 (Part 1& 2). The requirement of voltage regulation (on HV or LV sides), location (physical and electrical) of tap winding (end of common/ series winding or at neutral end), range of voltage variation, no. of steps etc. shall be as given in **Annexure-A**.

22.2.1.2 The **OLTC** shall be of **high speed transition resistor type**. OLTC shall be motor operated suitable for local as well as remote operation. The diverter switch or arcing switch shall be designed so as to ensure that its operation once commenced shall be completed independently of the

control relays or switches, failure of auxiliary supplies etc. To meet any contingency which may result in incomplete operation of the diverter switch, adequate means shall be provided to safeguard the transformer and its ancillary equipment. **The current diverting contacts shall be housed in a separate oil chamber not communicating with the oil in main tank of the transformer and the chamber shall be designed to withstand the vacuum.** The contacts shall be accessible for inspection without lowering oil level in the main tank and the contacts shall be replaceable.

22.2.1.3 The voltage class, maximum tapping current, step voltage of OLTC shall have adequate design margin for safe & reliable service life of both OLTC and transformer. OLTC shall have long contact life, quick & easy to disassemble diverter switch inserts, simple to adjust & control and easy to replace diverter's contacts etc.

22.2.1.4 Necessary safeguards shall be provided to avoid harmful arcing at the current diverting contacts in the event of operation of the OLTC gear under overload conditions of the transformer.

22.2.1.5 The OLTC oil chamber shall have oil filling and drain valve, oil sampling valve, relief vent and level glass. Oil sampling valve, accessible from ground, shall be provided to take sample of oil from the OLTC chamber. It shall also be **fitted with an oil surge relay** which shall be connected **between OLTC oil chamber and OLTC conservator tank**. **Provision of a suitable device like tie-in-resistor has to be made, wherever required, to limit the recovery voltage to a safe value.** The use of tie-in-resistor (if used) shall be clearly marked in rating and diagram plate of the transformer. The whole of the driving mechanism shall be of robust design and capable of giving satisfactory service without undue maintenance.

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

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

22.2.2 Local OLTC Control Cabinet (Drive Mechanism Box)

22.2.2.1 OLTC shall be suitable for manual (handle operated) and electrical (motor operated) operation. For local manual operation from Local

OLTC Control cabinet (Drive Mechanism Box), an external handle shall be provided.

22.2.2.2 **OLTC's Local control cabinet shall be mounted on the tank** in accessible position. The cranking device/handle for manual operation for OLTC gear shall be removable and suitable for operation by a man standing at ground level (preferably at a height less than1800mm). The mechanism shall be complete with the following:

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

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

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

(d) The manual control, considered as back up to the motor operated on load tap changer control, shall be interlocked with the motor to block motor start-up during manual operation.

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

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

22.2.2.3 For electrical operation from local as well as remote, motor operated mechanism shall be provided. It shall not be possible to operate the electric drive when the manual operating gear is in use. It shall not be possible for any two controls to be in operation at the same time. Transfer of source in the event of failure of operating AC supply shall not affect the tap changer. Thermal device or other means shall be provided to protect the motor and control circuit.

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

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

(b) Emergency Push Button to stop OLTC operation

(c) Cubicle light with door switch

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

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

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

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

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

22.2.2.6 Operating mechanism for on load tap changer shall be designed to go through one step of tap change per command only, until the control switch is returned to the off position between successive operations/ repeat commands.

22.2.2.7 Limit switches shall be provided to prevent overrunning of the mechanism and shall be directly connected in the control circuit of the operating motor provided that a mechanical de-clutching mechanism is incorporated. In addition, a mechanical stop shall be provided to prevent over-running of the mechanism under any condition. An interlock to cut-out electrical control when it tends to operate the gear beyond either of the extreme tap positions.

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

22.2.2.9 'Local-remote' selector switch shall be provided in the local OLTC control cabinet. In Local mode, all electrical commands from remote (i.e. from CMB, digital RTCC, SCADA, SAS etc.) shall be cut-off/blocked. Electrical operations to change tap positions shall be possible by using raise/lower push buttons under local mode from Driving Mechanism (DM) Box. In remote mode electrical commands from CMB/ digital RTCC/SCADA/SAS etc. shall be executed. The remote-local selector switch shall be having at-least two spare contacts per position.

22.2.2.10 For 3-phase transformer, the following minimum LED indications shall be provided in DM box:

(a) INCOMPLETE STEP
(b) OLTC motor overload protection operated
(c) Supply to DM Motor fail
(d) OLTC IN PROGRESS
(e) Local / Remote Selector switch positions of DM
(f) OLTC upper/lower limits reached
(g) 415V Main AC supply ON
(h) 415V Standby AC supply ON

22.2.2.11 The following minimum contacts shall be available in DM Box. For three phase unit, and these contacts shall be further wired to digital RTCC panel/relevant BCU (as applicable):

(a) INCOMPLETE STEP which shall not operate for momentary loss of auxiliary power.
(b) OLTC motor overload protection
(c) Supply to DM Motor fail
(d) OLTC IN PROGRESS
(e) Local/Remote Selector switch position
(f) OLTC upper/lower limits reached

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

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

22.2.3 OLTC Control from Common Marshalling Box (CMB) (For single phase transformer units)

22.2.3.1 It shall be possible to monitor, control/operate, the OLTC of all the three 1-phase transformers of a transformer bank from Common Marshalling Box (CMB). The control and monitoring terminations of a spare transformer unit (1-Ph) shall be brought to CMB. The necessary switching arrangement through male-female plug-in TB assembly shall be provided for replacing spare unit with any one of the faulty phase unit for monitoring & control from CMB.

22.2.3.2 'Independent-combined-remote selector switch, raise/lower switch and emergency stop Push Button shall be provided in the common marshalling box for OLTC control.

22.2.3.3 When the selector switch is in '**independent'** position, the OLTC control shall be possible from individual Local OLTC Control Cabinet (DM Box) only.

22.2.3.4 In '**combined'** position, raise-lower switch (provided in the CMB), shall be used to operate for bank of three single phase transformers from CMB.

22.2.3.5 In '**remote'** position control of OLTC shall be possible from digital RTCC/SCADA/SAS etc.

22.2.3.6 From CMB, the operation of OLTC shall be for 3-phases of transformer units without producing phase displacement. Independent operation of each single phase transformer from CMB/digital RTCC/SCADA/SAS will be prevented.

22.2.3.7 Following minimum LED indications shall be provided in CMB:

(a) INCOMPLETE STEP
(b) OLTC motor overload protection operated
(c) Supply to DM Motor fail
(d) OLTC IN PROGRESS
(e) Local / Remote Selector switch positions of DM
(f) OLTC upper/lower limits reached
(g) 415V Main AC supply ON
(h) 415V Standby AC supply ON

22.2.3.8 Following contacts shall be wired to TBs in CMB for further wiring to C & R Panels:
(a) 415V Main AC supply Fail
(b) 415V Standby AC supply Fail

22.2.3.9 Following contacts shall be wired to TBs in CMB from DM box for further wiring to digital RTCC Panel/relevant BCU (as applicable):

(a) INCOMPLETE STEP
(b) OLTC motor overload protection operated
(c) Supply to DM Motor fail
(d) OLTC IN PROGRESS
(e) Local / Remote Selector switch positions of DM

(f) OLTC upper/lower limits reached
(g) 'Independent-combined-remote' selector switch positions of CMB

22.2.3.10 Further, OLTC tap position digital indications for all three 1-Ph Transformer units either separately or through selector switch shall be provided in CMB. The same shall also be wired to digital RTCC panel/relevant BCU (as applicable) to display tap positions for all three 1-ph units separately.

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

Requirement of digital RTCC relays may be specified by the utility for existing conventional substations as per its practice. For substations/ power plants having Substation Automation System, Control & monitoring of OLTC shall be carried out through Substation Automation System. All the functionalities specified for digital RTCC shall be realised in soft logic in Substation Automation System. All hardwire signals from/to OLTC shall be wired to Bay Control Units (BCUs) provided by the owner/contractor, as applicable. Wherever, digital RTCC relay is required following specification may be followed.

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

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

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

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

22.2.4.5 **Digital RTCC relay** shall be **microprocessor based** adopting the latest state of the art design & technology with **in-built large LCD** (or better) display for ease of programming and viewing. The unit supplied shall be field programmable so that in the event of change in transformer/

location, it could be customized to suit site conditions without sending back to works. The programming shall be menu driven and easily configurable. If it is designed with draw out type modules, it should take care of shorting all CT inputs automatically while drawing out. The CT/VT ratio shall be field programmable and Relay shall display the actual HV Voltage and current considering suitable multiplying factors. The system shall be self-sufficient and shall not require any additional devices like parallel balancing module etc.

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

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

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

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

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

22.2.4.11 **Master/Follower/Independent/Off mode**

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

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

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

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

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

22.2.4.12 **Raise/Lower control:** The remote OLTC scheme offered shall have provision to raise or lower taps for the complete bank of three 1-phase transformers / 3-Phase Transformers. Individual 1-phase OLTC operation shall not be possible from the remote control panel.

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

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

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

22.2.4.16 The relays shall ensure completion of lowering/raising of the OLTC tap, once the command is issued from the relay. "Step-by-Step" operation

shall be ensured so that only one tap change from each tap changing pulse shall be effected. If the command remains in the "operate" position, lock-out of the mechanism is to be ensured.

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

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

22.2.4.19 The relay shall have self-check of power on and shall continually monitor all functions and the validity of all input values to make sure the control system is in a healthy condition. Any monitoring system problem shall initiate the alarm.

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

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

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

23.0 SCADA INTEGRATION (if applicable)

All the online monitoring equipment i.e. Optical Temperature Sensors & Measuring Unit, Online Dissolved Gas (Multi-gas) and Moisture Analyzer, On-line insulating oil drying system (Cartridge type) etc. provided for individual transformer/reactor unit including spare unit (if any), shall be IS/IEC 61850 compliant (either directly or through a Gateway). These monitoring equipment are required to be integrated

with SAS through managed Ethernet switch conforming to IS/IEC 61850. This Ethernet switch shall be provided in IMB (for 3-Ph unit) / CMB (for 1-Ph unit). The switch shall be powered by redundant DC supply (as per available Station DC supply). Ethernet switch shall be suitable for operation at ambient temperature of 50 Deg C. All required power & control cables including optical cable, patch chord (if any) upto IMB (for 3-Ph unit) / CMB (for 1-Ph unit), all the cables from RTCC to DM and any special cable between IMB (for 3-Ph unit) / CMB (for 1-Ph unit) to switchyard panel room/control room shall be in the scope.

However, fiber optic cable, power cable, control cables, as applicable, between IMB (for 3-Ph unit) / CMB (for 1-Ph unit) to switchyard panel room/control room and power supply (AC & DC) to MB and integration of above said IS/IEC-61850 compliant equipment with Substation Automation System may be a part of sub-station contract.

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

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

24.1 Each transformer unit shall be provided with local OCTC/OLTC Drive Mechanism Box (DMB), Cooler Control Cabinet/Individual Marshalling Box, **Digital RTCC panel** (as applicable) and Common Marshalling Box (for a bank of three 1-phase units). Each reactor unit shall be provided with Individual Marshalling Box and Common Marshalling Box (for a bank of three single phase unit).

24.2 Common marshalling box (for single phase unit) shall be of size not less than 1600mm (front) X 650mm (depth) X 1800mm (height). Individual **Marshalling Box (IMB) and Cooler Control Box** shall be **tank mounted** or ground mounted. All cabinets except CMB & Digital RTCC panel shall be tank mounted. All separately mounted cabinets and panels shall be free standing floor mounted type and have domed or sloping roof for outdoor application. The gland plate shall be at least 450 mm above ground level.

24.3 The Cooler Control Cabinet (CCC)/Individual Marshalling Box (IMB), Common Marshalling Box (CMB), and **all other outdoor cubicles**

(except OLTC Drive Mechanism box) shall be made **of stainless steel sheet of minimum Grade SS 304 and of minimum thickness of 1.6 mm. Digital RTCC panel** shall be made of **CRCA sheet of minimum thickness of 2.0 mm** and shall be painted suitably as per **Annexure–K**.

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

24.5 All doors, removable covers and plates shall be gasketed all around with suitably profiled. All gasketed surfaces shall be smooth straight and reinforced if necessary to minimize distortion to make a tight seal. For Control cubicle/Marshalling Boxes etc. which are **outdoor type**, all the **sealing gaskets shall be of EPDM rubber or any other (approved) material** of better quality, whereas for all **indoor** control cabinets/Digital RTCC panel, the **sealing gaskets shall be of neoprene rubber or any other (approved) material** of better quality. The gaskets shall be tested in accordance with approved quality plan and IS: 3400.

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

24.7 Ventilating Louvers, if provided, shall have screen and filters. The screen shall be fine wire mesh of brass. All the control cabinets shall be provided with suitable lifting arrangement. Thermostat controlled space heater and cubicle lighting with ON-OFF switch shall be provided in each panel.

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

25.1 For Single Phase unit

25.1.1 **Two auxiliary power supplies of 415 volts, three phase four (4) wire** shall be provided by the purchaser **at Common Marshalling Box (CMB**) through bus bar arrangement. All loads shall be fed by one of the two sources through an electrically interlocked automatic transfer scheme housed in the CMB. Power **supply to individual phase unit shall be extended from the CMB**. Power supply to spare unit shall be

extended from nearest CMB only. Suitably rated power contactors, separate MCBs/MCCBs shall be provided in the CMB for each circuit.

25.1.2 For each circuit, suitably rated MCBs/MCCBs as required for further distribution of auxiliary power supply to Drive Mechanism (DM) boxes, Online Gases and moisture monitoring system, Online drying system and Fibre optic sensor Box etc. (as applicable), shall be provided in Individual Marshalling Boxes (IMB)/Cooler Control Cubicle(CCC). Power from CMB (through bus bar at CMB) to IMB (at bus inside) through cable shall be provided.

25.1.3 Auxiliary power supply distribution scheme shall be submitted for approval.

Supply and laying of Power, Control and special cables from CMB to IMB/CCC (including spare unit) & further distribution from IMB/CCC to all accessories is in the scope of the manufacturer/contractor (as applicable). Further any special cable (if required) from CMB to Owner's Control Panels is also in the scope of the manufacturer/contractor (as applicable).

25.2 For Three Phase Transformer

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

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

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

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

Normal Voltage	Variation in voltage	Frequency (in Hz)	Phase/Wire	Neutral connection
415 V	±10%	50±5%	3 Phase 4Wire	Solidly earthed
240 V	±10%	50±5%	1 Phase 2 Wire	Solidly earthed
220 V	190 V to 240 V	DC	Isolated 2 wire system	--
110 V	95 V to 120 V	DC	Isolated 2 wire system	--
48 V	--	DC	2 wire system (+) earthed	--

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

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

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

25.2.6 For spare unit which is not connected through isolator switching arrangement, 415 volt, three phase four (4) wire AC supply shall be provided for heater, On line drying system, On line DGA etc. as applicable.

26.0 BUSHING CURRENT TRANSFORMER AND NEUTRAL CURRENT TRANSFORMER

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

26.2 It shall be possible to remove the turret mounted current transformers from the Transformer tank without removing the tank cover. Necessary

precautions shall be taken to minimize eddy currents and local heat generated in the turret.

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

26.4 **For 1-phase Transformer, one number single phase current transformer (outdoor)** shall be provided **for each bank of transformer for earth fault protection** and shall be located in the neutral conductor connecting common neutral point with earth.

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

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

27.0 TOOLS & TACKLES

Each transformer/reactor shall be supplied with a full kit of tools & spanners of required sizes; bushing handling & lifting tools with nylon rope/belt, with a rack for holding them; required numbers of hydraulic jacks for lifting the transformers, and for changing the plane of rotation of wheels. All spanners shall be single ended and case hardened. Tirfors with wire rope and slings with grippers etc. for hauling the transformer/reactor to the plinth are to be supplied along with each transformer/reactor. Utility may add / remove tools as per their requirement.

28.0 FITTINGS & ACCESSORIES

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

For Transformer/Reactor:

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

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

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

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

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

(f) Conservator air cell rupture detection relay

(g) Air release plug

(h) Inspection openings and covers

(i) Bushing of each type with metal parts and gaskets to suit the termination arrangement

(j) Winding & Oil temperature indicators (local & remote)

(k) Cover lifting eyes, transformer/reactor lifting lugs, jacking pads, towing holes and core and winding lifting lugs

(l) Protected type alcohol in glass thermometer or magnetic or micro-switch type dial type temperature indicator as applicable (mercury should not be used)

(m) Rating and diagram plates (in English & Hindi or as specified by the utility) on transformers and auxiliary apparatus

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

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

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

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

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

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

(u) Valves schedule plate

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

(w) Ladder (suitably placed to avoid fouling with bushing or piping) to climb up to the transformer/reactor tank cover with suitable locking arrangement to prevent climbing during charged condition. Additional ladder for conservator in case it is not tank mounted .

(x) Suitable platform for safe access of flow sensitive non-return valve and buchholz relay shall be provided, in case these are not accessible from transformer/reactor top.

(y) Haulage/ lifting lugs

(z) Suitable terminal connectors on bushings

(aa) Suitable neutral bus connection

(bb) Suitable terminal connectors of surge arrester for NGR

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

(dd) On line insulating oil drying system (in 400 kV and above level Transformers/ Reactors) as per **Annexure-U**

(ee) Oil Sampling Bottle & Oil Syringe (if specified) as per **Annexure-V**

For Oil filled type Neutral Grounding Reactor (if applicable)

(a) Conservator for NGR main tank with drain valve, isolating valve, vent pipe and prismatic oil level gauge

(b) Pressure relief devices with trip contact

(c) Buchholz relay with isolating valves on both sides, bleeding pipe with pet cock at the end to collect gases and alarm/trip contacts

(d) Air release plug

(e) Inspection openings and covers

(f) Bushings with metal parts and gaskets to suit the termination arrangement

(g) Oil temperature indicators

(h) Cover lifting eyes, reactor lifting lugs, jacking pads, towing holes and core and winding lifting lugs

(i) Rating and diagram plates

(j) Marshalling Box (Tank mounted)

(k) Cooling equipment as applicable

(l) Bushing Current Transformers, Neutral CT (if applicable)

(m) Drain valves/plugs shall be provided in order that each section of pipe work can be drained independently

(n) Terminal marking plates

(o) Valves schedule plate

(p) Bottom oil sampling valve with threaded male adaptors, Drain valves, Filter valves at top and bottom, shut off valves on both sides of Buchholz relay at accessible height, Sampling gas collectors for Buchholz relay at accessible height, Valve for vacuum application etc.

(q) Suitable terminal connectors on bushings

(r) Ladder to climb up to the tank cover with suitable locking arrangement to prevent climbing during charged condition.

(s) Haulage/ lifting lugs

(t) Two earthing terminals each on tank, marshalling boxes etc.

For Air Core type Neutral Grounding Reactor (if applicable)

(a) Rating and diagram plates
(b) Terminal marking plates
(c) Suitable terminal connection arrangement
(d) Lifting lugs
(e) Support structure etc.

29.0 INSPECTION AND TESTING

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

30.0 DRAWINGS/DOCUMENTS/CALCULATIONS

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

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

31.0 RATING & DIAGRAM PLATE

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

Information to be provided on the plate:

For Transformer:

Manufacturer's name, country and city where the transformer was assembled					
MVA Rating, Voltage ratio, Type of transformer (for example 315MVA 400/220/33kV Auto Transformer)					
Type of Cooling			Applicable Standard		
Rated Power at different cooling			Rated frequency	Hz	
HV/IV	MVA	--/--/--	Number of phases		
LV	MVA		% Impedance / Ohmic Impedance		
Rated Voltage			(a) HV-IV		
HV	kV		Min. tap	%	
IV	kV		Principal Tap	%	
LV	kV		Max. Tap	%	
Rated Current			(b) HV-LV	%	
HV	A		(c) IV-LV	%	
IV	A		Vector Group		
LV	A		Core mass	kg	
Rated Thermal Short Circuit withstand	kA (sec)		Copper Mass		

capability Current and Duration					
Basic Insulation Level (Lightening Impulse/Switching Impulse/Power Frequency Withstand Voltage)			(a) HV	kg	
HV	kVp/ kVp/ kVrms		(b) IV	kg	
IV	kVp/ kVp/ kVrms		(c) LV	kg	
LV	kVp/ kVp/ kVrms		(d) Regulating	kg	
Neutral	kVp/ kVp/ kVrms		Core & Coil Mass	kg	
Guaranteed Temperature rise over ambient temperature of 50 Deg. C			Transportation Mass	kg	
(a) Top Oil	^{0}C		Tank & Fitting mass		
(b) Winding	^{0}C		Type & total mass of insulating oil	kg	
Vacuum withstand Capability of the tank	mm of Hg		Total mass	kg	

OLTC make and rating (current & Voltage class)			Quantity of oil in OLTC	Ltrs	
Noise level at rated voltage and at principal tap	dB		Transformer oil Quantity	Ltrs	
Tan delta of winding			Paint Shade		
Moisture content	ppm		No load loss at rated voltage & frequency	KW	
Manufacturer's Serial number			Load loss at rated current & frequency (at 75^0C) for HV & IV/LV winding	KW	
Year of manufacture			I^2R loss at rated current & frequency (at 75^0C) for HV & IV/LV winding	KW	
Work Order No.			Auxiliary loss at rated voltage & frequency	KW	
Purchaser's Order No. & Date					
OGA Drg. No.					
Vector Group Diagram					
Winding Connection diagram (Connection between all windings including tap windings, ratings of built-in current transformers, etc. shall be presented on the diagram)					
Table giving details of OLTC like tap position Nos. and corresponding tapping voltage, tapping current & connection between terminals for different tap positions etc.					
Details of Current Transformers (e.g. Bushing CTs, CT for WTI) installed in transformer like the location, core Nos., ratio(s), accuracy class, rated output (VA burden), knee point voltage, magnetizing current, maximum CT secondary resistance, terminal marking and application of the current transformer					
Warning: "Main conservator is fitted with an air cell"					

Tie-in-resistor has been used in OLTC (if applicable)
Purchaser's Name

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

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

For Reactor:

Manufacturer's name, country and city where the reactor was assembled					
MVAR Rating, Voltage & Type of Reactor (for example 80MVAR, 420kV Line reactor with NGR / bus reactor)					
Type of Cooling			Applicable Standard		
Rated Power at rated voltage	MVAR		Rated frequency	Hz	
Rated Voltage	kV		Number of phases		
Maximum operating Voltage	kV		% Impedance	%	
Rated Current	A		Zero sequence reactance	Ohm	
Winding connection			Ratio of zero sequence reactance to positive sequence reactance (X0/X1)		
Reactance at rated voltage & frequency	ohms		Vibration and tank stress	Micron & kg/sq. mm	
Basic Insulation Level (Lightening Impulse/Switching Impulse/Power			Core mass	Kg	

Frequency Withstand Voltage)					
HV end/ terminal	kVp/ kVp/ kVrms		Copper Mass	Kg	
Neutral	kVp/ kVp/ kVrms		Core & Coil Mass	Kg	
Guaranteed Temperature rise over ambient temperature of 50 Deg. C			Transportation Mass	Kg	
(a) Top Oil	^{0} C		Tank & Fitting mass		
(b) Winding	^{0} C		Type & total mass of insulating oil	kg	
Vacuum withstand Capability of tank	mm of Hg		Total mass	Kg	
Noise level			Reactor oil Quantity	Ltrs	
Tan delta of winding			Paint Shade		
Moisture content	ppm		Total loss at rated current & frequency (at 75^{0}C)	KW	
Manufacturer's Serial number			I^2R loss at rated current & frequency (at 75^{0}C)	KW	
Year of manufacture					
Work Order No.					
Purchaser's Order No. & Date					
OGA Drg. No.					

Details of Current Transformers (e.g. Bushing CTs, CT for WTI) installed in transformer like the location, core Nos., ratio(s), accuracy class, rated output (VA burden), knee point voltage, magnetizing current, maximum CT secondary resistance, terminal marking and application of the current transformer
Purchaser's Name

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

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

For Neutral Ground Reactor (NGR):

Manufacturer's name, country and city where the NGR was assembled					
Voltage & Type of NGR (for example 145kV Oil-filled /Air Core NGR)					
Type of Cooling			Applicable Standard		
Connection			Rated frequency	Hz	
Rated Voltage	kV		Number of phases		
Rated Current	A		Core mass	Kg	
Rated Short time current	kA (for –sec)		Copper Mass	Kg	
Rated impedance	ohms		Core & Coil Mass	Kg	
Basic Insulation Level (Lightening Impulse/Switching Impulse/Power Frequency Withstand Voltage)			Transportation Mass	Kg	
HV end/ terminal	kVp/ kVp/		Tank & Fitting mass		

	kVrms				
Ground side	kVp/ kVp/ kVrms		Type & total mass of insulating oil	Kg	
Guaranteed Temperature rise over ambient temperature of 50 Deg. C			Total mass	Kg	
(c) Top Oil	^{0} C		NGR oil Quantity (if applicable)	Ltrs	
(d) Winding	^{0} C		Paint Shade		
Manufacturer's Serial number			Vacuum withstand Capability of tank	mm of Hg	
Year of manufacture			Tan delta of winding		
Work Order No.			Moisture content	ppm	
Purchaser's Order No. & Date					
OGA Drg. No.					
Purchaser's Name					

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

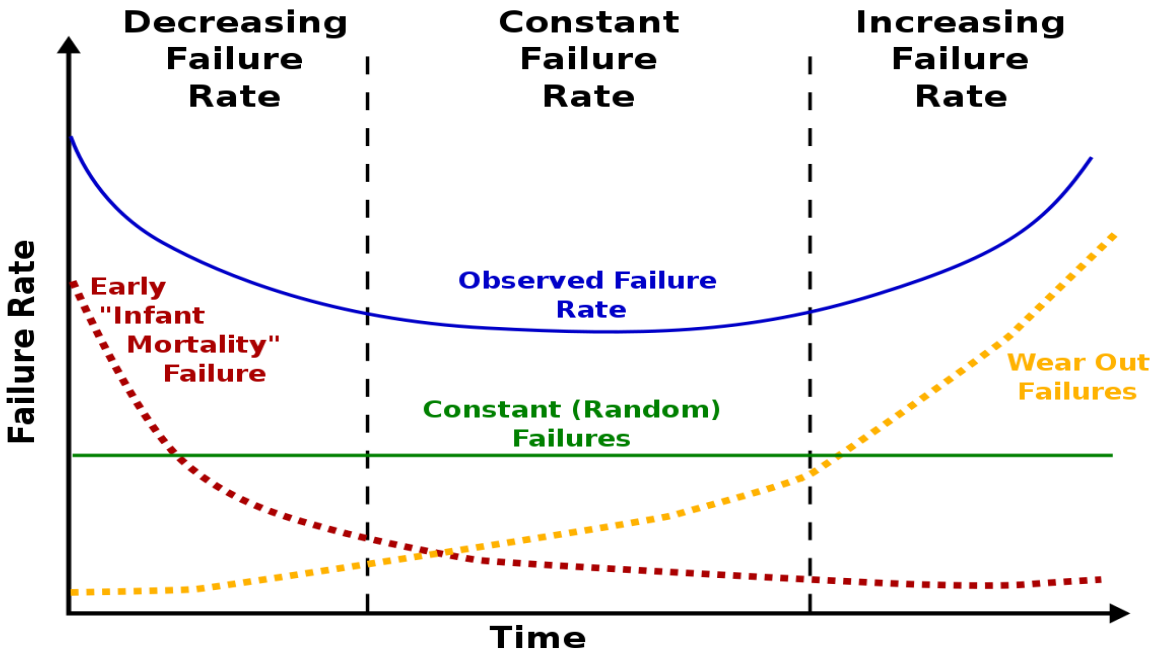
Plates with identification and characteristics of auxiliary equipment according to standards for such components (bushings, current transformers, cooling equipment etc.) shall be provided on the components themselves.

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

32.1 The long term performance of transformer/reactor depends on design/technology, quality of material used, robustness & consistency

of manufacturing process, installation, operation and maintenance etc. The erection, testing and commissioning of transformer/reactor shall be performed under strict supervision of representative of OEM and provisions specified in **Chapter 5– Transportation, erection, testing & commissioning** shall be followed.

32.2 Transformer/ Reactor failure generally follows the Bathtub Curve as shown below:



32.3 As can be seen from the Bath Tub curve, the "Infant mortality" failures, which are caused due to manufacturing related defects/issues that occur in the first few years of service (say 1 or 2 years). But continued successful operation of transformer/reactor primarily depends on operating conditions and O&M practices being followed by utilities. Improper maintenance or negligence on the part of user e.g. non-replenishment of saturated silica gel, non-release of air trapped after air-cell commissioning, oil seepages, lack of routine maintenance, failure to check tan-delta & capacitance of winding and bushing, absence of thermal scanning of terminal interfaces, lack of DGA monitoring etc., can also lead to serious consequences. It can therefore be said that the responsibility of manufacturer and maintenance & monitoring obligations of the end user are equally important for a long and trouble free service life of transformer/reactor. Moreover, any abnormality observed during operation needs to be addressed immediately. The transparency in sharing of information, mutual co-

operation and discussion on issues/problems between user and manufacturer are the only way to resolve many of these problems. The manufacturer can take this as an opportunity to understand the issues and can improve on the design & manufacturing practices. Similarly, the utility has the opportunity to understand the deficiency from their side and should rectify/try to improve on their actions as a responsible user. There is no single conclusive test based on which utility should take drastic steps regarding replacement/rejection of component/equipment.

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

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

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

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

   The transformer with DGA Status-3 does not necessarily give any conclusive information regarding health of transformer or indicate that transformer is faulty. It can only be concluded that its behaviour is somewhat unusual and warrants additional investigation and/or precautions. The transformer should be placed under increased surveillance. Other diagnostic tests should also be

conducted to supplement the DGA for taking further course of action in consultation with manufacturer.

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

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

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

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

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

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

33.0 PHYSICAL INTERCHANGEABILITY OF TRANSFORMER/ REACTOR OF DIFFERENT MAKE

Block foundation shall be adopted to facilitate the physical inter-changeability of transformers/reactors of different make on same foundation thereby the outage time of replacement of spare/new transformer or reactor would be minimized. The design shall take into

account the provision of soak pit and oil collecting pit for transformer/reactor. The details are given at **Annexure-P.**

34.0 LIST OF CODES/ STANDARDS/ REGULATIONS/ PUBLICATIONS

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



Chapter-3

Design Review

CHAPTER-3

DESIGN REVIEW

1.0 Introduction

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

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

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

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

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

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

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

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

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

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

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

2.0 Stages of Design Review (DR)

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

(A) Pre-Tender Design Review

- Technical capability and manufacturing experience of vendor

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

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

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

(C) Contract Design Review

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

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

- Review of the electrical design including dielectric, losses, short circuit, noise and thermal performance and mechanical layout design including lead routing and bushing termination after route

survey (if any) shall be carried out for enabling the manufacturer to order key raw materials and major accessories.

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

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

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

3.0 Mode of Design review

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

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

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

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

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

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

  - ❖ The manufacturer should demonstrate how their design will function reliably within the operating requirements including

transient conditions and meet the performance guarantees and present evidence of calculations/analysis performed in order to ensure that the specified requirements will be met.

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

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

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

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

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

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

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

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

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

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

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

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

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

- ❖ The intended shipping process should also be reviewed.

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

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

Calculation of no-load losses:

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

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

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

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

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

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

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

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

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

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

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

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

  Where,

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

Winding eddy losses = Estimated from empirical formulae or electromagnetic software

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

Calculation of weight of core:

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

Calculation of current density of winding conductor:

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

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

5.0 References:

(a) CIGRE Technical Brochure No. 529 -2013 Guide lines for conducting design reviews for Power Transformers
(b) CIGRE Technical Brochure No. 673-2016 Guide on Transformer Transportation
(c) IEEE Standard C57.156-2016 Guide for tank rupture mitigation of oil immersed transformers
(d) CIGRE Technical Brochure No. 530-2013 Guide for conducting factory capability assessment for Power Transformers
(e) IEEE Standard C57.150-2012 Guide for Transformer Transportation
(f) IS 2026/IEC 60076 Power Transformers-Part 5 Ability to withstand short circuit



Chapter-4

Quality Assurance Programme

CHAPTER- 4

QUALITY ASSURANCE PROGRAMME

1.0 INTRODUCTION

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

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

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

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

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

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

2.0 GENERAL REQUIREMENTS - QUALITY ASSURANCE

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

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

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

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

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

2.6 No material shall be despatched from the manufacturer's works before the same is accepted, subsequent to pre-despatch final inspection including verification of records of all previous

tests/inspections by Purchaser's authorised representative and duly authorised for despatch.

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

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

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

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

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

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

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

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

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

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

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

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

3.0 QUALITY ASSURANCE DOCUMENTS

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

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

3.3 Typical contents of QA Documentation is as below:-

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

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

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

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

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

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

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

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

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

4.3 The Manufacturer shall give the Inspector ten (10) days written notice of any material being ready for testing. Such tests shall be to the Manufacturer's account. The Inspector, unless the witnessing of the tests is virtually waived and confirmed in writing,

will attend such tests within ten (10) days of the date on which the equipment is noticed as being ready for test/inspection.

4.4 Virtual Stage inspection & Factory Acceptance Test (FAT)

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

4.4.1 The resources required for virtual inspection/testing:

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

(a) High speed Wi-Fi Internet

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

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

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

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

(e) Measuring Instruments with valid calibration certificates

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

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

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

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

4.4.2 Procedure for virtual inspection / testing:

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

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

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

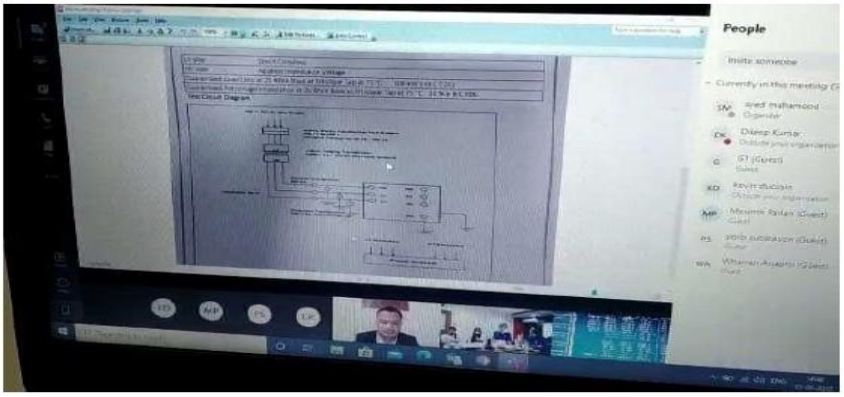
(d) Online inspection/FAT shall be done through online application platform like – Microsoft Teams, Skype, Google meet, Google hangout, WhatsApp, etc., considering the system compatibility and security in consultation with the utility/purchaser. Online recording facility of the activities performed or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

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

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

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

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



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

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

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

far as possible, resistance measurement should be done inside the Control Room to avoid any obstructions or interfere of personnel.

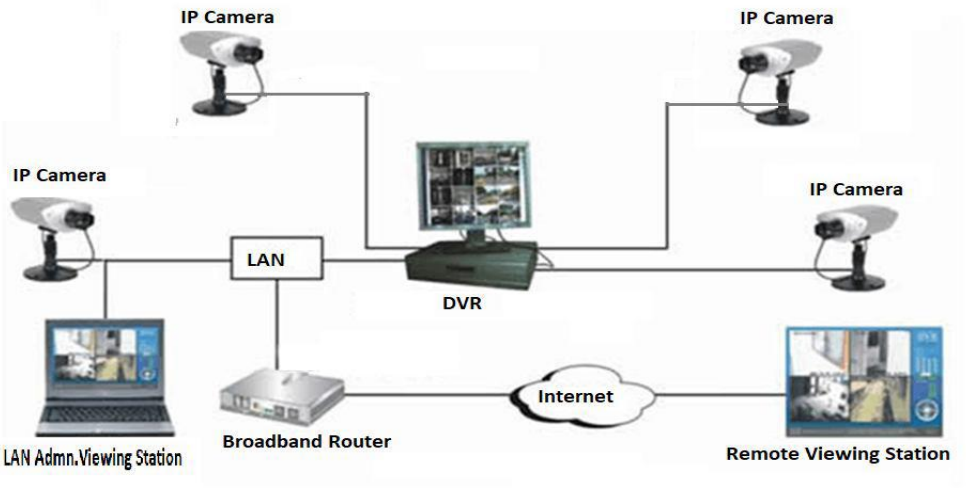
(l) During testing, one camera shall always be focused towards test bay area where the transformer / reactor is under test for online overview of connections. If one camera is not enough to see both transformer and test leads, more no. of cameras shall be deployed. This will enable complete testing connection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

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

(n) The image quality shall be good enough for assessment of the condition of the transformer which may affect the quality & performance of transformer. The factors affecting image quality include:

- Poor image resolution.
- Image out of focus.
- Inadequate lighting /Glare from strong light source/shadows
- Frequent loss of connectivity between the Inspection team and the onsite Video monitors.

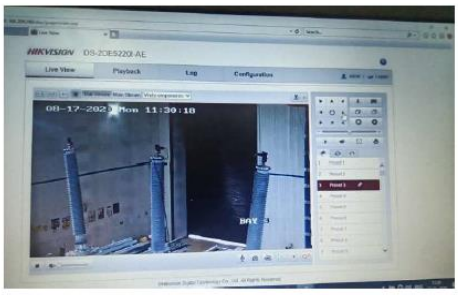
(o) The Two-way Audio-Video communication Scheme for stage inspection/FAT of transformer/reactor through web shall be as follows:



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









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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

5.0 INSPECTION AND TESTING

The inspection envisaged by the purchaser is given below. However, the manufacturer shall draw up and carry out a comprehensive inspection and testing programme in the form of detailed quality plan duly approved by Purchaser for necessary implementation during manufacture of the equipment. All accessories and components of transformer shall be purchased from source, approved by the purchaser. All process tests, critical raw material tests and witness/ inspection of these testing shall be carried out as per approved Manufacturing Quality Plan (MQP) by the purchaser.

5.1 Factory Tests

5.1.1 The manufacturer shall carry out all type & routine tests specified in "**Annexure-D** and **Annexure-E".** All tests shall be done in line with latest IS: 2026/IEC 60076 or as per procedure specified in

this document**.** Complete test report shall be submitted to purchaser after proper scrutiny and signing on each page by the test engineer of the manufacturer.

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

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

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

5.1.5 Tank Tests

(A) Oil Leakage Test

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

(B) Vacuum Test

All transformer/reactor tanks shall be subjected to the specified vacuum. The tank designed for full vacuum (760 mm of mercury at sea level) shall be tested at an internal pressure of 3.33 KN/Sq.m absolute (25 torr) for one hour. The permanent deflection of flat plate after the vacuum has been released shall not exceed the values specified below:

Horizontal Length of flat plate (in mm)	**Permanent deflection (in mm)**
Up to and including 750	5.0
751 to 1250	6.5
1251 to 1750	8.0
1751 to 2000	9.5
2001 to 2250	11.0
2251 to 2500	12.5

2501 to	3000	16.0
Above	3000	19.0

(C) Pressure Test

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

5.2 Stage Inspection

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

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

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

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

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

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

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

5.3 Type Tests on fittings

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

a) Bushing (Type test as per IS/IEC:60137) (Seismic withstand test for 400 kV and above voltage class)
b) OLTC (Test as per IS 8468/IEC:60214 and degree of protection test for IP-55 on Driving mechanism box)
c) Buchholz relay
d) OTI and WTI
e) Pressure Relief Device (including degree of protection test for IP 55 in terminal box)
f) Sudden Pressure Relay (including degree of protection test for IP 55 in terminal box)
g) Magnetic Oil Level gauge & Terminal Box degree of protection test for IP-55.
h) Air Cell (Flexible air separator) - Oil side coating, Air side under Coating, Air side outer coating and coated fabric as per IS: 3400/ BS: 903/ IS: 7016
i) Marshalling & common marshalling box and other outdoor cubicle (IP-55 test)
j) Bus post Insulators
k) Oil pump
l) Cooling fan & motor assembly
m) RTCC Panel (IP-43 test)

6.0 Pre-Shipment Checks at Manufacturer's Works

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

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

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

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

1g: Start recording
2g: Warning
3g: Alarm

Further, drop-out setting shall be 1g and threshold setting shall be in the range of 5g to 10g.

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

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

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

Chapter-5

Transportation, Erection, Testing & Commissioning



CHAPTER-5

TRANSPORTATION, ERECTION, TESTING AND COMMISSIONING

1.0 Transportation

1.1. The supplier shall be responsible to select and verify the route, mode of transportation and make all necessary arrangement with the appropriate authorities for the transportation of the equipment. The dimension of the equipment shall be such that when packed for transportation, it shall comply with the requirements of loading and clearance restrictions for the selected route. It shall be the responsibility of the supplier to coordinate the arrangement for transportation of the transformer/reactor for all the stages from the manufacturer's work to site.

1.2. The supplier shall carry out the route survey along with the transporter and finalise the detail methodology for transportation of transformer/reactor and based on route survey; any modification/extension/improvement to existing road, bridges, culverts etc. if required, shall be in the scope.

1.3. **The inland transportation of the transformer/reactor shall be on multi-axel low platform trailers of adequate capacity and equipped with GPS system for tracking the location of transformer at all times during transportation from manufacturer works to designated site.** The supplier shall intimate to purchaser about the details of transporter engaged for transportation of the transformer/reactor for tracking the units during transit. **Requirement of Hydraulic trailer is envisaged for a load of more than 40 T.** The transportation during monsoon period should be avoided as far as possible.

1.4. All metal blanking plates and covers which are specifically required for transportation and storage of the transformer/ reactor shall be considered as part of the transformer/reactor and shall be handed over to the Purchaser after completion of the erection. Bill of quantity of these items shall be included in the relevant drawing/document.

1.5. **The supplier shall despatch the transformer/reactor filled with dry air conforming to EN 12021 at positive pressure.** The necessary arrangement shall be ensured by the supplier to take care of pressure drop of dry air during transit and storage till completion of oil filling during erection. A dry air pressure testing valve with necessary pressure gauge and adaptor valve shall be provided. **The duration of the storage of**

transformer/reactor at site with dry air, shall preferably be limited to three months (including the duration of transportation), after which the recommendation of manufacturer is to be followed if it is not filled with oil. The dry air cylinder(s) (with regulating valves) provided to maintain positive pressure can be taken back by the supplier after oil filling.

In case turret, having insulation assembly, is transported separately then positive dry air pressure shall be ensured.

1.6. The largest / heaviest package of transformer / reactor shall be sufficiently lashed and same shall be checked before dispatch from the manufacturing unit.

1.7. **Transformer/reactor shall also be fitted with at least 2 numbers Electronic impact recorders (on returnable basis) in diagonally opposite position (to eliminate chances of loss of data to failure of recorder) during transportation to measure the magnitude and duration of the impact in all three directions.** The impact recorder shall be mounted on the upper side of the tank (width wise). The acceptance criteria and limits of impact, which can be withstood by the equipment during transportation and handling in all three directions, shall not exceed "3g" for 50 msec (20Hz) or as per OEM standard, whichever is lower.

Following setting of impact recorder shall be ensured at the time of installation with transformer/reactor unit before despatch from factory:

1g: Start recording
2g: Warning
3g: Alarm

Further, drop-out setting shall be 1g and threshold setting shall be in the range of 5g to 10g.

2.0 Points to be checked after receipt of transformer/reactor at site in presence of manufacturer's and purchaser's representative:

2.1. The transformer/reactor **unloading and handling work at site** should be **carried out by skilled people, under the supervision of manufacturer's representative**.

2.2. A careful external inspection must be made when transformer/reactor arrives at site. Condition of each package

and its contents and visible parts of transformer/reactor etc. shall be checked for any damage and recorded.

2.3. Pressure and Dew point of dry air shall be checked after receipt of transformer/reactor at site. It should be within permissible band as per the graph given in Fig.-1.

2.4. In case of transportation of transformer/reactor in oil filled condition, oil level & leakage (if any) shall be checked.

2.5. In case of any damage or dry air/ oil leakage beyond permissible limit, the manufacturer shall be informed immediately.

2.6. In case of dry air leakage is beyond permissible limit, the dry air pressurisation to be done on a continuous basis to safe guard the transformer Core Coil Assembly (CCA) condition till the problem is located and solved.

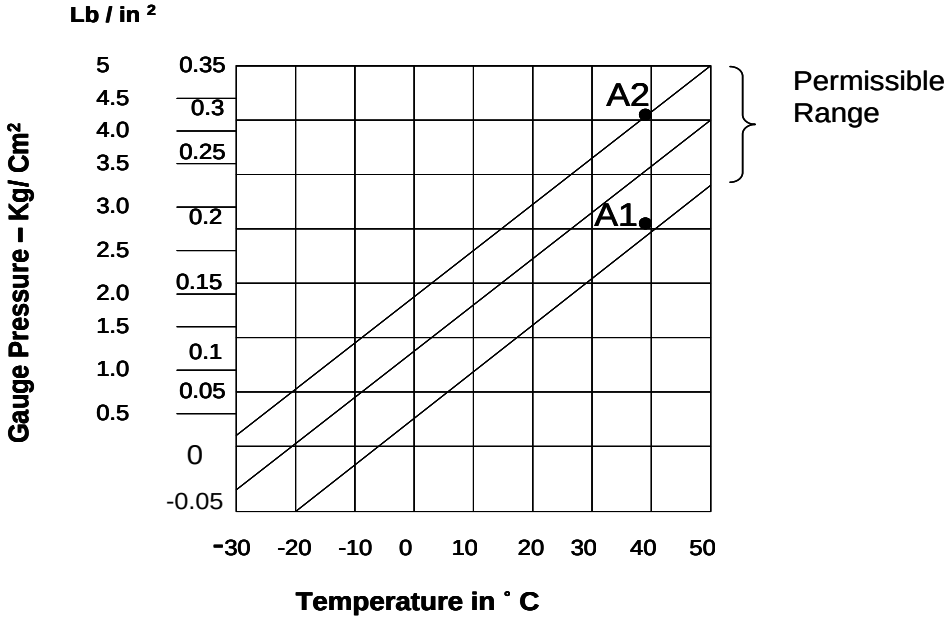
2.7. **Core Insulation Test shall be carried out to check healthiness of insulation between core to tank, core to yoke clamp (frame) and yoke clamp (frame) to tank.** (Not applicable for Air Core Reactors)

2.8. In case of transformer transported with oil, a sample of oil should be taken from the bottom of the tank and tested for BDV and moisture content.

2.9. The data of impact recorder shall be analysed jointly by the purchaser in association with the manufacturer. In case the **impact recorder indicates shocks of ≥ 3g during shipment, further course of action for internal inspection shall be taken jointly by the manufacturer & supplier.** Impact Recorder should be detached from the Transformer/ Reactor, preferably after the main unit has been placed on its foundation.

2.10. Unpacking and inspection of all accessories shall be carried out taking all precautions so that the tools used for opening do not cause damage to the contents. Proper storage of all accessories shall be ensured after unpacking in line with the OEM's recommendation. Fragile instruments like oil level gauge, temperature indicators, etc. are to be stored indoor. Any damaged or missing components shall be reported to equipment manufacturer and insurance agency so that the same can be investigated or shortage made up as per the terms/ conditions of the contract. All accessories for long storage shall be packed by OEM in special packing case.

Graph showing variation of Pressure v/s Temperature of gas for gas filled unit during Transport or storage



Example: For 40 ˚C Temperature (Depending upon the pressure of gas at the time of filling),
- minimum pressure of gas can be 0.185 Kg/ Cm² at point A1
- maximum pressure of gas can be 0.32 Kg/ Cm² at point A2

Fig.-1

3.0 Storage of the main unit and the accessories at site:

3.1 If erection work cannot start immediately due to some reasons, then accessories shall be repacked into their own crates properly and packing list should be retained.

3.2 All packing cases shall be kept above ground by suitable supports so as to allow free air flow underneath. The storage space area shall be such that it is accessible for inspection, water does not collect on or around the area and handling/transport is easy. Proper drainage arrangement in storage areas to be ensured so that in no situation, any component gets submerged in water due to rain, flooding etc.

3.3 **It is preferable to store the main unit on its own location/foundation. If the foundation is not likely to be ready for more than three (3) months, then suitable action has to be planned by the responsible agency for proper storage of the Unit as per the recommendation of OEM.**

3.4 **If the transformer/reactor is to be stored up to three (3) months (including the duration of transportation) after arrival at site, it can be stored with dry air filled condition.**

Dry air pressure shall be monitored on daily basis so that chances of exposure of active part to atmosphere may be avoided. In case of drop in dry air pressure, dew point of dry air shall be measured to check the dryness of the transformer/reactor. If there is drop in dew point, fresh dry air need to be filled. Leaks shall be identified and rectified and dry air shall be filled to the required pressure.

3.5 **In case the transformer/reactor is to be stored for more than 3 months, it shall be stored in oil filled condition. Processed oil shall be filled which complies with the required specification with moisture content ≤ 5ppm and BDV ≥ 70kV. In case of storage of transformer/reactor in oil-filled condition, the oil filled in the units shall be tested for BDV and moisture contents once in every three months. The oil sample shall be taken from bottom valve. If BDV is less and moisture content is more than as given for service condition, then oil shall be filtered.**

3.6 **<u>Procedure for Long Storage of Spare Transformers & Reactors at Site</u>**

The transformer/reactor units, to be used as cold spare, are kept in storage condition for long period and utilized for replacing failed units or problematic units as and when required. The standard practice/guideline for long time storage of transformer/reactor and its accessories is as follows:

(a) The spare transformer/reactor shall be unloaded at site and placed on a raised platform specifically made for long storage. The platforms should be constructed before the spare unit reaches site. The proposed platform shall be about 1000mm above ground level for ease of shifting on trailer for any emergency transportation. It is to be ensured that the anchoring points are also constructed on both sides of the platform for ease of placement of transformer/reactor on the platform.

(b) The transformers/reactors are to be erected for pre-commissioning tests to keep the spare ready for use. The following steps to be followed:

- **Internal inspection** shall be carried out as per Clause No. 5 to check any abnormality inside the tank and photographed for future reference.
- **Turrets & bushings** are to be erected for complete testing of the transformer/reactor. It is advised to carryout Capacitance & Tan delta measurement before erection

after taking it out from packing case to ensure healthiness.

- **For Transformer, OLTC** (diverter switch & MOM box) are to be erected and driving shaft is to be aligned properly. Conservator of OLTC is also to be erected.
- **The Conservator** is to be mounted on transformer tank and all equalizing pipes are to be connected.
- **Cooler banks** (radiators, headers etc.) are to be inspected for any damage, rust, etc. and shall be packed again for long storage as these shall not be erected during storage of the transformer/ reactor. :
- **On line oil Drying system** provided along with the Transformer is to be installed & commissioned on Transformer.
- Oil is to be processed and filled in transformer/reactor. Oil sample is to be drawn from oil drums for testing of various parameters. The oil is to be filled in the transformer tank as per standard procedure and is to be circulated to obtain the required parameter.
- RTCC panels, MBs etc are to be inspected and stored safely.
- Earthing provision:
    - When bushings are erected in transformer/reactor, all the bushings are to be shorted and earthed when not used.
    - Earthing provision is to be provided near the storage platform and the body of the transformer/ reactor is to be earthed with 50x6 mm strip during storage. If earth pit or earth grid is available nearby, the same shall be used.
- Once the oil is filled in the transformer/ reactor and oil circulation is completed, oil sample need to be sent to any NABL accredited oil laboratory for testing. The pre-commissioning tests shall be carried out as per Clause No. 12 and the test results are to be forwarded to the OEMs and observations / comments are to be recorded.

(c) Once the pre-commissioning test results have been reviewed and are acceptable, the bushings are to be removed by lowering the oil and the bushing-openings to be blanked off

with blanking plates. Oil is to be filled up to requisite mark on MOG of temporary conservator provided on main tank.

Alternatively, the transformer/reactor can also be kept in a completely assembled oil-filled condition with all the bushings & conservator erected. In this case all the bushings as well as the main tank of the equipment should be shorted and earthed. In case the spare transformer/reactor is stored in an area not shielded/protected against lightening, arrangement may be made for a temporary lightening mast in its vicinity.

(d) Following actions are required during storage of the transformer/reactor:

- Oil parameters are to be checked every six (6) month and record is to be maintained.
- Circulation of oil is to be carried out every six months to keep the oil in healthy condition. BDV and moisture values are to be checked and maintained after filtration.
- The condition of the dehydrating material silica gel is to be checked every three (3) month. The colour of silica gel shall be blue. In case the colour of 50 % of volume of silica gel is found to be pink, the same should be replaced/re-generated.
- Manual operation of OLTC is to be exercised every six months for all Taps (applicable for transformers).
- Long duration storage insurance may be taken as per utility's policy.

(e) All the spares of the transformer/reactor are to be properly identified and packing list kept ready for transportation of the equipment to any location on emergency basis. Oil tankers are also to be kept available in the substation where spares are stored and when request is received, the oil in the equipment needs to be drained and transported in dry air filled condition.

3.7 Storage of Resin Impregnated Paper (RIP) bushings

(a) Resin Impregnated Paper (RIP) bushing technology offers number of advantages over Oil Impregnated Paper (OIP) bushing. Oil leakage is completely eliminated. Self-extinguishing property of RIP does not allow spread of fire. High thermal strength (because of Class E insulation-120°C) provides a large margin to ageing in service. However, these bushings by design are susceptible to absorption of moisture which will affect the dielectric

strength of the paper used in the manufacturing of bushing. Proper storage of RIP bushings in dry & clean environment and protection against any mechanical damage is essential to keep it healthy. It is advisable to cover the RIP bushing package box with a plastic or tarpaulin sheet to avoid ingress of moisture.

(b) The standard package box with cover shall be designed for long term storage of the RIP bushings. The package should always be kept in the covered area to prevent the possibility of ingress of moisture during long term storage. Oil end portion of RIP type bushings shall be fitted with metal housing with positive dry air pressure and a suitable pressure monitoring device shall be fitted on the metal housing during storage to avoid direct contact with moisture with epoxy. The pressure of dry air needs to be maintained in case of leakage of dry air. If any drying agents have been provided along with the RIP bushing, the same must be retained and checked from time to time.

(c) Adequate precautions must also be taken to ensure that the storage of RIP bushing with polymer housing, which is susceptible to attacks by rodents or birds, is done in a rodent/pest-free environment by using PVC coated mesh or any other material for wrapping. Bushings which are kept in storage container can be used even after long term storage without any further testing of the bushing. A photograph of a suitably stored RIP bushing is shown below:



4.0 Insulating Oil

4.1. When insulating oil is dispatched to site separately, it is usually in sealed steel drums. **Oil received in drums must be stored on an elevated platform. Drums are to be placed horizontally with its opening cap in middle.** In some of the cases, oil is supplied in tankers also. The oil to be used for filling and topping up must comply with oil specifications given in Technical Specification for acceptance criteria. Oil Samples shall be taken from oil drums/ tanker received at site and sent to NABL accredited oil Lab for oil parameter testing. As high dielectric losses cannot be removed by filter treatment, such lots have to be rejected. If the oil is supplied in railroad or trailer tanks, one or two samples are sufficient. If the oil is delivered in 200 litres drums, the following scheme for checking is recommended.

Number of drums delivered	No. of drums to be checked
2 to 5	2
6 to 20	3
21 to 50	4
51 to 100	7
101 to 200	10
201 to 400	15

In case any doubt arises, number of drums to be checked needs to be increased. However, before filling oil, each drum has to be physically checked for free moisture and appearance. A data sheet shall be maintained indicating the number of drums supplied in each lot and number of drums of each lot used in filling a particular Transformer/ Reactor. The oil test results carried out as above shall also be recorded.

The copy of test certificate of routine testing at oil refinery should be available at site for comparison of test results.

4.2. **Samples from Oil Drum**

Check the seals on the drums. The drum shall first be allowed to stand with bung (lid) vertically upwards for at least 24 hours. The area around the bung shall be cleaned and clean glass or brass tube long enough to reach within 10mm of the lower most part of the drum shall be inserted, keeping the uppermost end of the tube sealed with the thumb while doing so. Remove the thumb thereby allowing oil to enter the bottom of the tube. Reseal the

tube and extract an oil sample. The first two samples should be discarded. Thereafter, the sample should be released into a suitable receptacle. **Samples shall be collected in clean steel bottles.** The bottles shall be rinsed with the same oil and shall be without any air bubble.

5.0 Internal Inspection

5.1 **Before starting erection, thorough internal inspection of transformer/reactor shall be carried out by engineer along with manufacturer's representative.**

5.2 Internal inspection shall preferably be **carried out in dry and sunny weather along with circulation of dry air (With working person inside the tank, a minimum of 20 cfm/0.56 cubic-meter/minute of breathable air and additional 5 cfm/0.14 cubic-meter/minute for each additional person should be purged in the tank. Entry of person inside the tank should be avoided if adequate space is not available as in case of smaller rating of transformer.)** using dry air generator of dew point -40^0 C or better and shall be completed as quickly as possible to avoid ingress of moisture. If the Ambient humidity exceeds 65 % the internal inspection is to be avoided.

5.3 Prior to making any entry into the transformer/reactor tank, a foreign material exclusion programme shall be established to avoid the danger of any foreign objects falling into the transformer/reactor:

- Loose articles should be removed from the pockets of anyone working on the transformer/reactor cover.
- All jewelry, watches, pens, coins and knives should be removed from pockets.
- Protective clothing and clean shoe covers are recommended.
- Tools should be tied with clean cotton tape or cord securely fastened.
- Plated tools or tools with parts that may become detached should be avoided.
- An inventory of all parts taken into transformer/reactor should be recorded and checked before closing inspection cover to assure all items were removed.

If any object is accidentally dropped into the transformer/reactor and cannot be retrieved, the manufacturer should be notified.

5.4 **The inspection should include**:

- Removal of any shipping, blocking or temporary support.
- Examination for indication of core shifting.

- Tests for unintentional core or core clamp grounds.
- Visual inspection of windings, leads, and connections including clamping, bracing, blocking, spacer alignment, phase barriers, oil boxes, and coil wraps.
- Inspection of De-energized Tap Changer (DETC) and in-tank On-Load Tap Changers (LTCs) including contact alignment and pressure.
- Inspection of current transformers including supports and wiring harness.
- Checks for dirt, metal particles, moisture, or other foreign material.
- Any other suspected damage based on impact recorder readings

In case of any abnormality noticed during internal inspection, same shall be referred to manufacturer immediately before starting erection activities.

Detailed photographs of all visible parts/ components as per above shall be taken during internal inspection and shall be attached with pre-commissioning report.

6.0 Precautions during erection

6.1 During all erection activities, a well-qualified and experienced representative of manufacturer shall be present at the site for supervision and other necessary activities.

6.2 **During erection**, efforts shall be made to **minimize the exposure of active parts (core and coils) of transformer/ reactor**. Moisture may condense on any surface cooler than the surrounding air. Excessive moisture in insulation or dielectric liquid lowers its dielectric strength and may cause a failure of transformer/ reactor.

6.3 Further, either dry air generator or dry air cylinders should be used all the time to minimize ingress of moisture. The transformer/reactor should be sealed/blanked and pressurised after working hours. **Transformer/reactor shall never be allowed to be opened without application of dry air**.

6.4 It is advisable to apply a slight overpressure with dry air inside the main tank to the tune of 30 kPa (0.3 atmospheres) at the end of the day. Next day the pressure shall be checked and suspected leaks is to be detected with leak detection instruments or with soap water or with plastic bags tightened around valves (being inflated by leaking air)

6.5 For oil-filled units, whenever oil is drained out below the inspection covers, job shall be treated as exposed. Other exposure activities are as below:

- Bushing erection
- Internal jumper connections of Bushings
- Fixing bushing turrets
- Core insulation checking (in case the checking point not accessible outside)
- Buchholz relay pipe work fixing on cover
- Gas release pipes/equaliser pipe fixing
- Entering inside the tank for connections/inspection etc.

For oil filled units depending upon the level up to which the oil is drained decides the exposure time. All such exposure time should be recorded in a log sheet to decide the oil processing (drying) and oil filling of transformer/reactor.

6.6 "**GET THE TRANSFORMER AND REACTOR UNDER OIL AS SOON AS POSSIBLE!**" It is good practice to proceed with the erection in such a sequence that all fittings and auxiliaries with oil seals to the tank are assembled first. The oil filling will then be performed as easily as possible. The "active part" inside - core and coils - is then impregnated and protected. It has good time to soak properly, before the unit shall be energized, while remaining fittings are assembled on the unit, and commissioning checks carried out.

6.7 For transformer/reactor with a gas pressure of 2.5-3 PSI, the acceptable limits of dew point shall be as under:

TABLE 1- Variation of dew point of dry air/N2 Gas filled in transformer/reactor tank w.r.t temperature

Temperature of Insulation in °F	Permissible dew point in °F	Temperature of Insulation in °C	Permissible dew point in °C
0	-78	-17.77	-61.11
5	-74	-15.0	-58.88
10	-70	-12.22	-56.66
15	-66	-9.44	-54.44
20	-62	-6.66	-52.22
25	-58	-3.33	-49.99
30	-53	-1.11	-47.22
35	-48	+1.66	-44.44

40	-44	+4.44	-42.22
45	-40	+7.44	-39.39
50	-35	+9.99	-37.22
55	-31	12.77	-34.99
60	-27	15.55	-32.77
65	-22	18.33	-29.99
70	-18	23.11	-27.77
75	-14	23.88	-25.55
80	-10	26.66	-23.33
85	-6	29.44	-21.11
90	-1	32.22	-18.33
95	+3	34.99	-16.11
100	+7	37.75	-13.88
110	+16	43.33	-8.88
120	+25	48.88	-3.88
130	+33	54.44	+0.55
140	+44	59.99	+5.55

6.8 Final tightness test with vacuum (i.e. leakage test or Vacuum Drop Test)

Before oil filling is started, a final check is made for the tightness of the transformer/reactor tank by applying vacuum. After vacuum is applied to a transformer/reactor main tank without oil, leakage test must be carried out to ensure that there are no leaks on the tank which would result in ambient air being drawn into the transformer/reactor. The following procedure is to be adopted:

- Connect the vacuum gauge to a suitable top valve of the tank. (Vacuum application and measurement should be performed only on top of the main tank) - A vacuum gauge of McLeod type or electronic type, with a reading range covering the interval of 1 kPa (1-10 mm mercury) to be used.
- Connect the vacuum pump to vacuum pulling valve
- Evacuate the transformer/ reactor tank until the pressure is below 50 mbar (5 kPa or about 2 mm of Hg).
- Shut the vacuum valve and stop the pump.
- Wait for an hour and take a first vacuum reading – say P1.
- Take a second reading 30 minutes later- say P2.
- Note the volume of the tank (quantity of oil required according to the rating plate) and expressed as volume, V, in m^3.

- Take the difference between P2 and P1, and multiply this with the oil quantity V. If the pressures are expressed in kPa, and the oil quantity in m^3, then the product shall be less than 3.6.

  (P2 – P1) x V < 3.6

  The transformer/reactor is then considered to be holding sufficient vacuum and is tight.
  Continue taking readings (for at least 2 to 3 hours) at successive 30 min intervals to confirm the result.
- If the leak test is successful, the vacuum pump shall be continued to run, until the pressure has come down to 0.13 kPa (1 Torr) or less. The vacuum shall then be held/maintained at that level for the duration as given in **Table-2** before the oil filling starts.
- If the specified vacuum cannot be reached, or if it does not hold, the location of the leakage in the transformer/reactor system shall be located and corrected.

In case the transformer is provided with an On Load Tap Changer (OLTC), while evacuating the main transformer tank, the pressure inside the diverter switch compartment is also be equalised with main tank so that both are evacuated simultaneously and no undue pressure is allowed on the tap changer chamber. While releasing vacuum, the tap changer chamber vacuum should also be released simultaneously. For this one pressure equalizer pipe should be connected between main tank and tap changer. Manufacturer's instruction manual shall be referred to protect the air cell/ diaphragm in the conservator during evacuation.

This vacuum must be maintained for the time specified as per the voltage class in Table-2 before and should also be maintained during the subsequent oil filling operations by continuous running of the vacuum pumps.

7.0 Drying of wet winding of transformer/reactor by application of vacuum, dry nitrogen gas filling and heating

The drying of a new transformer/reactor is required on the first commissioning and when the moisture gets absorbed by the solid insulation used in transformer/reactor due to various reasons. The process of drying out a transformer/reactor requires care and good judgment. **If the drying out process is carelessly or improperly performed, a great damage may result to the transformer/reactor insulation. In no case shall a transformer/reactor be left unattended during any part of the dry out period unless on-line dry-out process is adopted** which incorporates all necessary safety features**.** The

transformer/reactor should be carefully watched throughout the dry-out process and all observations to be carefully recorded.

When the transformer/reactor is being dried out, it is necessary to **ensure that firefighting equipment is available near the transformer/reactor as a precaution** as there are chances of fire as we are dealing with heat and inflammable oil.

7.1 Isolation Required

All the openings of transformer/reactor main tank like openings for coolers/radiators, conservator, OLTC etc. are to be properly isolated and totally blanked.

7.2 Procedure

(a) Fill the main transformer/reactor tank with dry N_2 gas (Use only dry N_2 gas as per IS: 1747 with less than 50 ppm moisture and 1% oxygen by volume) until it comes to a positive pressure of 0.15 kg/cm^2. The pressure is to be maintained for about 48 hrs. However, at the end of first 12 hrs., transformer/reactor tank shall be thoroughly checked for any leakage. If any leakage is found, necessary action shall be taken to rectify the problem and tank shall be pressurized for about 48 hrs. as mentioned above, otherwise the process to be continued. At the end of 48 hrs., dew point of Nitrogen gas at outlet is measured. If the dew point is not within acceptable limits as per **Table-I**, dry out method should be continued.

(b) While dry Nitrogen gas circulation is in progress, the heaters are to be installed around the transformer/reactor tank. The heaters are to be kept ON till a temperature of about 75°C–80°C of the core & winding of transformer/reactor is achieved as measured by top oil temperature in the transformer/reactor.

(c) After ascertaining that there is no leakage, the vacuum pulling on the transformer/reactor tank is to be started until absolute vacuum (1-5 torr) is achieved and the same is to be maintained for about 48 hours (minimum)running the vacuum pump continuously. The duration of vacuum can vary between 48 to 96 hrs., depending upon the dew point being achieved. During the running of Vacuum pump, the condensate shall be collected for measurement. Observe the rate of condensate collection on hourly basis. Depending on the value of rate of condensate (less than 40 ml/hr for 24 hrs), continuation of further vacuum shall be decided.

(d) Then the vacuum is broken with dry Nitrogen gas. The dew point of Nitrogen at the inlet is to be measured and should be of the order of - 50 °C or better. Develop the pressure of Nitrogen upto the positive pressure of 0.15 kg/cm2 and maintain it for 24 hours. Heating from outside is to be continued while Nitrogen circulation is in progress. Then the Nitrogen pressure is released and the dew point of air at the outlet is measured. If the dew point is within acceptable limits as per **Table-I**, then the dryness of transformer/reactor is achieved. In case the required dew point is not achieved, the transformer/reactor is subjected to vacuum treatment for 48 hours (minimum). The dry Nitrogen gas is pressurised, maintained for 24 hours and the dew point is measured. The cycle is to be repeated till desired dew point as per **Table-1** is achieved.

(e) Duration of vacuum cycle may vary between 48-96 hrs. Initially two dry Nitrogen gas cycles may be kept for 24 hrs. Afterwards it may be kept for 48 hrs., depending upon dew point being achieved.

7.3 After completion of drying process, oil filling and hot oil circulation is to be carried out before commissioning. Please ensure standing time as per **Table-2** given below before charging.

Note: If already known that the transformer/reactor is wet based on the tests or exposure time, then (a) above can be skipped to save time.

Table – 2

Voltage class	**Application of Vacuum & holding for (before oil filling)***	**STANDING TIME After Oil circulation and before energizing**
Up to 145kV	12 HRS	12 HRS
145 kV and up to 420kV	24 HRS	48 HRS
Above 420 kV	36 HRS	120 HRS

*Without running the vacuum pump and leakage rate to be ≤ 40mbar-lit/sec

After the completion of standing time, air release operation is to be carried out in Buchholz relays, turrets and other release points given by the manufacturers before charging. If the transformer has oil pumps, then the oil pumps are to be operated for a duration of 10 minutes before conducting the air release.

8.0 Oil Filling

Once the oil is tested from the drums and found meeting the requirements, the oil is transferred to oil storage tank for oil filtration before filling inside the transformer.

The drums or trailer tanks shall not be emptied to the last drop - a sump of an inch or so shall be left, to avoid possible solid dirt or water at the bottom.

Before being used, the tanks and hoses shall be visually inspected inside for cleanness. Any residual oil from earlier use shall be carefully removed, and the tank is flushed with a small quantity of new oil, which is then discarded.

After filtration, **particle count shall be done (Limiting value for the particle count are 1000 particle/100 ml with size ≥ 5 µm; 130 particle/100 ml with size ≥ 15 µm.) and** oil sample is tested for meeting specification for new oil.

Prior to filling in main tank at site, it shall be tested for:

(a) Break Down voltage (BDV) : 70 kV (min.)
(b) Moisture content : 5 ppm (max.)
(c) Tan-delta at 90 °C : Less than 0.0025
(d) Interfacial tension : More than 0.04 N/m

For transformer/reactor dispatched with dry air filled from the works, the filling of oil inside the tank shall be done under vacuum. **Transformer/reactor** of high voltage ratings and their **tanks are designed to withstand full vacuum**. Manufacturer's instructions should be followed regarding application of full vacuum during filling the oil in the tank.

When filling a transformer/reactor with oil it is **preferable that the oil be** pumped into the bottom of the tank through a filter press or other reliable oil drying and cleaning device should be interposed between the pump and the tank (please refer Fig.-2).

The oil flow at the entry valve must be controlled to maintain a positive pressure above atmospheric and to limit the flow rate if necessary to 5000 litres/hour, or a rise in oil level in the tank

not exceeding one meter/hour (as measured on the oil level indicator).

Continue oil filling until the level reaches approximately 200 mm above the ambient oil level indicated on the magnetic oil level gauge in the expansion vessel. Then, release the vacuum, with dry air of dew point -40° C or better (for > 220 kV, -25° C for others).

The diverter tank can now be topped up at atmospheric pressure. Reconnect oil outlet hose to valve on flange on tap changer diverter head. Reinstate breather and very slowly top up the diverter switch such that the correct level is reached in the diverter expansion vessel. In the event the expansion vessel is overfull drain oil from flange into a suitable container until the correct level is reached.

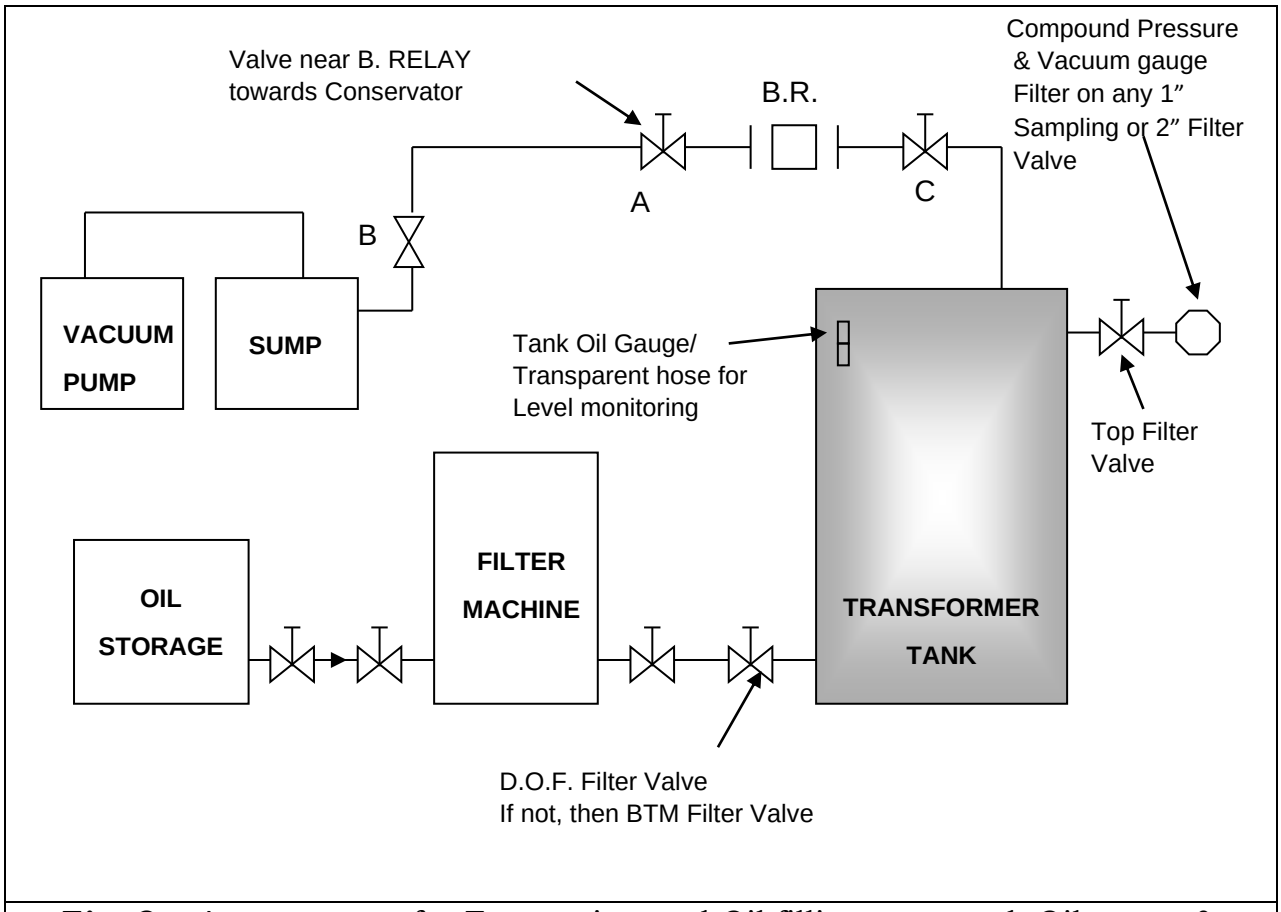


Fig.-2 : Arrangement for Evacuation and Oil filling upto tank Oil gauge & Conservator

When the oil filling, under vacuum of the transformer/reactor main tank and diverter tank, is complete, the cooling system/ radiator bank can be filled (without vacuum) at atmospheric

pressure, via an oil processing plant. Oil must be admitted, very slowly, through the bottom cooler filter valve and the top cooler filter valve with air release valve kept open to atmosphere. As the oil level reaches the top vent, then top valve and air release valve are to be closed and the processing plant can be shut down.

Note: Care must be taken not to pressurize the coolers/radiators.

Upon completion, open the top cooler isolating valve in order to equalize the pressure in the cooler with the transformer/reactor tank. This will also allow contraction or expansion of the oil as the ambient temperature changes.

Before filling oil into the conservator, the air cell/bellow to be inflated to 0.5 PSIG i.e. 0.035 kg/cm2 max. or upto the value recommended by the manufacturer by applying pressure (N2/Compressed dry air) so that it can take shape. After releasing pressure, breather pipe is to be fitted however it is recommended not to fit breather in position, instead a wire mesh guard may be connected over the flange of the pipe to prevent entry of any insect inside the pipe. This will ensure free air movement from the air cell to the atmosphere.

Use flow meter/indicator on outlet of filter machine and regulate the flow using the valve to limit oil filling rate to 2000 litres per hour max. in case filter capacity is more.

Oil to be pushed slowly into conservator through the transformer/reactor via valve No. 5 (valve 2, 3 & 4 to remain open) till the oil comes out first through valve Nos. 2 & 3 (close these valves) and then through valve No. 4. Allow some oil to come out through valve No.4. Oil should come out freely into the atmosphere. This will ensure that air inside the conservator is expelled out and the space surrounding the air cell is full of oil. Close valve No. 4. During all these operations valve No.1 shall be in closed position.

Excess oil from the conservator is to be drained by gravity only through valve No. 1 or through drain valve of the transformer/reactor via valve No. 5. Do not use filter machine for draining oil from the conservator. Also do not remove Buchholz relay and its associated pipe work, fitted between the conservator and the transformer/reactor tank while draining oil.

Stop draining oil till indicator of magnetic oil level gauge reaches position-2 on the dial, which is corresponding to 30°C reading on the oil temperature indicator. Fill the conservator according to the oil temperature and not the atmospheric temperature.

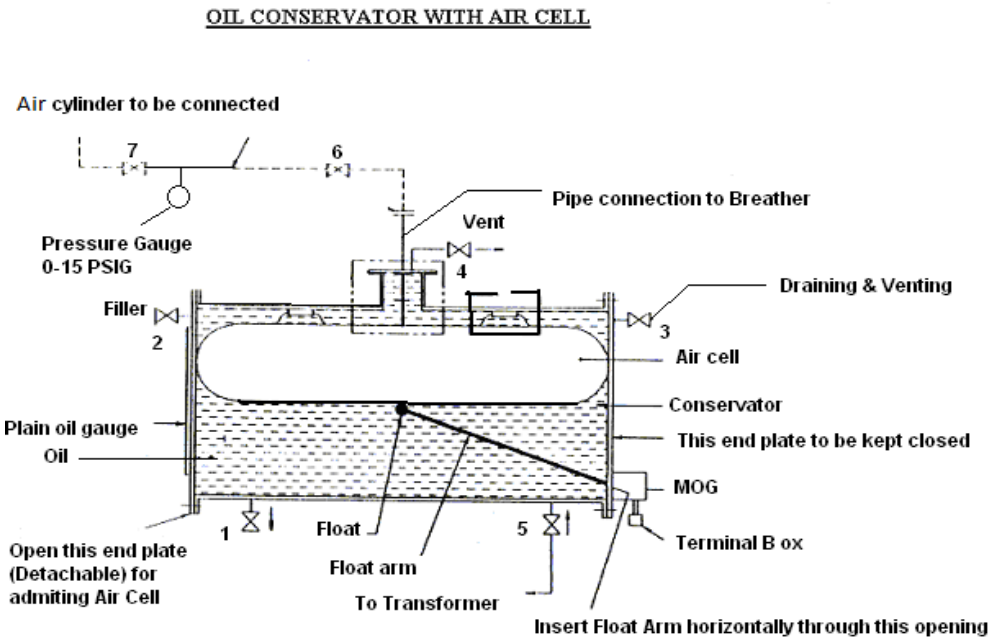


Fig.-3 : General Arrangement For Oil Conservator

After Oil filling, Hot Oil Circulation has to be applied to the transformers/reactors except under the circumstances when active part of transformer/reactor gets wet. Following conditions can be considered to define the transformer/reactor wet:

1. If transformer/reactor received at site without positive dry air pressure.
2. If Dry air not used during exposure while doing erection activities
3. Overexposure of active part of transformer/reactor during erection (Overexposure when exposure > 12 Hrs)

Under above *mentioned conditions, manufacturer shall take necessary action for effective dry out of the Transformer/ Reactor.*

The oil sample from the transformer/reactor tank, after filling in tank before commissioning should meet the parameters specified in the specification elsewhere.

9.0 Hot oil circulation using high vacuum oil filter machine

To ensure proper dryness and absorption of possible trapped gas bubbles, the oil in the tank is circulated through the vacuum filter as shown in Fig.-4. The circulation procedure for the main tank is as follows:

(a) The transformer/reactor is connected to the oil filter machine in a loop through the top and bottom filter valves. **The direction of circulation shall be from the transformer/reactor to the filter at the bottom and from the filter to the transformer/reactor at the top. (Please note that at the initial oil filling time, the direction is reverse to avoid air bubble formation).**

(b) The **temperature of the oil from the filter to the transformer/reactor** should be around 60° C and **in no case it should go beyond 70° C** otherwise this may cause oxidation of oil.

(c) The circulation shall proceed until a volume of oil corresponding to 2 times the total oil volume in the tank has passed through the loop. (At freezing ambient temperature the circulation time is increased: circulate 3 times the volume at temperature down to minus 20° C, increase to 4 times below that temperature).

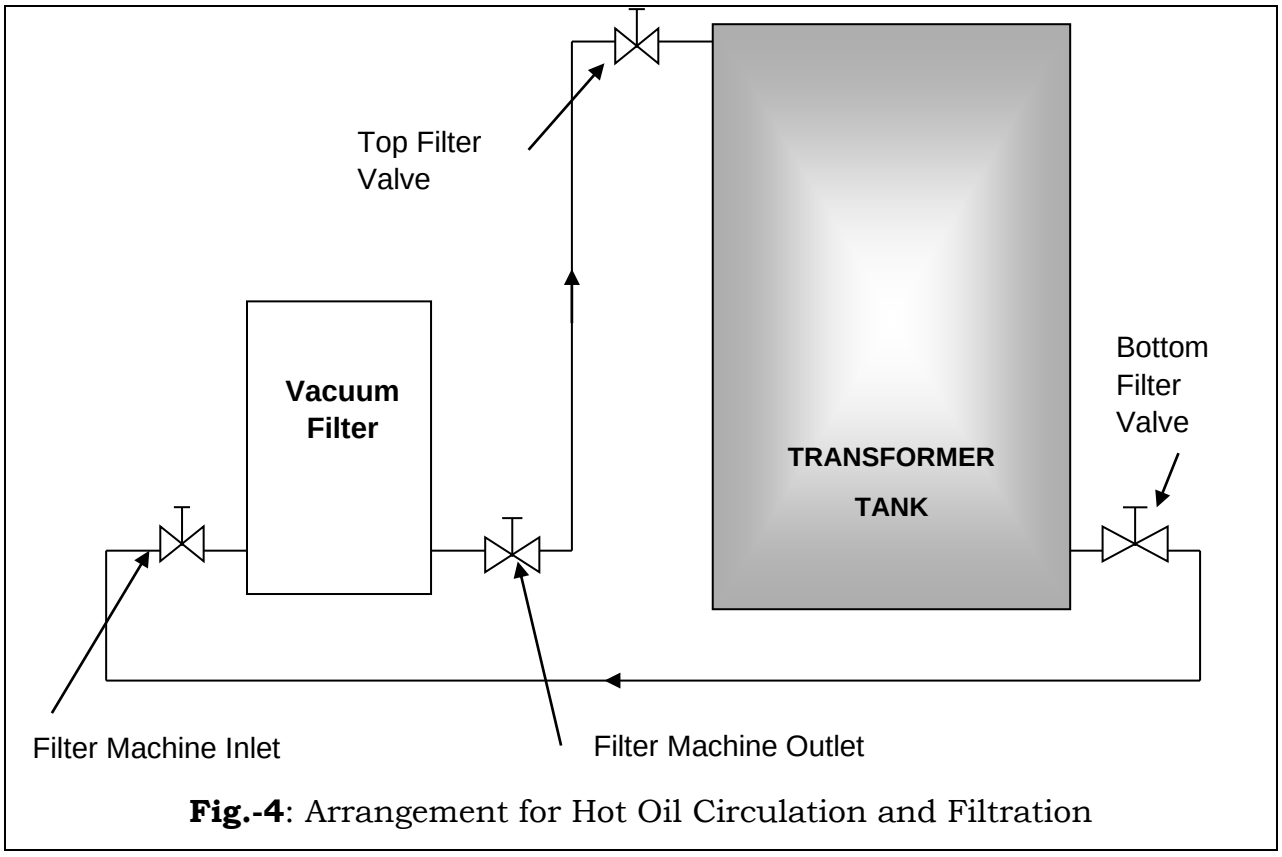


Fig.-4: Arrangement for Hot Oil Circulation and Filtration

10.0 Safety measures and precautions

The following safety measures and precautions shall be followed:

(a) Keep recommended fire extinguishers at site.
(b) During hot oil circulation, keep fire extinguisher ready near transformer.
(c) Carry out all pre-commissioning test and final commissioning check as elaborated in this document before energizing transformer.
(d) Take precaution while handling PRV devices having heavy springs in compression to safeguard person and system.
(e) Provide adequately rated cables & fuses.
(f) Never apply voltage when transformer is under vacuum
(g) Oil spillage shall be inspected regularly and attended, if any. Oil shall not be allowed to fall on ground.
(h) Keep all combustible items at safe distance to reduce risk of fire.
(i) No welding work shall be taken up near transformer.
(j) Welding on oil filled transformer shall be avoided as far as possible. If, under special circumstances, welding is absolutely necessary, it shall be done as per instruction of manufacturer only.
(k) All erection personnel must use Personal Protective Equipment like, helmet, safety shoe, boiler suit, etc.
(l) Electrical equipment like filter machine, dry air generator etc., must be earthed.
(m) First Aid box shall be kept ready at site.
(n) Adequate lighting must be available for clear visibility
(o) Cordon off the working area, particularly when transformer augmentation work in a switchyard is taken up.
(p) All major erection activity like bushing, conservator and radiators must be carried out with crane of adequate capacity and boom size.
(q) Never carry out work with unskilled workers.
(r) Safety posters, like “No Smoking”, “Wear Helmet”, etc., must be displayed.
(s) Use approved and tested Earth rods
(t) Safety Nodal Officer to make sure that site is cleared on daily basis to prevent fire hazards.

11.0 Inspection and Testing at Site

The Contractor shall prepare a detailed inspection and testing schedule/programme in consultation with the OEM for field activities covering areas right from the receipt of material stage up to commissioning stage and shall got it approved by the

Purchaser. An indicative pre-commissioning checks & test, commissioning check and final energization is given below. . Supplier shall follow purchaser approved Field Quality Plan (FQP). Testing of oil sample at site shall be carried out as per specification.

12.0 Pre-Commissioning checks and tests for Transformers and Reactors

Once oil filling is completed, following pre-commissioning checks and tests are performed to ensure the healthiness of the Transformer/ Reactor prior to its energization.

The following checks should be carried out before commencement of the pre-commissioning tests:

(a) Ensure that transformer/reactor and its auxiliaries are free from visible defects on physical inspection
(b) Ensure cleanliness of transformer/reactor and the surrounding areas
(c) Ensure that all fittings are as per out line General Arrangement Drawing
(d) Ensure that bushings are clean and free from physical damages
(e) Ensure that oil level is correct in all bushings
(f) Ensure that oil level in Main/OLTC Conservator tank in MOG is as desired.
(g) Ensure gear box oil level in OLTC
(h) Ensure that OTI and WTI pockets are filled with transformer oil
(i) Ensure that cap in the tan delta measurement point in the bushing is tight and grounded
(j) Ensure unused secondary cores of Bushing CT's, if any, has been shorted
(k) Ensure CT secondary star point has been formed properly and grounded at one end only as per scheme
(l) Ensure that Buchholz Relay is correctly mounted with arrow pointing towards conservator
(m) Ensure all power and control cable terminals are tightened
(n) Ensure all cables and ferrules are provided with number as per cable schedule
(o) Ensure that external cabling from junction box to relay/control panel is completed
(p) Ensure operation of cooling fans, oil pumps etc.
(q) Ensure correct operation of all protection devices and alarms/trip :
    i) Buchholz relay
    ii) Pressure Relief Device
    iii) Sudden Pressure Relay (if applicable)

iv) Excessive winding temperature
v) Excessive oil temperature
vi) Low oil flow
vii) Low oil level indication
viii) Fan and pump failure protection (as applicable)

(r) Check for the adequate protection on the electric circuit supplying the accessories.
(s) Ensure operation of OLTC manually & electrically at local and remotely by RTCC/BCU/SAS
(t) Ensure that indication of tap position on Diverter switch, Drive mechanism & RTCC are same.
(u) Ensure working of numerical AVR
(v) Ensure that the cable glands have been packed properly. The unused holes if any have also been blanked.

The following pre-commissioning tests shall be carried out before energization:

(a) Insulation resistance measurement for the following:

i) Control wiring
ii) Cooling system motor and control circuit
iii) Main windings (PI & DAI)
iv) Tap changer motor and control (as applicable)

(b) Test on Bushing CTs
(c) 2 kV for 1 minute test between bushing CT terminal and earth
(d) Polarity and vector group test (for transformer)
(e) Ratio test on all taps (for transformer)
(f) Magnetising current test
(g) Magnetic balance test (for 3 phase transformer/reactor)
(h) Capacitance and Tan delta measurement of winding and bushing
(i) Tan delta of bushing at variable frequency (Dielectric frequency response)
(j) Frequency response analysis (FRA).
(k) Measurement of vibration and noise level (for reactor)
(l) Short circuit impedance test
(m) Contact resistance measurement
(n) Measurement of resistance of all windings on all steps of the tap changer
(o) Protection relay settings
(p) Measurement of safety clearances
(q) Measurement of earth pit resistance

13.0 Final commissioning checks

The following commissioning checks should be carried out before energization of the transformer/ reactor:

(a) All the pre-commissioning test results of unit are verified and compared with factory results before commissioning.
(b) No leakage of oil in any part of unit.
(c) Ensure safe electrical clearance of conductor jumpers in the switchyard with transformer/ reactor body, gantry, column, jumpers, fire wall etc.
(d) Ensure that tertiary winding terminals are insulated, when they are not used/ connected to any system.
(e) Ensure earthing of Neutral, main tank body, radiator frame structure, fans and motor.
(f) Neutral earthing conductor of suitable size must run through support insulator and connected to two separate earthing pits which are in turn connected to main earth mat of switchyard.
(g) Ensure that conductor jumpers connected to HV, LV and tertiary terminals are not tight and should have the allowance for contraction. Also ensure that connectors are properly tightened at bushing terminal.
(h) Ensure that R.Y.B designated terminals of transformer/ reactor are matching with R,Y,B buses of switchyards on HV and LV side.
(i) Ensure oil level in the Bushings.
(j) Ensure continuity of OLTC operation at all taps.
(k) In a transformer bank of three single phase units, ensure master-slave OLTC scheme.
(l) In a transformer bank of three single phase units, ensure tertiary connection and protection scheme (if provided).
(m) Ensure oil filling in conservator tank according to temperature scale in MOG and also ensure oil level in prismatic glass.
(n) Ensure that all valves between main tank and radiator banks are opened.
(o) Ensure those radiator valves connected to header are open.
(p) Ensure that valve to conservator tank via Buchholz relay is open.
(q) Ensure physical operation of local protections like Buchholz, PRV, Surge relay of OLTC etc.
(r) Ensure OTI and WTI settings of fan & pumps operation, Alarm and Trip as per approved drawings. Fan and pump operation shall be ensured locally and remotely.
(s) Review and ensure protection scheme of power transformer/ reactor with over all protection scheme at remote end in control room.

For Transformer:

- Differential Protection
- Restricted Earth Fault (REF) Protection.
- Over current and Earth fault protection / impedance protection.
- Over fluxing Protection
- Tertiary Protection (if applicable)
- Over load alarm
- OTI & WTI- alarm and trip
- RTCC panel/relay interface with protection system
- Local protection like Buchholz, PRV etc.
- MOG-low oil alarm
- Integration of on-line condition monitoring equipment (if applicable).
- Integration of RTCC with BCU/SCADA system

For Reactor:

- Differential Protection
- Restricted Earth Fault (REF) Protection.
- Reactor backup protection (impedance protection/ Over current and Earth fault protection)
- OTI & WTI- alarm and trip
- Local protection like Buchholz, PRV etc.
- MOG-low oil alarm
- Integration of on-line condition monitoring equipment (if applicable).

(t) Ensure the common earthing of tank, frame and core provided in transformer.

(u) Ensure the shorting of spare cores of bushing CT's.

(v) Ensure that cap in the tan delta measurement point in the bushing is put back.

(w) Ensure Fire Protection System and oil drain valve operation before charging and commissioning.

(x) Oil test results after filtration must be within specified limit.

(y) Spares like bushings shall be tested and kept ready before charging and commissioning.

(z) Allow minimum period of 24 hrs. after filtration for oil temperature to settle down.

(aa) Ensure release of air from plugs provided on top of main tank, conservator and radiator headers.

(bb) Take charging clearance certificate from all erection agencies for removal of man, material and T&P from site.

(cc) Ensure healthiness of Air Cell.

(dd) Ensure availability of oil in the breather cup in main tank/ OLTC tank.

(ee) Ensure all rollers are locked with rails if transformer is on rollers

(ff) Ensure door seals of Marshalling Box are intact and all cable gland plate's unused holes are sealed.

(gg) Ensure change over operation of AC supply from source- I to source-II in local master control cubicle.

(hh) Ensure that all associated equipment of the bay e.g. CB, Isolator/Earth switch, CT/PT/CVT etc. has been checked properly as per OEM's recommendations and utility practice.

14.0 Energization of transformer/ reactor

Commissioning of transformer / reactor is not complete unless it is put into regular service. Following activities to follow:

(a) Perform DGA just before commissioning

(b) Initially charge the transformer under no load.

(c) Continuously observe the transformer operation at no load for at least 24 hours.

(d) Gradually put the transformer on load, check and measure increase in temperature in relation to the load and check the operation with respect to temperature rise (monitor OTI & WTI), vibration, oil leakage, oil level indicators & gas detector relay and noise level etc.

(e) Check OLTC operation.

(f) Carry out Thermo-vision scanning of HV/LV terminals and tank body.[This test should be carried out once the transformer/reactor is stabilised and operating at higher temperature (> 60 deg.C)]

(g) Carry out DGA of oil after 24 hours, one week, 15 days, one month & 3 months of energisation at site, thereafter as per normal frequency of 6 months / as and when required based on the trend analysis.

Contractor shall prepare a comprehensive commissioning report and hand over testing and commissioning records to operation staff for future reference and record.

15.0 Significance of various tests

Significance of various tests to be performed on transformer/reactor is given below:

Sr. No.	Name of Test/ Check point	Purpose of test/check
(a)	Core insulation tests	Used for detecting any accidental

		grounds which could results in circulating currents if multiple path exists between the core & frame and core & ground. i.e. to check that core is earthed only at one point.
(b)	Earth pit resistance measurement	To check the resistance of earth pit provided for Transformer/reactor neutral grounding. Proper treatment is to be given if the resistance is more than desirable value.
(c)	Winding Insulation Resistance (IR) measurement	Test reveals the condition of insulation (i.e. degree of dryness of paper insulation), presence of any foreign contaminants in oil and also any gross defect inside the transformer/reactor (e.g. Failure to remove the temporary transportation bracket on the live portion of tap-changer part).
(d)	Capacitance and Tan δ / Dissipation Factor (DF) measurement of bushings / windings	Dissipation factor/ Tan δ/ Loss factor and capacitance of winding/ bushing provides an indication of the quality and health of insulation in the winding/ bushing. Changes in the normal capacitance of an insulator indicate abnormal conditions such as the presence of moisture layer, short circuits (condition of inter-winding insulation) or open circuits in the capacitance network.
(e)	Turns ratio (Voltage ratio) measurement	To determine the turns ratio of transformers to identify any abnormality in tap changers/ winding due to shorted or open turns etc.
(f)	Vector Group & Polarity	To determine the phase relationship and polarity of transformer connections
(g)	Magnetic Balance test	This test is conducted only in three

		phase transformers to check the imbalance in the magnetic circuit
(h)	Floating Neutral point measurement	This test helps to confirm the connectivity of the NEUTRAL to the earthing system.
(i)	Measurement of Short Circuit Impedance	This test is used to detect winding movement that usually occurs due to heavy fault current or mechanical damage during transportation or installation since dispatch from the factory.
(j)	Exciting/Magnetizing current measurement	To determine the condition of magnetic core structure, shifting of windings, failures in turn to turn insulation or problems in tap changers. These conditions change the effective reluctance of the magnetic circuit thus affecting the current required to establish flux in the core.
(k)	Operational checks on OLTCs	To ensure smooth & trouble free operation of OLTC during operation.
(l)	Tests/ Checks on Bushing Current Transformers (BCTs)	To ascertain the healthiness of bushing current transformer at the time of erection
(m)	Operational Checks on protection System	Operational Checks on cooler bank (pumps & Fans), Breathers (Silica gel), MOG, temperature gauges (WTI/OTI), gas actuated relays (Buchholz, PRD, SPR etc.) and simulation test of protection system
(n)	Stability of Differential, REF protection of Transformer/ Reactor	This test is performed to check the proper operation of Differential & REF protection of Transformer & Reactor by simulating actual conditions. Any problem in CT connection, wrong cabling, relay setting can be detected by this test.
(o)	Frequency Response	To assess the mechanical integrity

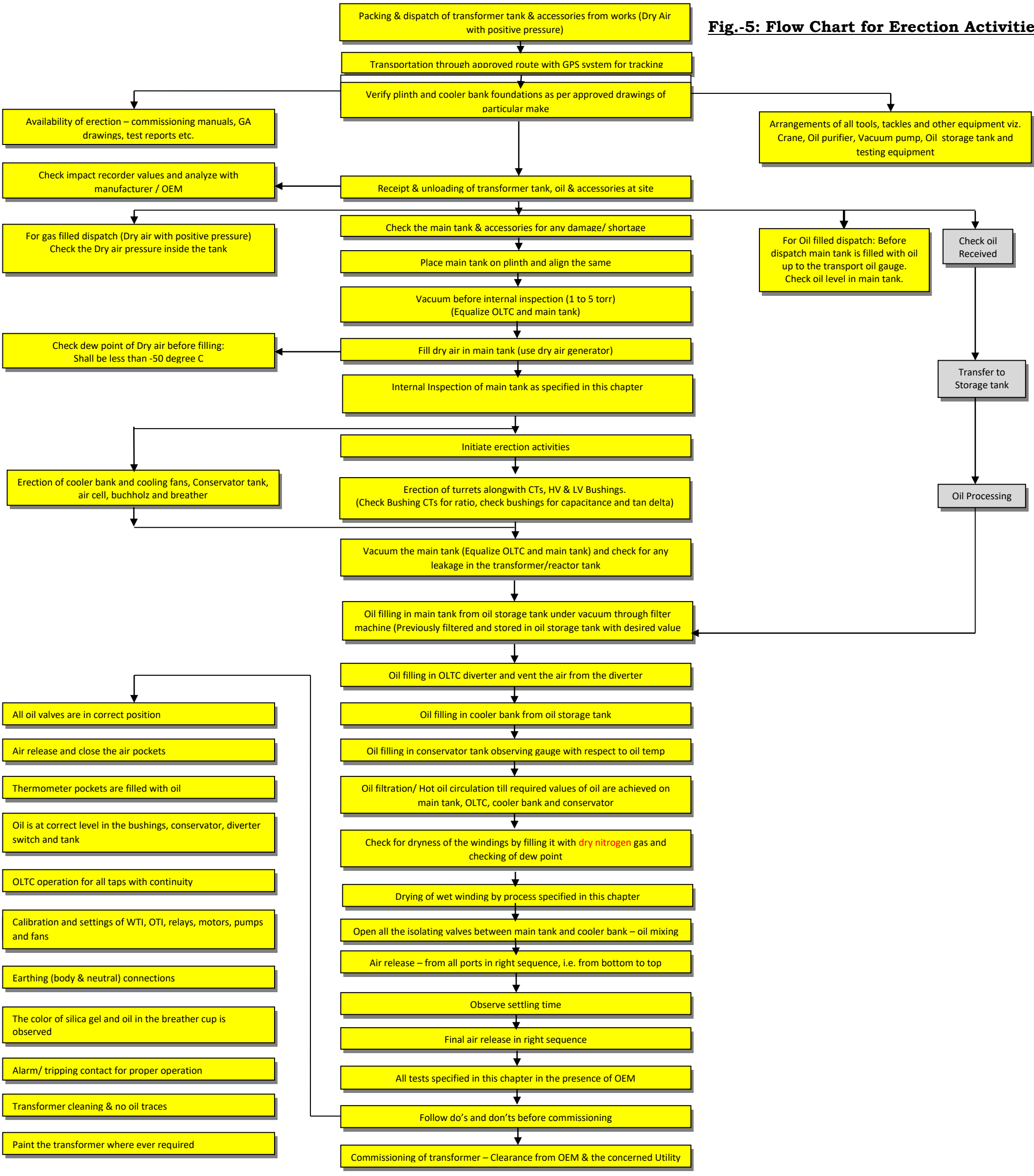
	Analysis (FRA)	of the transformer/reactor. Transformers while experiencing severity of short circuit current loses its mechanical property by way of deformation of the winding or core. During pre-commissioning this test is required to ascertain by comparison with the factory results that transformer/reactor active part has not suffered any severe impact/ jerk during transportation.
(p)	Winding resistance measurement	To check for any abnormalities due to loose connections on bushing or tap changer, broken strands and high contact resistance in tap changers (OLTC contact problem).
(q)	Dissolved Gas Analysis (DGA) of oil sample	The nature, amount and rate of generation of individual fault gases indicate the type & degree of the abnormality (like partial discharge, overheating, arcing etc.) responsible for gas generation. DGA analysis helps the user to identify the reason for gas formation & materials involved and indicate urgency of corrective action to be taken.
(r)	Tan delta of bushing at variable frequency (Dielectric frequency response)	Helps to establish relationship between insulation condition (e.g. moisture in paper & ageing of paper) and diagnostic quantities. It is not possible to identify problems like PD in bushings, development of bridging of grading layers etc., which is not reflected in capacitance/Tan δ measurement at 50Hz. The Tan δ measurement at variable frequency (in the range of 20 Hz to 350 Hz) shall be carried out on each condenser type bushing (OIP & RIP/RIS) at site and the result shall be compared with factory results to verify the healthiness of the bushing.

All test records of FAT, tests at site & pre-commissioning tests before energisation of the transformer/reactor shall be kept in digital form for future reference & record and should also be available with operation staff of substation/switchyard for ready reference.

16.0 Flow chart for erection activities

The complete process of erection from the point of dispatch from the factory to commissioning is illustrated in the form of a flow chart given below **(Fig.-5)** to ensure that erection activities are carried out properly with safety and without damage to transformer/reactor.

Fig.-5: Flow Chart for Erection Activities



Key points:

1) Oil Samples for DGA shall be taken at intervals of 24 hrs, 1 week, 15 days,1 month and then 3 month after commissioning and thereafter as per periodic maintenance schedule.
2) PT Values shall be between 1.5 to 2.2
3) All bolts to be tightened as per the torque value provided by OEM.
4) Never exceed oil temperature beyond 60degree C during oil processing.
5) Oil BDV and PPM shall be more than 70KV and less than 5 respectively.
6) Fill the oil in conservator tank as per the temperature scale in MOG.
7) Settling time:
   i) 66KV: 24hrs
   ii) 132KV: 36hrs
   iii) 220KV: 48hrs
   iv) 400KV: 48hrs
8) Refer OEM manual for details of equipment handling, erection and testing.
9) Set WTI/ OTI and fans/ pumps operation as per approved drawing.
10) Ensure that no bushing core CT's are left open circuit and tan delta caps are in place.
11) Ensure tank, core and frame earthing.

Note : 1 mbar = 0.75 torr



Chapter-6

Condition Monitoring & Life Cycle Management

CHAPTER 6

CONDITION MONITORING AND LIFE CYCLE MANAGEMENT

1.0 Introduction

Electrical equipment deterioration phenomena are related to electric, thermal, mechanical, chemical, environmental and combined stresses. Hence, failure of transformers/reactors could be due to insulation failure, or thermal failure, or mechanical failure or combination of these. Due to frequent system faults, over loading, environmental effect, unexpected continuous operating voltage and over voltage stresses of the system during the operation, many equipment fails much before their expected life span. There is no escape from normal long term ageing process but premature failure can be avoided by proper maintenance. Preventive maintenance is the key to keeping equipment healthy and in service. The most cost-effective maintenance approach is the one, which gives a high level of reliability while keeping maintenance cost minimum. The type of maintenance practices usually being followed by various utilities is conventional Time-Based Maintenance (TBM) or Corrective Maintenance (CM) or Condition-Based Maintenance (CBM) or Reliability Centred Maintenance (RCM). Different maintenance strategies (TBM/CM/CBM/RCM) have different impact on Life Cycle Cost (LCC) of equipment.

TBM practice is based on concept of preventive maintenance in pre-defined intervals. Unfortunately, as maintenance interval is increased, the equipment reliability is compromised. Condition-Based Maintenance (CBM) program offers an attractive option to overcome the shortcoming of traditional TBM.

The benefits of Condition Based Maintenance are as follows:

- Provides advance information about health of equipment for planning a major maintenance/overhaul
- Reduces maintenance cost
- Defers capital and maintenance expenditure
- Reduces forced outages of equipment
- Improves safety of operating personnel, reliability and quality of supply to customer
- Provides valuable information for life assessment of equipment for possible extension
- Helps in “Run-Refurbish-Replacement” decision

For reliable operation of vital assets like transformers/reactors, it is necessary to identify problem at early stage before a catastrophic failure occurs. The Condition Based Maintenance (CBM), which has become accepted approach world over, has also gained acceptance by Indian utilities. Condition Monitoring for any device is defined as "A generic procedure/activities directed towards identifying and avoiding root cause failure modes." Condition monitoring activities can be described as the process of monitoring a parameter in the equipment, in order to identify a significant change which is indicative of a developing fault. It is a major component of predictive maintenance.

Monitoring could be continuous/temporary on-line or off-line. The on-line measurements offer the advantages of continuous supervision and the minimization of errors due to incorrect sampling and analysis. In the present scenario, the Residual Life Assessment (RLA) of transformers/reactors in service/operation would play a vital role in assessing the possibility of extending the service life and also for investment decision and future planning of the entire power transmission system.

In the factory, the transformer/reactor can be tested using a plethora of means and at all voltage ranges. However, at site the testing options are severely limited. Since transformers/reactors play an important role in the electrical power system it is imperative to conduct testing on a regular basis. The goal of testing is to confirm the transformer's/reactor's ability to continue functioning properly and to reduce the chance of failure.

The test should be carried out using reliable and calibrated testing instruments of proven credentials having accuracy of repeatability. The equipment should be properly shielded for immunity from electromagnetic induction effect encountered in the switchyard.

As per *Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations*, diagnostic equipment shall be employed to assess the health of various equipment in substations and switchyards of 132 kV and higher voltages. Portable type on-line diagnostic equipment and off-line diagnostic equipment shall be provided for one or a cluster of substations or switchyards, depending upon the size of the substations or switchyards. On-line diagnostic equipment may be provided for the critical equipment, the health of which is to be monitored continuously.

Utilities can also follow Reliability Centred Maintenance (RCM) practice. RCM is a structured process that identifies the effects of failures and defines the appropriate maintenance path for managing their impacts. RCM identifies the most technically and economically effective approach to maintenance. It is an optimised strategy that takes into account not only the operation time and/or the technical condition of an asset, but also its position in the network, its operational importance, any potential safety or environmental risk arising from its failure and any likely consequence of its potential outage. An important transformer serving many power consumers may require a higher level of maintenance than when a backup unit is available in an emergency. The extent of maintenance to be performed on a transformer is proportional to the level of risk associated with the unit. In practice, the criticality index is usually combined with a health index to prioritise maintenance activity. RCM may be applied to components either together or in isolation.

RCM can not only improve the reliability of the system but also can reduce the required maintenance significantly resulting in significant reduction in O&M cost.

2.0 Conventional Tests for Condition Monitoring

The following conventional tests on transformers/reactors are carried out at site and the test results are compared to the factory test results/pre-commissioning results. Acceptable values and frequency of carrying out these tests has been specified in the table in **Appendix** given at the end of the chapter.

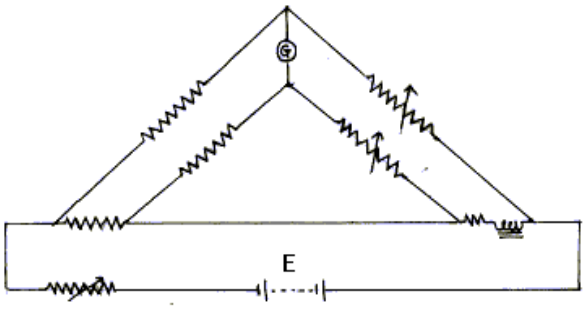
2.1 Winding Resistance Measurement

Winding resistance is measured in the field in order to check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers etc. as a pre-commissioning checks & after a failure event and the measured values are compared with the factory test values.

As the resistance of transformer/reactor winding is low, the measurement has to be carried out with the help of Kelvin Double Bridge/Transformer ohmmeter. Normally winding resistance values 1 ohm or above is measured using Wheatstone Bridge and winding resistance values less than 1 ohm is measured using micro-ohm meter or Kelvin Bridge.

The winding resistance measurement shall preferably be done when the difference in the top and bottom temperature of the winding (temperature of oil in steady-state condition) is equal to or less than 5°C. **The winding resistance measurement should preferably be carried out after completion of all other LV tests, as after this test core gets saturated.** The tests like magnetizing current, magnetic balance etc. carried out after winding resistance measurement test may be affected and indicate ~~a~~ misleading results, if the core is not de-magnetized before carrying out these tests.

For star connected winding with neutral brought out, the resistance shall be measured between the line and neutral terminal and average of three sets of reading shall be considered the tested value. If neutral bushing is not available on Star connected windings, measurement shall be taken between each phase and ground (if the neutral is grounded), or between pairs of bushings as if it were a Delta connected winding. *In future, test shall be repeated in same fashion so that proper comparison can be made.* The connections shall be as shown:



For star connected auto-transformers the resistance of the HV side is measured between HV terminal and IV terminal, then between IV terminal and the neutral at all Taps. The tap changer should be changed from contact to contact so that contact resistance can also be checked. For delta connected windings, such as tertiary winding of transformers, measurement shall be done between pairs of line terminals and resistance per winding shall be calculated as per the following formula:

Resistance per winding = 1.5 x *Measured value*

The winding temperature reading shall be taken while doing the resistance measurement and the resistance at 75°C shall be calculated as per the following formula:

$R_{75} = R_t (235+75) / (235+t)$,

Where R_t = Resistance measured at winding temperature t degree C

Results are to be compared to other phases in Star-connected transformers/reactors or between pairs of terminals on a Delta–connected winding to determine if resistance value is too high. Because field measurements make it unlikely that precise temperature measurements of the winding can be made, the expected deviation for this test in the field is **5.0 %** of the factory test value. Precision in field measurements using digital instruments is affected by the presence of stray fields of relatively low capacitances. Comparison of readings with identical units has much more significance. As a check, Key gases increasing in DGA in case of close connections or broken strands or OLTC contact problems, will be ethane and/or ethylene and possibly methane.

2.2 Voltage Ratio Test (only for transformers)

Voltage Ratio Test is carried out in case any fault has occurred which is suspected to have affected one of the windings (completely or partially). The turns ratio of a transformer is the ratio of the number of turns in a higher voltage winding to that in a lower voltage winding.

To carry out the test, keep the tap position in the lowest position and IV and LV terminals open. Apply 3 phase, 415 V or single phase 230 V supply depending on transformer type on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV and IV/LV (as applicable) terminals simultaneously. Repeat this for each of the tap position separately and after interchanging the voltmeters of HV and IV/LV (as applicable) windings and then average the readings for final calculation of ratio.

The above tests can also be performed by using Transformer Turns Ratio (TTR) meter available in convenient portable/hand-held form. They operate at low voltages, such as 8-10 V and 50-60 Hz, so that the test can be performed on a transformer even when the oil is removed. Two windings on one phase of a transformer are connected to the instrument, and the internal bridge elements are varied to produce a null indication on the detector, the exciting current is also being measured in most cases.

Results of the transformation turns or voltage ratio are absolute, and may be compared with the specified values measured during factory testing. The turns ratio tolerance should be within 0.5% of the nameplate specifications. For three phase Y connected winding this tolerance applies to phase to neutral voltage. If the phase-to-neutral voltage is not explicitly indicated in the nameplate, then the rated phase-to-neutral voltage should be calculated by dividing the phase-to-phase voltage by √3.

If there are shorted winding turns, the measured ratio will be affected. Out-of-tolerance ratio measurements may be symptomatic of shorted turns, especially if there is an associated high excitation current. Out-of-tolerance readings should be compared with prior tests because in some instances, the design turns ratio may vary from the nameplate voltage ratio on some taps because of the need to utilize an incremental number of winding turns to make up the taps while nameplate voltage increments may not exactly correspond. This error may combine with measurement error to give a misleading out-of-tolerance reading.

Ratio measurements must be made on all taps to confirm the proper alignment and operation of the tap changers.

Open turns in the excited winding will be indicated by very low exciting current and no output voltage. Open turns in the output winding will be indicated by normal levels of exciting current, but no or very low levels of unstable output voltage.

The turns ratio test also detects/indicates high-resistance connections in the lead circuitry or high contact resistance in tap changers by higher excitation current and a difficulty in balancing the bridge during measurement.

2.3 Excitation/Magnetization Current Measurement

Exciting/magnetizing current is the current required to force a given flux through the core. Exciting/magnetizing current measurement is carried out to locate defect in magnetic core structure such as shorted laminations or break down of core bolt insulation, turn to turn insulation failure, shifting of winding, problem in tap changer etc. **This test should be done before DC measurements of winding resistance to reduce the effect of residual magnetism. Therefore,**

transformer/reactor under test is to be demagnetized before commencement of magnetizing current test.

The test comprises a simple measurement of single-phase current on one side of the transformer/reactor (usually the high-voltage side in case of a transformer) with the other side left floating (with the exception of a grounded neutral). Three-phase transformers are tested by applying single-phase 10 kV voltage to one phase (HV terminals) at a time. Tap position is kept alternatively in the lowest position, normal position and highest position with IV & LV terminals open. Voltages applied on each phase on HV terminals and current in each phase of HV terminal are measured. The test is repeated for IV winding keeping HV and LV open and measure phase to phase voltage between the IV terminals and current on each of the IV terminals.

The set of reading for current measurement in each of the tap position should be equal. Unequal currents shall indicate possible short circuits in winding. Results between similar single-phase units should not vary more than 10 %. The test values on the outside legs should be within 15 % of each other, and values for the centre leg should not be more than those for either of the outside legs for a three-phase transformer. Results compared to previous tests made under the same conditions should not vary more than 25%. The comparison of the test values of healthy condition with the faulty condition shall help in pinpointing the trouble spots.

If an out-of-tolerance reading is experienced while turns ratio, winding resistance, and impedance tests are normal, residual magnetism should be suspected. Residual magnetism may be eliminated or reduced by applying a DC voltage to the windings through a voltage divider. The voltage should be raised from zero to a maximum value that will yield a current of no more than 10 A through the winding and then returned to zero. Care must be taken not to break the circuit while DC current is flowing in the winding. The polarity should then be reversed and the procedure repeated. Repeat the process several times, each time reducing the magnitude of current and each time reversing the polarity. The excitation current test should then be repeated.

2.4 Insulation Resistance

Insulation resistance (IR) of windings is the simplest and most widely used test to check the soundness of transformer/reactor insulation.

This test reveals the condition of insulation (i.e. degree of dryness of paper insulation), presence of any foreign contaminants in oil and also any gross defect inside the transformer/reactor (like failure to remove the temporary transportation bracket on the live portion of tap-changer part). Insulation resistance is measured by means of Megger which is available in 500 V, 1000 V, 2500 V and 5000 V ratings. For transformer/reactor windings with voltage rating 11 kV and above, 2.5 kV megger shall be used. IR value measurements of EHV transformers/reactors shall preferably be done with 5 kV motorized/digital megger.

IR measurements shall be taken between the windings collectively (i.e. with all the windings being connected together) and the earthed tank (earth) and between each winding and the tank, the rest of the windings being earthed. **Before taking measurements the neutral should be disconnected from earth.** Following table gives combinations of IR measurements for auto-transformer, three-winding transformer & Shunt Reactor.

For Auto-transformer	**For 3 winding transformer**	**For Shunt Reactor**
HV + IV to LV	HV + IV to LV	HV to E
HV + IV to E	HV to IV+ LV	
LV to E	HV + LV to IV	
	HV + IV +LV to E	

Date and time of measurement, sl. no., make of megger, oil temperature and IR values at intervals of 15 seconds, 1 minute and 10 minutes should be recorded.

IR values may be checked with the values in manufacturer's test certificate and these values may be used as bench marks for future IR monitoring in service. IR values vary with type of insulation (transformer oil or air), temperature, and duration of application of voltage and to some extent applied voltage.

Unless otherwise recommended by the manufacturer the following IR values as a thumb rule may be considered as the minimum satisfactory values at 30°C (one minute measurements) at the time of commissioning.

Rated Voltage class of winding	Minimum desired IR value at 1 minute (Meg ohm)
11kV	500 MΩ
33kV	1000 MΩ
66kV & above	1500 MΩ

Even if the insulation is dry, IR values will be low if the resistivity of oil is poor. With the increase in duration of application of voltage, IR value increases. The increase in insulation resistance is an indication of dryness of insulation.

The ratio of 60 second insulation resistance to 15 second insulation resistance value is called Dielectric Absorption Coefficient or Index (DAI). For oil filled transformers/reactors with class A insulation, in reasonably dried condition, the absorption coefficient at 30°C will be more than 1.3.

2.5 Polarization Index Test

It is a ratiometric test, insensitive to temperature variation and may be used to predict insulation system performance even if charging currents (i.e. capacitive, absorption or leakage currents) have not diminished to zero. Since leakage current increases at a faster rate with moisture present than does absorption current, the megohm readings will not increase with time as fast with insulation in poor condition as with insulation in good condition. This results in a lower polarization index. An advantage of the index ratio is that all of the variables that can affect a single megohm reading, such as temperature and humidity, are essentially the same for both the 1 min and 10 min readings. The polarization index test is performed generally by taking megohm readings at the following intervals at a constant DC voltage: 1 min and then every minute up to 10 min. The **Polarization Index (PI)** is the ratio of the 10 min to the 1 min megohm readings.

$$PI = R_{10} / R_1$$

Where PI is Polarization Index and R is resistance

The following are guidelines for evaluating transformer/reactor insulation using polarization index values:

Polarization Index	Insulation Condition
Less than 1	Dangerous
1.0-1.1	Poor
1.1-1.25	Questionable
1.25-2.0	Fair
2.0 – 4.0	Good
Above 4.0	Excellent

A Polarization Index (PI) of more than 1.25 and Dielectric Absorption Index of more than 1.3 are generally considered satisfactory for a transformer/reactor when the results of other low voltage tests are found in order. PI less than 1 calls for immediate corrective action.

2.6 Capacitance and Tan Delta of Windings

Dissipation Factor (DF)/Loss factor (Tan δ) and capacitance measurement of winding is carried out to ascertain the general condition of the insulation of the winding of transformer/reactor.

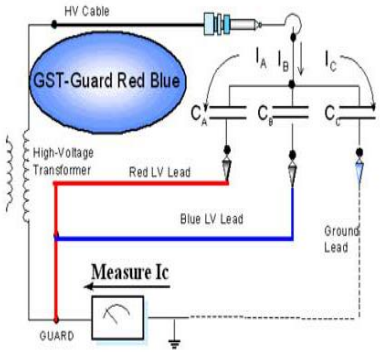
For tan delta & capacitance measurement of transformer/reactor winding, the voltage rating of each winding under test must be considered and the test voltage selected accordingly. If neutral bushings are involved, their voltage ratings must also be considered in selecting the test voltage. **Removal of Jumpers from Bushings is pre-requisite for C & Tan δ measurement of windings**.

UST mode is used to measure insulation between two ungrounded terminals of the apparatus, isolate an individual section of insulation and test it without measuring other connected insulation.

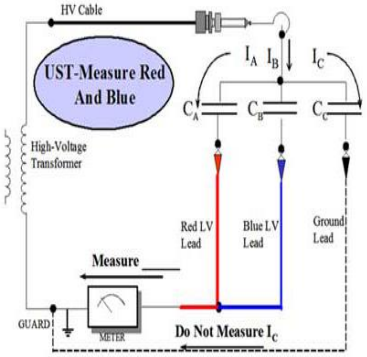
In the GST mode, both leakage paths are measured by the test set. The current, watts loss, and capacitance parameters of the UST and GSTg tests should equal the parameters in the GST test. This gives the overall condition or power factor of the test specimen.

The GST Guard (GSTg) tests measures the total current leaking to ground only. In UST mode, ground is considered guard since grounded terminals are not measured and the only current measured is the current flowing on the other two leads. Any current flowing to a grounded terminal is bypassed directly to the AC source return.

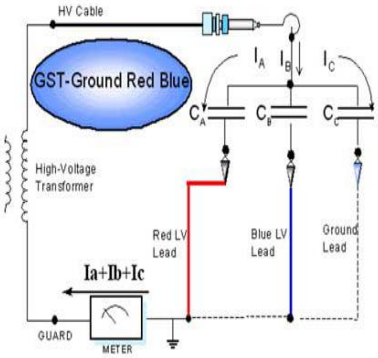
If the sum of the UST and GSTg parameters do not equal the GST parameters, then either the test set is malfunctioning or the test leads are configured incorrectly.



GST-Guard Red Blue Test Mode



UST Measure Red Blue Test Mode



GST Ground Test Mode

The summary of possible combination for measurement of tan delta & capacitance is given below:

Auto-Transformer /2- winding	**Test Mode**	**Shunt Reactor**	**Test Mode**	**3 winding Transformer**	**Test Mode**
HV + IV to LV (C_{HL})	UST	HV to E	GST	HV to IV (LV open) (C_{HI})	UST
HV + IV to E (LV guarded) (C_H)	GSTg			HV to LV (IV open) (C_{HL})	UST
(HV + IV) to (LV+E) (C_{HL}+ C_H)	GST			IV to LV(HV open) (C_{IL})	UST
LV to HV + IV (C_{LH})	UST			HV to E (IV+LV guarded) (C_H)	GSTg
LV to E (HV+IV guarded) (C_L)	GSTg			IV to E (HV+LV guarded) (C_I)	GSTg
LV to (HV + IV+E) to (C_{HL}+ C_L)	GST			LV to E (HV+IV guarded) (C_L)	GSTg

Changes in the normal capacitance indicate abnormal conditions such as the presence of moisture, layer short circuits or open circuits in the capacitance network.

Dissipation Factor measurements indicate the following conditions of insulation:

- Chemical deterioration due to time and temperature.
- Contamination by water, carbon deposits, bad oil, dirt, etc.
- Severe leakage through cracks and over surfaces.
- Ionisation

Environmental factors like variation in temperature, relative humidity, surrounding charged objects etc. may influence measurement of dielectric dissipation factor. Care shall be taken to control the above factors during measurements.

An increase of DF accompanied by a marked increase in capacitance usually indicates excessive moisture in the insulation. Increase of DF alone may be caused by thermal deterioration or by contamination other than water.

Maximum values of Dissipation Factor (Tan Delta) of class A insulation e.g. oil impregnated paper insulation is 0.005. Rate of change of tan Delta and capacitance is very important. The rate of change of tan δ more than 0.001 per year needs further investigation. Capacitance value can vary between +10% and -5%. Comparison of test results can be done with similar piece of equipment, which was tested under the same conditions.

2.7 Capacitance and Tan Delta of Bushings

Insulation power factor or dissipation factor (Tan δ) and Capacitance measurement of bushing provide an indication of the quality and health of the insulation in the bushing. For getting accurate results of Tan delta and Capacitance without removing the bushing from the transformer, a suitable test set capable of taking measurement by ungrounded specimen test (UST) method shall be used. It utilises the test tap of the bushing and a Tan delta/Capacitance test set. Both Tan delta and Capacitance can be measured using the same set up.

Test voltage to be applied shall not exceed half of the power frequency test voltage or 10 kV, whichever is lower. It is desirable to have the frequency of the test set or measuring bridge different from but close to operating power frequency; so that stray power frequency currents do not interfere with the operation of the instrument.

Measurements shall be made at similar conditions as that of a previous measurement. The oil-paper insulation combination of bushings exhibit fairly constant tan delta over a wide range of operating temperature. Hence, effort is to be made for testing at temperature near to previous test—so that temperature correction factor need not be applied. The following precautions/ steps are to be taken:

- Porcelain of the bushings shall be clean and dry before test. Remove any dirt or oil with clean dry cloth.
- Test shall not be carried out when there is condensation on the porcelain. Preferably, tests shall not be carried out when the relative humidity is in excess of 75%.

- Terminals of the bushings of each winding shall be shorted together using bare braided copper jumper. These jumpers shall not be allowed to sag. Transformer windings of the bushing not being tested shall be grounded.

- Measure and record the ambient temperature and relative humidity for reference. Record OTI and WTI during the measurement.

- Do not test a bushing (new or spare) while it is in its wood shipping crate, or while it is lying on wood. Wood is not as good an insulator as porcelain and will cause the readings to be inaccurate. Keep the test results as a baseline record to compare with future tests.

Environmental factors like variation in temperature, relative humidity, surrounding charged objects etc. have great influence on measurement of dielectric dissipation factor. Care shall be taken to control the above factors during measurements. Testing during periods of high humidity or precipitation should be avoided; otherwise proper evaluation of test results becomes very difficult. A very small amount of water vapour on the surface of external insulation could increase the amount of leakage current and will appear as increased loss in the test result.

There should not be wide variation in the measured values of tan delta (dissipation factor) of the bushings of transformer/reactor (measured at periodic intervals) when compared with previous references. For bushings, the tan delta value shall not exceed 0.005 (during first

charging). However, there should not be any deviation of more than 0.001 from initial tan delta value of the bushing.

The main capacitance (C1) of the bushing i.e., the capacitance between high voltage terminal and test tap is not affected by the surrounding conditions and the accepted deviation from the values measured at factory tests should not be more than 5%. The capacitance between bushing test tap and ground is largely influenced by the stray capacitances to grounded parts in the transformer and hence larger deviation in the measured value shall be accepted when compared with the factory test value.

2.8 Short Circuit Impedance (only for transformers)

This test is used to detect winding movement that usually occurs due to heavy fault current or mechanical damage during transportation or installation since dispatch from the factory.

The measurement is performed in single phase mode. This test is performed for the combination of two winding. One of the winding is short circuited and voltage is applied to other winding. The voltage and current reading are noted. The test shall be conducted with variac of 0-280 V, 10 A, precision RMS voltmeter and ammeter. The conductors used for short-circuiting one of the transformer windings should have low impedance (less than 1m-ohm) and short length. The contacts should be clean and tight.

The measured impedance voltage should be within 3 percent of impedance specified in rating and diagram nameplate of the transformer. Variation in impedance voltage of more than 3% should be considered significant and needs to be further investigated.

2.9 Operational checks and Inspection of OLTC (only for transformers)

On-Load Tap Changers (OLTCs) are designed to be operated while the transformer is energized. OLTCs may be located either on the high voltage winding or on the low voltage winding, depending on the requirements of the user, the cost effectiveness of the application and tap changer availability. OLTC being a current interrupting device requires periodic inspection and maintenance. The frequency of

inspections is based on time in service, range of use and number of operations.

Normally the temperature of the OLTC compartment may be few degrees Celsius less than the main tank. Any temperature approaching or above that of the main tank indicates an internal problem in OLTC. Prior to opening the OLTC compartment, it should be inspected for external symptoms of potential problems. The integrity of Paint (blister or damage to the coat may be due to exposure to contamination with salts and the leftover residue on the surface may absorb moisture weakening the strength of underlying steel tank), weld leaks, oil seal integrity, pressure relief device and liquid level gauge etc. should be inspected prior to opening of the OLTC compartment.

After de-energization, for internal inspection, close all valves between oil conservator, transformer tank and tap-changer head, then lower the oil level in the diverter switch oil compartment by draining of oil. After opening the OLTC compartment, the door gasket should be inspected for any sign of deterioration. The compartment floor should be inspected for debris that might indicate abnormal wear and sliding surfaces should be inspected for signs of excessive wear.

The following checks should be carried out during inspection and maintenance and the manufacturer's service engineer should be consulted for any assistance required in maintenance/overhauling activity to ensure trouble free operation in the future:

- Functioning of control switches
- OLTC stopping on position
- Fastener tightness
- Any signs of moisture ingress indicated by rusting, oxidation or free standing water and leakages etc.
- Mechanical clearances as specified by manufacturer's instruction booklet
- Operation and condition of tap selector, changeover selector and arcing transfer switches
- Drive mechanism operation
- Counter operation
- Position indicator operation and its co-ordination with mechanism and tap selector positions
- Limit switch operation

- Mechanical block integrity
- Proper operation of hand-crank and its interlock switch
- Physical condition of tap selector
- Freedom of movement of external shaft assembly
- Extent of arc erosion on stationary and movable arcing contacts
- Inspect barrier board for tracking and cracking
- After filling with oil, manually crank throughout entire range
- Oil BDV and Moisture content (PPM) to be measured and recorded

Finally, the tap selector compartment should be flushed with clean transformer oil and all carbonization which may have been deposited should be removed. Minimum BDV should be 50 kV and Moisture content should be less than 20 PPM.

2.10 Measurement of Oil Parameters

Following parameters of oil shall be checked and measured by testing:

a. Visual Inspection/Color
b. Dielectric Strength (BDV)
c. Moisture Content (PPM)
d. Dielectric Loss/Power factor/Dissipation factor (Tan Delta)
e. Inter facial Tension (IFT)
f. Acidity (Neutralization No.)
g. Oxidation Stability/Ageing test
h. Particle Count (For 400 kV and above transformer & reactor)

Values of these parameters shall be as per specification (Chapter-2 and Annexure-L).

Inhibitor concentration for inhibited oil in service needs to be monitored and eventually maintained. For this purpose IEC 60422 may be referred.

2.11 Dissolved Gas Analysis (DGA) and Interpretation

DGA is one of the most widely used diagnostic tools for detecting and evaluating faults in transformer / reactors. The fundamental purpose of DGA is to discriminate between normal and abnormal condition. Oil and oil-immersed electrical insulating materials decompose under the influence of thermal and electrical stresses and generate gaseous decomposition products of varying composition which dissolve in the

oil. The nature, amount and rate of generation of the individual component gases that are detected are indicative of the type and degree of the abnormality responsible for the gas generation.

The purpose of DGA is to detect the internal faults within the oil-filled electrical equipment at an early stage and also to find incipient faults such as partial discharge, over-heating, arcing etc. The data obtained from this test is applied to various DGA techniques available in IEEE, IEC standards etc. such as IEEE.C57.104, IEC-60599 etc. for the interpretation of the test results that may give the type, severity and sometimes location of the fault.

The transformer/reactor undergoes electrical, mechanical, chemical and thermal stresses during its service life which may result in slow evolving incipient faults inside the transformer. The gases generated under abnormal electrical or thermal stresses are hydrogen(H_2), methane(CH_4), ethane(C_2H_6), ethylene(C_2H_4), acetylene(C_2H_2), carbon monoxide(CO), carbon dioxide(CO_2), nitrogen(N_2) and oxygen(O_2) which get dissolved in oil. Collectively these gases are known as FAULT GASES, which are routinely detected and quantified at extremely low level, typically in parts per million (ppm) in Dissolved Gas Analysis (DGA). CO & CO_2 formation increases not only with temperature but also with oxygen content of oil and the moisture content of paper. Large quantity of CO & CO_2 are evolved from overheating of cellulose. Most commonly used method to determine the content of these gases in oil is by Headspace extraction and Gas Chromatograph.

Interpretation of DGA Results:

The interpretation of DGA results is often complex. The interpretation of DGA data begins with the detection of an abnormal condition. There is no direct/definite interpretation method to indicate exact location & type of fault and to evaluate the condition of a transformer. There are several possibilities wherein DGA status can be very different from the actual condition of the transformer. Some cause of gas generation are related to fault conditions (e.g. arcing, overheating, PD). At times, gases generation may be related to more benign conditions like stray gassing (a non-damage fault), contamination, previous fault now inactive, and mild core overheating, rusting or other chemical reactions involving steel, uncoated surfaces or protective paints etc. Additionally, some pre-failure conditions especially mechanical or insulating system weakness will not generate

gas. Some normal conditions also generate gases, for example, normal ageing, and insulating liquid oxidation.

Detection of gas does not give any conclusive status of health by itself. Prior DGA results should be used for characterization of increments and rates. If abnormal DGA results are found, any available supplementary information, such as test and maintenance records, loading pattern, environmental conditions, etc., should be consulted for possible clues as to the origin and nature of the abnormalities. Comparison of DGA data from sister units is also useful in absence of such information.

The different interpretation methods only provide guidelines to take an engineering judgment about the equipment.

Some important extract of IEEE.C57.104-2019 and IEC-60599-2015 method of evaluation Dissolved Gas is given below for guidance only.

IEC 60599 method for Gas Analysis:

This method is applicable only when the fault gas results are ten times the sensitivity limit of the Gas Chromatograph (GC). As per IEC 60567 the sensitivity limit for the GC should be 1 ppm for all the hydrocarbons and 5 ppm for Hydrogen. In this method three ratios viz. C_2H_2/C_2H_4, CH_4/H_2 & C_2H_4/C_2H_6 are used for interpretation. Each ratio is assigned a code depending upon the range of values of ratios. These codes in different combinations are then used for diagnosis of type of fault such as Partial Discharge (PD), low energy discharge (D1), High energy discharge (D2), thermal faults of various temperatures ($T1<300°C$, $300°C<T2<700°C$ & $T3>700°C$).

Fault often start as incipient faults of low energy, which may develop into more serious ones of higher energies, leading to possible gas alarms, breakdowns & failures.

Typical faults in Power Transformers

Type	Fault	Examples
PD	Partial discharges	Discharges in gas-filled cavities resulting from incomplete impregnation, high-humidity in paper, Oil super saturation or cavitation, and leading to X-wax formation.
D1	Discharges of	• Sparking or arcing between bad

Type	Fault	Examples
	low energy	connections of different or floating potential, from shielding rings, toroids, adjacent disks or conductors of winding, broken brazing or closed loops in the core. • Discharges between clamping parts, bushing and tank, high voltage and ground within windings, on tank walls. • Tracking in wooden blocks, glue of insulating beam, winding spacers, Breakdown of oil, selector breaking current.
D2	Discharges high energy	• Flashover, tracking, or arcing or high local energy or with power follow-through • Short circuits between low voltage and ground, connectors, windings, bushings and tank, copper bus and tank, windings and core, in oil duct, turret. Closed loops between two adjacent conductors around the main magnetic flux, insulated bolts of core, metal rings holding core legs.
T1	Thermal fault t<300 °C	• Overloading of the transformer in emergency situations • Blocked item restricting oil flow in windings • Stray flux in damping beams of yokes
T2	Thermal fault 300 °C <t<700°C	• Defective contacts between bolted connections, gliding contacts, contacts within selector switch (pyrolitic carbon formation), connections from cable and draw-rod of bushings. • Circulating currents between yoke clamps and bolts, clamps and laminations. In ground wiring, defective welds or clamps in magnetic shields. • Abraded insulation between adjacent parallel conductors in windings.
T3	Thermal fault t>700 °C	Large circulating currents in tank and core Minor currents in tank walls created by a high uncompensated magnetic field Shorting links in core steel laminations.

Following DGA Interpretation Table applies directly to all transformer sub-types, except those equipped with a communicating OLTC.

DGA Interpretation Table

Case	Characteristic Fault	$\frac{C_2H_2}{C_2H_4}$	$\frac{CH4}{H2}$	$\frac{C2H4}{C2H6}$
PD	Partial discharges	NS[a]	<0.1	<0.2
D1	Discharges of low energy	>1	0.1 – 0.5	>1
D2	Discharges of high energy	0.6 – 2.5	0.1 -1	>2
T1	Thermal fault T < 300°C	NS[a]	>1 but NS[a]	<1
T2	Thermal fault 300°C < 1 < 700°C	<0.1	>1	1-4
T3	Thermal fault > 700°C	<0.2 [b]	>1	>4

NOTE 1 – In some countries, the ratio C_2H_2/C_2H_6 is used, rather than the ratio CH_4/H_2. Also in some countries, slightly different ratio limits are used.

NOTE 2 – The above ratios are significant and should be calculated only if at least one of the gases is at a concentration and a rate of gas increase above typical values.

NOTE 3 – CH_4/H_2 <0.2 for partial discharges in instrument transformers.

CH_4/H_2 <0.007 for partial discharges in bushings.

NOTE 4 – Gas decomposition patters similar to partial discharges have been reported as a result of stray gassing of oil.

a. NS = Non- significant whatever the value
b. An increasing value of the amount of C_2H_2 may indicate that the hot spot temperature is higher than 1000°C

IEEE C57.104 Method of Evaluation:

DGA status:

The classification process and recommendations given below are based on gas levels and level variation norms obtained from a statistical analysis of a large population of DGA results (90th and 95th percentiles). This procedure is a guideline only.

DGA Status 1	Considered as probably normal	Normal transformer operation can be continued.
DGA Status 2	Considered as possibly suspicious	Warrant additional investigation. If the fault diagnosis reveals an issue of Partial Discharges (PD), low temperature fault (T1), or stray gassing (S), this would be treated as a less urgent issue, but still may affect future life of the insulation system. Otherwise, increased sampling frequency should be maintained or started. Transformers having a DGA Status 2 due only to Gas levels exceeding the values in Table 1 (especially if the only high levels are for carbon oxides), could be reassigned to routine sampling if there is no sign of active gassing during a year or more of increased sampling frequency (all samples below Table 3 and Table 4).
DGA Status 3	Considered as probably suspicious	The transformer should be placed under increased surveillance and additional transformer testing is recommended. Consultation with the transformer manufacturer or a transformer expert is also recommended. If after complete review of the available information, the transformer condition is deemed acceptable for continuous operation, then it is suggested to simply maintain surveillance typical of a lower DGA status. An example of this would be a transformer having a DGA Status 3 due only to gas levels exceeding the values in Table 2 (especially if the only high levels are for carbon oxides) when several samples taken over a year or more indicate no sign of active gassing (all samples below Table 3 and Table 4).
Extreme DGA	Active faults generate gases at such a high	Gas levels or changes that are much larger than those provided in Table 2 and Table 3 warrant immediate extra

results	rate that detection and assessment do not require finesse, or significant work.	investigation, which may include additional oil analysis and physical or electrical testing. Internal inspection might be considered

The transformer with DGA Status 2 or Status 3 (i.e., being above statistical norms) is not necessarily faulty. It can only be concluded that its behavior is somewhat unusual and warrants additional investigation and/or precautions to be implemented, either simple or extensive, as evaluated by the DGA expert.

DGA Status Norms:

DGA status norms are shown in Table 1 through Table 4:

Table 1- 90th percentile gas concentrations as a function of O_2/N_2 ratio and age in µL/L (ppm)

		O_2/N_2 Ratio ≤ 0.2				O_2/N_2 Ratio > 0.2			
		Transformer Age in Years				Transformer Age in Years			
		Unknown	1-9	10-30	>30	Unknown	1-9	10-30	>30
Gas	Hydrogen (H_2)	80	75		100	40	40		
	Methane (CH_4)	90	45	90	110	20	20		
	Ethane (C_2H_6)	90	30	90	150	15	15		
	Ethylene (C_2H_4)	50	20	50	90	50	25	60	
	Acetylene (C_2H_2)	1	1			2	2		
	Carbon monoxide (CO)	900	900			500	500		
	Carbon dioxide (CO_2)	9000	5000	10000		5000	3500	5500	

Note:- During the data analysis, it was determined that voltage class, MVA, and volume of mineral oil in the unit did not contribute in significant way to the determination of values provided in Table 1.

Table 2- 95th percentile gas concentrations as a function of O_2/N_2 ratio and age in µL/L (ppm)

		O_2/N_2 Ratio ≤ 0.2				O_2/N_2 Ratio > 0.2			
		Transformer Age in Years				Transformer Age in Years			
		Unknown	1-9	10-30	>30	Unknown	1-9	10-30	>30
Gas	Hydrogen (H_2)	200	200			90	90		
	Methane (CH_4)	150	100	150	200	50	60		30
	Ethane (C_2H_6)	175	70	175	250	40	30	40	
	Ethylene (C_2H_4)	100	40	95	175	100	80	125	
	Acetylene (C_2H_2)	2	2		4	7	7		
	Carbon monoxide (CO)	1100	1100			600	600		
	Carbon dioxide (CO_2)	125000	7000	14000		7000	5000	8000	

Note:- During the data analysis, it was determined that voltage class, MVA, and volume of mineral oil in the unit did not contribute in significant way to the determination of values provided in Table 2

Table 3- 95th percentile values for absolute level change between successive laboratory DGA samples in µL/L (ppm)

		Maximum µL/L (ppm) variation between consecutive laboratory DGA samples	
		O_2/N_2 Ratio ≤ 0.2	O_2/N_2 Ratio > 0.2
Gas	Hydrogen (H_2)	40	25
	Methane (CH_4)	30	10
	Ethane (C_2H_6)	25	7
	Ethylene (C_2H_4)	20	
	Acetylene (C_2H_2)	Any Increase	
	Carbon monoxide (CO)	250	175
	Carbon dioxide (CO_2)	2500	1750

Note:- Contribution of voltage class, MVA, and volume of mineral oil in the unit was not studied for Table 3 as they have not been retained for Table 1 and Table 2. Data was insufficient to study age influence.

Table 4- 95th percentile values from multi-points (3-6 points) rate analysis of laboratory DGA samples with all gas levels below Table 1 values, in µL/L/year (ppm/year)

		Maximum µL/L/year (ppm/year) rate in function of the period between first and last point of the laboratory DGA series (3 to 6 samples)			
		O_2/N_2 Ratio ≤ 0.2		O_2/N_2 Ratio > 0.2	
		Period between first and last point of the series			
		4-9 Months	10-24 Months	4-9 Months	10-24 Months
Gas	Hydrogen (H_2)	50	20	25	10
	Methane (CH_4)	15	10	4	3
	Ethane (C_2H_6)	15	9	3	2
	Ethylene (C_2H_4)	10	7	7	5
	Acetylene (C_2H_2)	Any increasing rate		Any increasing rate	
	Carbon monoxide (CO)	200	100	100	80
	Carbon dioxide (CO_2)	1750	1000	1000	800

Note:- Contribution of voltage class, MVA, and volume of mineral oil in the unit was not studied for Table 4 as they have not been retained for Table 1 and Table 2. Data was insufficient to study age influence.

Methods using Ratio of the Gases

The associated faults for the different evolved gases can be correlated as follows:

- Hydrogen (H_2) is created primarily from corona partial discharge and stray gassing of oil, also from sparking discharges and arcs.
- Methane (CH_4), Ethane (C_2H_6), and Ethylene (C_2H_4) are created from heating of oil or paper.
- Acetylene (C_2H_2) is created from arcing in oil or paper at very high temperatures above 1000 °C.
- Carbon Monoxide (CO) and Carbon Dioxide (CO_2) are created from heating of cellulose or insulating liquid.

(a) Duval Triangle 1 method uses three gases corresponding to the increasing energy content or temperature of faults: methane (CH_4) for low energy/ temperature faults, ethylene (C_2H_4) for high temperature faults, and acetylene (C_2H_2) for very high temperature/energy/arcing

faults. On each side of the triangle are plotted the relative percentages of these three gases.

The percentage of each individual gas is calculated from the accumulated total of these three fault gases. The same is then traced on the Duval triangle and the intersection indicates possible problems within the transformer/reactor.

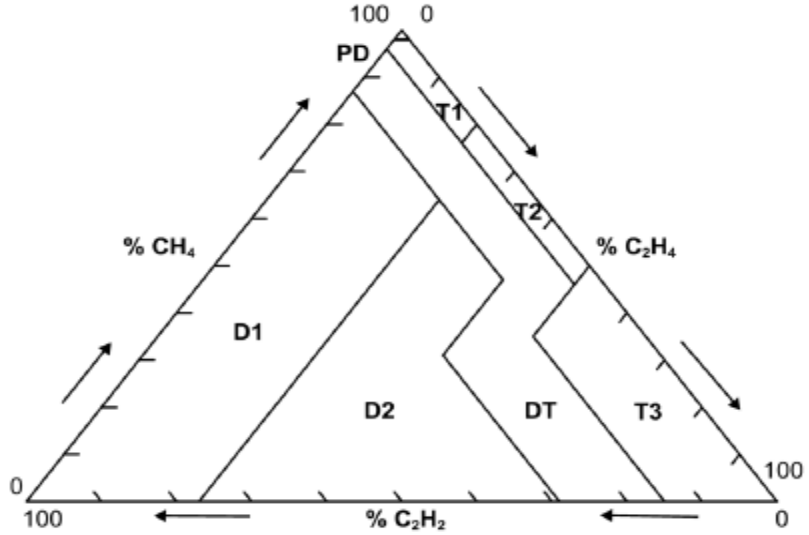


Fig.: Duval Triangle 1 Method

The Table below gives the numerical values for fault zone boundaries of Duval Triangle 1 Method expressed in ($\%CH_4$), ($\%C_2H_4$), and ($\%C_2H_2$).

Gas% / Fault	% CH_4	% C_2H_4	% C_2H_2
PD	$\geq$ 98	-	-
T1	< 98	< 20	< 4
T2	-	$\geq$ 20 and <50	< 4
T3	-	$\geq$ 50	< 15
DT	-	< 50	$\geq$ 4 and <13
	-	$\geq$ 40 and <50	$\geq$ 13 and <29
	-	$\geq$ 50	$\geq$ 15 and <29
D1	-	< 23	$\geq$ 13
D2	-	$\geq$ 23	$\geq$ 29
	-	$\geq$ 23 and <40	$\geq$ 13 and <29

(b) The Rogers Ratio method is a more comprehensive scheme using only three ratios viz. CH_4/H_2, C_2H_2/C_2H_4 & C_2H_4/C_2H_6, which details temperature ranges for overheating conditions based on Halstead's

research and some distinction of the severity of incipient electrical fault conditions.

Case	***R2 (C_2H_2/C_2H_4)***	***R1 (CH_4/H_2)***	***R5 (C_2H_4/C_2H_6)***	***Suggested Fault Diagnosis***
0	<0.1	0.1 – 1.0	<0.1	Unit normal
1	<0.1	<0.1	<0.1	Low-energy density arcing –PD (See Note)
2	0.1-3.0	0.1 to 1.0	>3.0	Arcing – High energy discharge
3	<0.1	0.1 to 1.0<1.0	1.0 to 3.0	Low temperature thermal
4	<0.1	>1.0	1.0 to 3.0	Thermal <700°C
5	<0.1	>1.0	>3.0	Thermal >700°C

Note: There is tendency for the ratio *C_2H_2/C_2H_4 and C_2H_4/C_2H_6 to increase to a ratio above 3 as the discharge develops in intensity*.

The limitation of the Rogers Ratios Method is that it cannot identify faults in a relatively large number of DGA results (typically 35%), because they do not correspond to any of the cases in column 1 of Table above even when μL/L (ppm) values are high and there is obviously a fault.

The Rogers Ratio Method and Duval Triangle 1 Method should not be used on samples with very low gas levels, which can be unreliable and inaccurate.

The DGA interpretation is still more of an art than a science. It is generally recognized by experts that increasing gas levels (i.e. gas generation rate) are more of concern than the levels themselves.

It is emphasized that DGA shall give misleading results unless certain precautions are taken. These are proper sampling procedure, Type of sampling bottle, cleanliness of bottle, duration of storage, method of gas extraction, good testing equipment and skilled manpower. Sampling of transformer insulating liquid for DGA by trained & experiences person and the consultation of a transformer expert with DGA interpretation experience is strongly recommended.

Specific information to be added to the DGA reports

Specific information to be added to the DGA reports is as follows:

- Date of commissioning
- Voltage class/ Voltage ratio, Power rating
- Oil Volume
- Oil Temperature
- Type of cooling system: ONAN, OFAF etc.
- Oil & gas sampling date
- Oil & gas sampling location
- Type of OLTC and whether it is communicating with main tank or not
- No. of OLTC operation,
- Load since last DGA
- Previous DGA done
- Special operation or incidences just before the oil or gas sampling such as tripping, gas alarm, degassing, repair, outage etc.

2.12 Frequency Response Analysis (FRA)

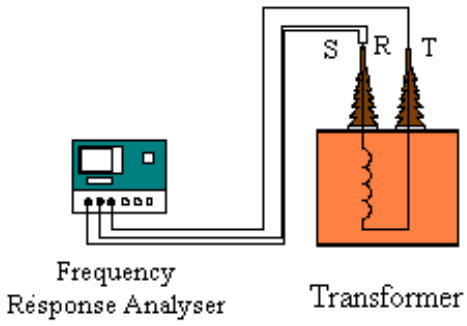
The frequency response analysis (FRA) is a technique that is used to diagnose the condition, or more importantly the change of mechanical condition, of a transformer by analyzing the transformer winding's frequency characteristics. FRA provides internal diagnostic information using nonintrusive procedures. The primary objective of FRA is to determine how the impedance of a test specimen behaves over a specified range of frequencies. The Short circuit forces can cause winding movement and changes in winding inductance or capacitance in Power Transformers. Recording the frequency response with these changes gives information regarding the internal condition of the equipment. Frequency Response Analysis (FRA) has proved to be an effective tool to detect such changes.

The measured response is usually shown graphically by plotting the logarithmic amplitude ratio of the output voltage to input voltage in dB (y-axis) against the frequency (x-axis). (The logarithmic often shows the complete frequency range more clearly. The linear scale is useful for looking at discrete frequency bands and to compare small differences at particular frequencies). The Frequency Response of a transformer winding (often called the FRA response curve) is quite complex and consists of decreasing and increasing magnitude (in dB) with respect to frequency. The various resonances (maxima) and anti-

resonances (minima) are determined by the electrical characteristics of the transformer winding.

Frequency Response Analysis (FRA) is made to assess the mechanical integrity of the transformer/reactor. Transformer/Reactor, while experiencing severity of short circuit current, loses its mechanical property by way of deformation of the winding or core. These changes cannot be detected through conventional condition monitoring techniques such as Dissolved Gas Analysis, Winding Resistance Measurement, Capacitance and Tan delta measurement etc. Sometimes even transportation without proper precaution may cause some internal mechanical damages. FRA measurement, which is a signature analysis, provides vital information of the internal condition of the equipment so that early corrective action could be initiated.

The transformer/reactor under test should be completely de-energized and isolated from the power system. All bushings of windings shall be disconnected from the system. It is important to record all relevant information which includes date & time of measurement, details of test equipment, name plate data of transformer and test setup like tap position, oil status (whether immersed or not), oil level, oil temperature and terminal grounded or shorted.



Sinusoidal signal output of approximately 2 V to 24 V rms from the Frequency Response Analyzer is applied and one measuring input (R1) is connected to the end of a winding and the other measuring input (T1) is connected to the other end of the winding. The voltage is applied and measured with respect to the earthed transformer/reactor tank. The voltage transfer function T1/R1 is measured for each winding for five standard frequency scans from 5 Hz to 10 MHz and the amplitude & phase shift results are recorded. At low frequencies, the influence of capacitance is negligible and winding behaves as an inductor. As the frequency of input signal increases, the capacitance begins to dominate. The low frequency analysis reveals the winding movements/deformation or core defects and the high frequency analysis reveals the condition of winding tightness and lead connections etc.

It is ensured that winding which is not under test is terminated in open condition in order to avoid undue variations of the results among the three phases. The same procedure is followed on subsequent tests on the same or similar units, to ensure that measurements could be effectively compared.

The voltage transfer function T1/R1 is measured for each winding for four standard frequency scans from 5 Hz to 2 MHZ and amplitude & phase shift results are recorded for subsequent analysis

Interpretation of the test results is based on subjective comparison of FRA responses taken at different intervals. If changes are observed in the later FRA spectrum with respect to the reference FRA spectrum, it is left to the experience of the analyst for qualitative condition assessment of the transformer/reactor. However, one should check for any significant shift in the resonance frequencies and emergence of new resonant frequencies in the later FRA response, which could be the result of any mechanical deformation in the transformer/reactor winding. As FRA is signature analysis, data of signature of the equipment when in healthy condition is required for proper analysis. Signatures could also be compared with unit of same internal design or with other phases of the same unit. Normally measured responses are analyzed for any of the following:

- Changes in the response of the winding with reference to earlier signature.
- Variation in the responses of the three phases of the same transformer/reactor.
- Variation in the responses of transformers/reactors of the same design.

In all the above cases the appearance of new features, i.e. production of new resonance peaks or valleys or major frequency shifts are causes for concern. The phase responses are also being recorded but normally it is sufficient to consider only amplitude responses.

The traces in general will change shape and will be distorted in the low frequency range (below 5 KHz) if there is a core problem. The traces will be distorted and change shape in higher frequencies (above 10 KHz), if there is winding problem. Changes of less than 3 decibels (dB) compared to baseline traces are normal and within tolerances.

The failure modes according to IEEE Std. C57.149-2012 is given below.

In general, the FRA test is sensitive to defects that cause geometric change(s) within a transformer. Any defect of this kind is referred to as failure mode even though such defect does not necessarily lead to a catastrophic failure of equipment. In fact, the popularity of the FRA test has been driven by the desire to detect mechanical failures within a transformer. Failure modes are not exclusive to geometric variations within a transformer and can include variation in the core's magnetic circuit and contact resistance.

FRA test variations can be caused by a single type of failure or a combination of two or more. Failure due to faults creates high over-currents through the transformer. As a result, the transformer experiences strong and often violent electromagnetic forces. These violent events can often lead to compounded failure modes. These compounded events can complicate the FRA analysis but often helps to better understand the condition of the transformer. The failure modes and explanation of each is as follows:

Sl. No.	Failure mode	Explanation
1	Radial "Hoop Buckling" deformation of winding	It is a winding compressive failure that is characterized by a pronounced change to the windings radial geometry. This type of failure can result from the high current electromagnetic forces caused by high over-current faults. The winding is subjected to high radial compressive (inwards) forces and will end up "buckling" along its entire length. The forces are concentrated on the inner windings. Radial winding deformation occurs in two forms, free and forced.
2	Axial winding elongation "Telescoping"	Axial winding movement includes two types of winding geometric changes. The winding is stretched or "telescoped" and then tightens due to a reduction in the windings radius. The geometric variations induced by this type of failure are complex and can lead to multiple resonances shifting across a broad frequency range.

3	Overall - Bulk & localized movement	These related failure modes describe the overall movement of windings or sections of windings. Considering a general movement of the winding, the causes could be due to a variety of reasons. Generally, this type of failure is used to describe the movement of the coils due to physical shock as a result of high current forces or transportation. Physical movement of the transformer could be due to shipping or seismic activity.
4	Core defects	Core defects failures cause changes to the core's magnetic circuit. Core defects can include burnt core laminations, shorted core laminations, multiple/unintentional core grounds, lost core ground, and joint dislocations.
5	Contact resistance	Though not necessarily a classical failure mode, high contact resistance readings can be detected by FRA testing. Any metal to metal mating surface that connects the bushings to the windings, LTC or DETC can lead to higher impedances through the test circuit applied. The end result can cause changes in both the low and highest frequencies. Poor contact resistance can be caused by connections that have worked themselves loose, corrosion, contact build-up or burning.
6	Winding turn-to-turn short circuit	Turn-to-turn faults are arguably one of the easier failure modes that can be identified by the FRA test. Turn-to-turn short-circuits can occur between two neighboring turns or between phases. The short can be either a low impedance solid short or high resistance leakage path.
7	Open circuited winding	An open circuit can be caused by connections that come loose or coils that become burned through due to a catastrophic thermal failure. The end result is very high impedances being inserted into the measurement circuit.

8	Winding looseness due to transportation	Winding looseness can be described as the gradual spreading of the disk-to-disk or turn-to-turn distances axially along a winding. This is particularly a transportation issue where before and after transportation transfer functions are compared on windings without oil and with transportation terminals for the winding leads. Winding looseness can occur during the transportation of a transformer when the blocking becomes loose and allows the winding to expand axially. The FRA does not detect loose blocks, but it detects the loose winding as a result of the loose blocking.
9	Residual magnetization	Though not necessarily a failure, residual magnetization within the core must be identified, so as not to be mis-interpreted as an actual fault. Residual magnetization is the flux density that remains in the core steel. DC winding resistance testing, switching operations, and geomagnetic phenomena are sources of residual magnetism. Residual magnetization can be identified by the shifting of the low frequency core resonance to the right compared to the demagnetized results. Residual magnetization can be removed by demagnetizing the core, and should be conducted if there is concern about the condition of the core.

It should be noted that the effects of deformations on the FRA measurements vary with transformer type and design. The same deformation type may affect different transformers differently. Frequency ranges for failure modes given in tables below are approximate and might be some overlap between ranges.

In general, changes of ± 3 dB (or more) in following frequency range may indicate following probable faults. Variation could either be a Shift or formation of new resonance peaks and valleys. The interpretation of FRA in different frequency range as derived from IEEE Std. C57.149-2012 is as follows:

Frequency Range	Probable Fault (assuming no other failure modes exist)
20 Hz – 10 kHz	Winding turn-to-turn short circuit (affected winding show the greatest change), Core defects (OC test)
5 kHz – 100 kHz	Axial winding deformation, Bulk winding movement, Contact resistance, Open circuit winding
50 kHz – 1 MHz	Radial winding deformation
100 kHz-500 kHz	Floating shield with local insulation carbonization (detectable response with changes in peaks and valleys)
1 MHz- 5 Mhz	Winding looseness due to transportation, Floating shield with local insulation carbonization (largest differences in peaks and valleys)

FRA relationship to other transformer diagnostics

The FRA results (depending on the particular test connections) can be used to confirm the results of other diagnostic tests. The comparison of these tests with FRA is given below:

Tests	Comparison with FRA
Single phase Excitation current	The test can be compared with the FRA's low frequency region for the open circuit test that is applied to the HV winding.
Turns ratio	The inductive inter-winding test most closely resembles the turns-ratio test properties at or around the fundamental power frequency.
Short circuit Impedance (Leakage Reactance)	The short-circuit test produces a response at lower frequencies that is associated with the leakage channel of the windings.
DC Winding Resistance	If the short-circuit test produces a horizontal response at frequencies, less than 30 Hz, then the FRA results can be compared to the DC winding resistance results.

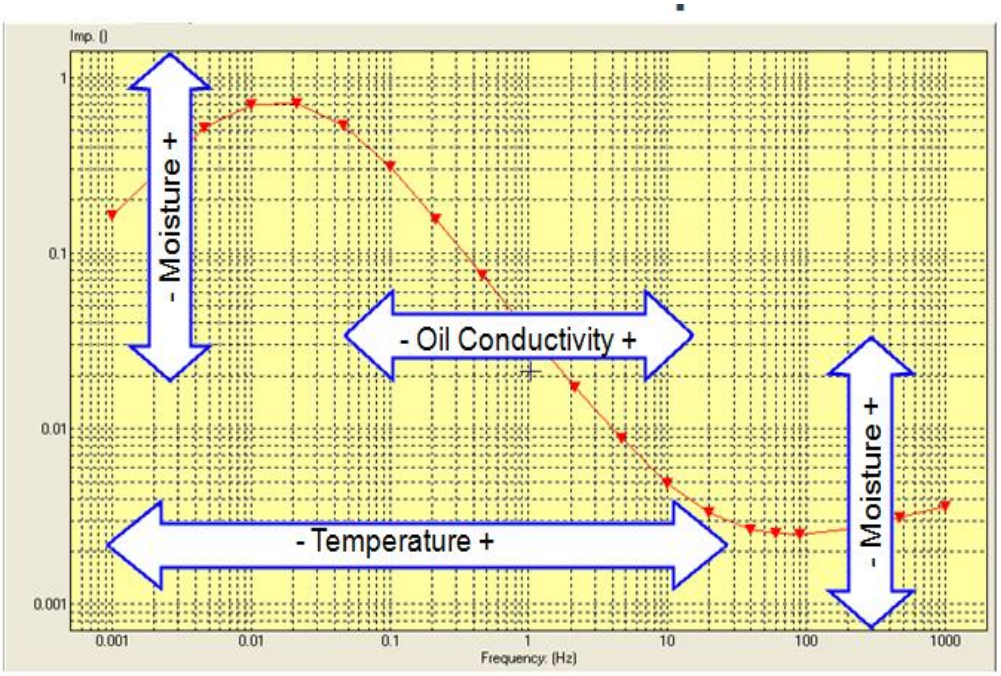
2.13 Frequency Domain Spectrometry of Bushings

Capacitance and dissipation factor (Tanδ) measurement at 50 Hz is a very common diagnostics techniques used for insulation condition assessment of the bushings since many decades. The moisture in paper, ageing of paper and other polar impurities in insulation can be detected by this measurement. However, relation between insulation condition (e.g. moisture and ageing) and C and Tan δ values at power frequency are sometimes uncertain. In many cases it has been observed that an initial developing fault in bushing may not always be reflected by Tan δ values at 50Hz. Similarly, a limitation of the capacitance method is that only partial breakdowns and contact problems in the main current path can be detected. Problems like partial discharge in bushings, partial breakdown between two capacitive layers are generally not reflected as any substantial change in capacitance value at 50Hz.

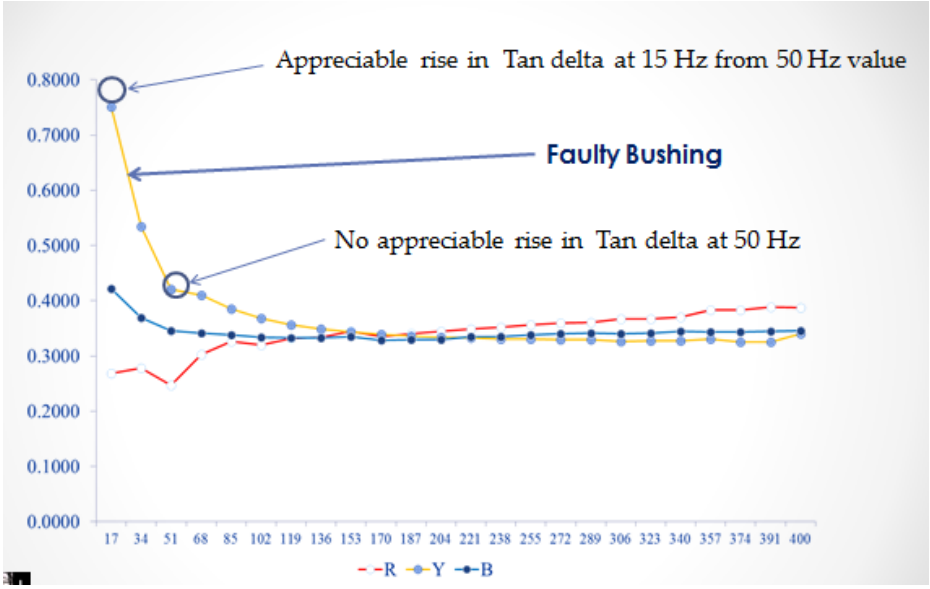
In all such cases, Capacitance and dissipation factor (Tanδ) measurement at variable frequency, known as Frequency Domain Spectroscopy(FDS), and supplemented by DGA is found to be a good method for condition assessment of OIP bushings. FDS includes measurement of C and dissipation factor over a frequency range of 1 mHz to 1 kHz and may be used to help arrive at conclusions about effect of polarisation, moisture content, ageing effect etc. in transformer/reactor insulation. FDS has very good correlation with DGA and can be verified by visual inspection after dismantling.

The permittivity, which can be used to characterize the insulation, is a dimensionless complex quantity, real part representing the energy stored in the electric field within the sample and imaginary part representing the energy losses. FDS characteristic of an oil-paper composite insulation represents the frequency and temperature dependency of permittivity and dissipation factor. In addition, defects like voids in paper, partial discharge and deposition of X-Wax in the bushings leading to high dielectric loss can be detected by the above measurement.

The FDS characteristic of the bushing may be interpreted in the manner as suggested:



An Example of the result comparison of a faulty bushing is as shown:



2.14 Partial Discharge (PD) Measurement

From Dissolved Gas Analysis (DGA), it is possible to detect PD. However, a direct measurement of PD is much helpful to ascertain a rapidly increasing rate of PD.

Partial discharges (PD) are localized dielectric discharges in a partial area of a solid or liquid electrical dielectric insulation system at rated voltage. It is in general a consequence of local electrical stress

concentration in the insulation or on the surface of the insulation. Partial discharges in a transformer/reactor deteriorate its insulation and can lead to failure of the unit.

Diagnostic PD measurements are recommended after conspicuous measured values such as increased gas-in-oil values. Partial Discharges can be measured in the field using Acoustic or UHF measurement method.

(a) Acoustic PD measurement

During a partial discharge, there occurs impulse conversion of some part of electric energy to mechanical energy, which is an acoustic emission wave. The acoustic emission is a group of phenomena involving generation of transient elastic (acoustic or vibro-acoustic) waves, resulting from liberation of intermolecular bond energy (deformation, cracking, phase transitions).

A typical measurement system for partial discharges detection based on acoustic emission method is composed of: (i) piezoelectric sensors, (ii) preamplifiers, (iii) signal conditioning unit, (iv) signal acquisition unit and (v) specialized software for digital signal processing. Proper acoustic coupling between the sensor and the surface of the tank shall be ensured in the detection of partial discharges in a power. For this purpose, silicone grease or gel dedicated for ultrasonic applications may be utilised. A lack of direct contact of acoustic sensor with the tank causes a strong attenuation of the AE amplitude signal, and thus a strong decrease in sensitivity of partial discharges detection may occur.

The correct interpretation of measurement results may be made difficult due to disturbances during on-site PD detection, for e.g., switching of on-load tap changer, thermal faults of transformer's active part, high-voltage switchgear operations near the investigated transformer, external/environmental noises (thunderstorms, rain, wind), core magnetostriction noise (Barkhausen effect), loose shielding connection in transformer tank etc.

(b) PD Detection with UHF Probe

The electromagnetic emission of a PD can also be measured using an UHF antenna which is inserted into the transformer/reactor tank. Due to the Faraday shielding of the tank this method is less sensitive

to external interferences and therefore more suitable for measurements in noisy environments for onsite/online measurements and monitoring. However, the transformer/reactor needs to have dedicated valves for providing the said sensors.

2.15 Moisture Measurement & Control

Moisture in the transformer/reactor oil can be measured and controlled using the Online Dryout System. This system has been recommended for 400 kV and above class transformers and reactors. The system is permanently installed which continuously keeps on removing the moisture while transformer/reactor is in charged stage. During the filtration process moisture PPM level is continuously monitored. This process removes moisture from transformer/reactor oil as well as the cellulose insulation.

The transformer/reactor oil is circulated through a series of cylinders filled with specially designed cartridges that absorbs moisture as well as removes solid contaminants from the oil. However, this may not be suitable for Wet transformers/Reactors which may require Off Line Dryout.

2.16 Thermovision Scanning

In order to avoid temperature rises beyond recommended limits in the electrical connections of the transformer/reactor, all screw-joints included should be checked and re-tightened based on readings from thermovision camera.

A thermovision camera determines the temperature distribution on the surface of the tank as well as in the vicinity of the jumper connection to the bushing. The information obtained by thermographs (as given below) is useful in predicting the temperature profile within the inner surface of tank and is likely to provide approximate details of heating mechanism. The following temperature rises above ambient have been found to be practical during infrared inspections:

Temperature rise above ambient (ºC) /Criticality		**Recommendation** (based on IEEE Std 62-2005)
0-10	Minor	Repair in regular maintenance schedule: Little probability of physical damage
11-39	Intermediate	Repair in near future (2-4 weeks); Inspect for

		physical damages
40-75	Serious	Repair in the immediate future (1-2 days). Disassemble and check for probable damage
>76	Critical	Critical problems; Repair immediately

3.0 Remnant Life measurement of Paper insulation

Paper is the major solid dielectric material within a transformer, used either as conductor wraps and impregnated with insulating liquid, or as barrier boards, wraps, spacers, and clamps in compressed or resin bonded forms. The major constituents of the paper are cellulose (about 90%), lignin (about 6%), and the remainder (about 4%). The three most common degradation factors of cellulose have been identified as thermal, oxidative, and hydrolytic.

When excessive paper degradation is suspected it is recommended to go for further analysis. Degradation of insulating paper can be ascertained by direct or indirect methods. Direct method employs Degree of Polymerization (DP), which requires a physical paper sample from the winding. However, this method being destructive to transformer, cannot be employed as a routine condition monitoring exercise. Furfural Analysis is an indirect method assessment of degradation of insulating paper.

For the oil-filled transformers, particularly which are in service for more than 15 years, it is advisable that the residual life should be estimated by assessing the extent of degradation of solid cellulosic paper insulation through Furan content analysis of oil and degree of polymerization of paper insulation. This would help utilities in making optimum use of transformers/reactors and also taking timely decision regarding Run-Refurbish-Replacement of transformers/reactors.

(a) Degree of Polymerization (DP)

One of the most dependable means of determining paper deterioration and remaining life is the DP test of the cellulose. The cellulose molecule is made up of a long chain of glucose rings which form the mechanical strength of the molecule and the paper. DP is the average number of these rings in the molecule. For DP measurement remove a sample of the paper insulation about 1 centimeter square from a convenient location near the top of center phase with a pair of tweezers. In general, in a three-phase transformer, the hottest most thermally aged paper will be at the top of the center phase. If it is not

possible to take a sample from the center phase, take a sample from the top of one of the other phases.

DP values for estimating remaining paper life:

New insulation	1000DP to 1400DP
60% to 66% life remaining	500DP
30% life remaining	300DP
0 life remaining (end of life)	200DP

(b) Furfural Analysis (FFA)

The immediate byproducts related to paper degradation are CO, CO_2, moisture, organic acids, and free glucose molecules. The free glucose degrades further into aromatic components known as furans. The presence of moisture and organic acids in the insulating liquid can further degrade the free glucose molecule into 5-hydroxymethyl-2-furfuryl or 5H2F. 5H2F is an unstable compound and can decompose further into 2-furaldehyde (2FAL) and other furans. The major furanic compound in oil which is stable is 2-furfuraldehyde (2FAL) and the others are present in very low or undetected level. The 2FAL is apparently stable for several years under the same conditions.

The concentration of the furanic compounds gives an indication of the condition of the paper in terms of the degree of polymerization, while the rate of change of furan concentration can indicate the rate of aging of paper. Generally, the total concentrations are less than 0.5 ppm and, in some cases, these levels may be maintained throughout transformer life. The types and concentrations of furans in the insulating liquid sample can also indicate the occurrence of abnormal stresses in a transformer, whether short duration overheating of the insulation or prolonged general overheating.

Generally, furanic compounds are extracted from the oil either by solvent extraction or solid phase extraction and measured by High Performance Liquid Chromatography (HPLC) with an UV detector. Furfuraldehyde/Furanic concentration can be measured colorimetrically using spectrophotometer. This method is rapid and accurate and measures only 2-Furfuraldehyde or 2-furfural (FAL) in oil. This technique is useful for quick screening of Furfuraldehyde in transformer oil.

When DGAs are required, always request that furans testing be completed by the laboratory to check for paper deterioration. In

healthy transformers, there are no detectable furans in the oil, or they are less than 100 part per billion (ppb). Normal deterioration of paper is characterized by rate of furan evolution as 50-90 ppb per year. Large amount of furans can be generated when temperature is above 120-130 deg. C. In cases where significant damage to paper insulation from heat has occurred, furan levels have been found to be at least 100 ppb and up to 70,000 ppb. The monitoring of furanic compounds by annual sampling of the oil and its analysis using High Performance Liquid Chromatography (HPLC) has been under used for condition monitoring on a routine basis for some in recent years by some utilities.

4.0 Monitoring of leakage of oil from Transformer / reactor and other maintenance checks

Leakage of Oil from transformer/reactor is considered as a serious quality lapse on the part of the Original Equipment Manufacturer (OEM) as no leakage of oil is expected during the operating life of the transformer/reactor. The utility should monitor and conduct visual inspection of the transformer/reactor tank and other body parts like pipes, flange joints in pipes, valves & its stems, oil pump, radiators, headers, screw joints, gasket joints, weld joints, and air bleed plugs, etc. regularly (on quarterly basis) to check any rusting and any leakage of oil. The records of inspection should be maintained properly. If leakage is noticed, the cause of such leakage shall be investigated and following action may be taken in consultation with OEM.

(a) Leakage at Screw joints: The presence of foreign material in threads, oval nipples, poor threads, improper fillers, and improper assembly can cause leakage through screw joints. It can be rectified with the proper tightening of screw joints & gasket joints.

(b) Leakage at Pipe joints: The pipework leakage at pipe joints may be due to slack unions or badly seated joints. The pipes should be aligned properly and the union joints should be tightened.

(c) Leakage at Gasket joint: Poor scarfed joints, insufficient or uneven compression, improper preparation of gasket surfaces can cause leakage at gasket locations. Gaskets sometimes shrink during service. It is, therefore, necessary to check the tightness of all bolts fastening gasketted joints. The bolts should be tightened to the correct pressure, evenly around the joints to avoid uneven pressure. Leaking gaskets should be replaced at the earliest opportunity.

(d) Leakage at Weld joint: The imperfect welds, material impurities, stress during transportation etc., can cause leakage in weld locations. If it is due to a defective weld, the same should be rectified after consulting the OEM.

Apart from Condition Monitoring tests and monitoring of leakage of oil, regular maintenance checks such as checking of oil level in bushing/conservator/OLTC conservator, manual actuation of cooler fans/pumps, checking condition of silica gel, cleaning of bushings etc. are equally important and should not be ignored. Such checks and their periodicity has been mentioned in the table given in the Appendix.

5.0 Transformer Assessment Indices (TAIs)

A Transformer Assessment Indices (TAIs) is one method that may help identify the transformers which most urgently need attention or intervention. The CIGRE document on Condition assessment of Power transformers (Reference /Brochure -761- WG A2.49) gives details on TAI.

6.0 Recommended, as-needed, and optional maintenance tests as per IEEE Std C57.152-2013

As per IEEE Std C57.152-2013, recommended, as-needed, and optional maintenance tests typically performed on liquid-filled power transformers during their commissioning, while they are in service, and after protection trips caused by either a system fault or an internal fault is given below.

Maintenance Test	**Liquid-filled power transformer**			
	Commissioning[a]	**In-service[b]**	**After protection trip due to system fault[c]**	**After protection trip due to internal fault[d]**
Main tank				
Tank pressure	Opt	Opt	Opt	REC
Core ground test	REC	AN	AN	REC
Insulating liquid quality tests and dissolved gas analysis(DGA)	REC	REC	AN	REC

Furan test	Opt	Opt[e]	Opt	REC
Vacuum	REC	Opt	Opt	REC
Insulation resistance	REC	AN	AN	REC
Winding resistance	REC	AN	AN	REC
Turns ratio (DETC taps)	REC	AN	AN	REC
Excitation current	REC	AN	AN	REC
PF/Tan-Delta	REC	AN	AN	REC
Partial discharge (PD)	Opt	Opt	Opt	Opt
Induced voltage	Opt	Opt	Opt	Opt
Frequency response analysis (FRA)	REC	AN	AN	REC
Dielectric frequency analysis (DFR)	Opt	Opt	Opt	Opt
Infrared	N/A	REC	N/A	N/A
Bushing				
Contact resistance	Opt	N/A	N/A	Opt
Infrared	N/A	REC	N/A	N/A
PF/Tan-Delta	REC	REC	AN	REC
Continuity	REC	N/A	N/A	REC
Load tap changer (LTC) and de-energized tap changer (DETC)				
Insulating liquid quality tests and DGA for LTC	REC	REC	AN	REC
Contact continuity for LTC	REC	AN	AN	REC
Infrared for LTC	N/A	REC	N/A	N/A
Motor current signature analysis for LTC	REC	AN	AN	REC
Vibration and acoustic measurement for LTC	Opt	Opt	Opt	Opt
Voltage dynamic testing for LTC	Opt	Opt	Opt	Opt

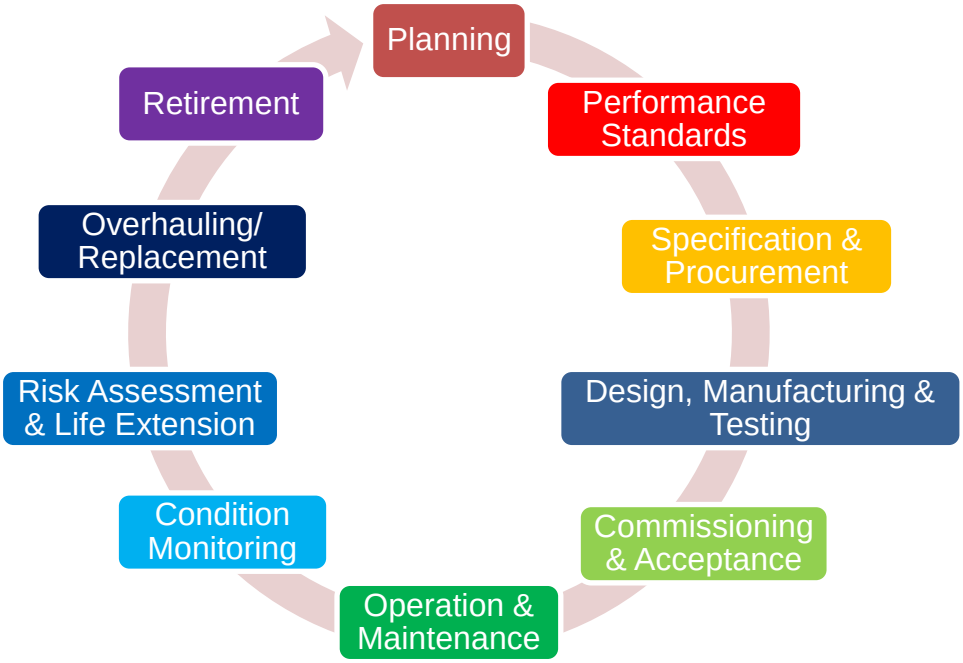
Ancillary equipment				
Gauges calibration	REC	REC	Opt	REC
Gas pressure relay calibration	REC	REC	Opt	REC
Pressure relief vent	REC	REC	Opt	REC
Cooling fan controls	REC	REC	Opt	REC
Cooling pump controls	REC	REC	Opt	REC
Arresters	REC	REC	REC	Opt
Bushing CTs	REC	AN	AN	AN

REC = Recommended
AN = As needed based on the REC Test results
Opt = Optional based on the AN test results
N/A = Not Applicable

[a]Newly installed or repaired units prior to energization
[b]In-service transformers may need to be de-energized and properly set up, depending on the test to be performed. Condition-based maintenance practice-oil quality, DGA, and Furan tests-may be carried out at a regular interval and the necessity of other tests depend upon the assesses condition for power and distribution transformers. For hermetically sealed distribution transformers, the first round of tests after commissioning may be time based, and thereafter, the frequency should depend on the assessed condition.
[c]After tripping of transformer due to system faults such as overcurrent.
[d]After tripping of transformer due to internal faults such as differential tripping (before repair).
[e]Furan Testing recommended for generator step-up(GSU) transformers and units operated above nameplate.

7.0 Life Cycle Management of Transformer/Reactor

Life Cycle Management is an integrated, information driven approach to all aspects of a product's life from its design inception, through its manufacture, deployment and maintenance, and culminating in its removal from service and final disposal. The entire process can be summarized as shown:



The conventional approach to Life Cycle Management can however be updated as shown below:

(a) **Feedback from Asset Manager**

The problems encountered in Operation & Maintenance and the measures felt necessary to enhance life of Equipment can be made part of relevant specifications, standards and maintenance practices. The feedback may also be relevant to the equipment manufacturer as well.

(b) **Life Assessment & Extension Measures of Equipment**

Optimum condition assessment helps in deferring additional capital investment and leads economic, technical, social and environmental benefits. By accurately assessing the weak part(s) of the equipment the utility will be able to target the component and will be able to adopt suitable life extension measures.

(c) **Introduction of new technologies**

Rapidly adopting new technologies shall give us better means to monitor and take decisions at both macro & micro level.

For assessing the remaining life of an Equipment – Paper condition, Oil Condition and Equipment loading needs to be assessed separately. In addition to the tests mentioned above the following tests shall be useful in predicting the Residual Life of the equipment:

- Furan Content
- Degree of Polymerisation
- Frequency Domain Spectrometry Results for Transformer
- Oil Parameters like Inhibitor content, Acidity, Sludge, etc
- Temperature & Loading Profile

Life Extension can then be achieved based on systematically analysing and addressing the problematic area on a techno economic basis.

APPENDIX

Condition Monitoring Tests, its frequency and acceptable values for Transformers and Reactors

Sl. No.	Test Name	Acceptable Values		Frequency
1.	Tan Delta for Bushing & winding	0.007 (Maximum) – for bushing 0.005 (Maximum) – for winding Note: a. Values to be followed during warranty period has been indicated in the chapter-2. b. Rate of Rise of Tan Delta (Bushing & Winding) shall not be more than 0.001 per year		Yearly (bushing) 4 yearly (winding)
2.	Capacitance for Bushing	- 5 % to + 5 % Variation from Factory Test results		Yearly
3.	Capacitance for Winding	- 5 % to + 10 % Variation from Factory Test results		4 Yearly
4.	Magnetizing current Test (Excitation Current Test)	Results between similar single-phase units should not vary more than 10 %. The test values on the outside legs should be within 15 % of each other, and values for the center leg should not be more than either outside for a three-phase transformers. Results compared to previous tests made under the same conditions should not vary more than 25%.		SOS
5.	Magnetic Balance Test (Three Phase) on transformer	Value of supply voltage in one phase is equal to sum voltage induced in other two phase. When supply voltage in middle limb, voltage induced in outer limbs should equal and roughly half of the supply voltage.		SOS
6.	Winding resistance (Resistance converted to 75 °C)	± 5% difference between phases or from Factory tests		SOS
7.	Voltage Ratio (All Taps) on transformer	±0.5% difference from nameplate specifications		SOS
8.	IR Value of Winding Min	Unless otherwise recommended by the manufacturer, 500 Mega-ohm for 66 kV and above voltage class		2 Yearly
9.	Polarization Index	Polarization Index	Insulation Condition	SOS

<table>
<tr><td></td><td rowspan="6">(Ratio of IR values at 10 min to 1 min)</td><td>Less than 1</td><td>Dangerous</td><td></td></tr>
<tr><td>1.0-1.1</td><td>Poor</td><td></td></tr>
<tr><td>1.1-1.25</td><td>Questionable</td><td></td></tr>
<tr><td>1.25-2.0</td><td>Fair</td><td></td></tr>
<tr><td>2.0-4.0</td><td>Good</td><td></td></tr>
<tr><td>Above 4.0</td><td>Excellent</td><td></td></tr>
<tr><td>10.</td><td>Core Insulation Test (Between core to clamp; clamp to tank; & core to tank)</td><td colspan="2">IR: Minimum 500 Mega Ohm;
Shall withstand 2.5 kV DC for 1 minute</td><td>SOS</td></tr>
<tr><td>11.</td><td>Neutral Earthpit Resistance Value</td><td colspan="2">Below 1 ohm</td><td>Yearly</td></tr>
<tr><td>12.</td><td>Turret/ Neutral CT Ratio Errors</td><td colspan="2">± 3%</td><td>SOS</td></tr>
<tr><td>13.</td><td>Vibration Level for reactors</td><td colspan="2">200 Microns (Peak to Peak)
60 Microns (Average)</td><td>SOS</td></tr>
<tr><td>14.</td><td>Sweep Frequency Response Analysis Tests (20 Hz to 5 MHz)</td><td colspan="2">In general, changes of ±3 dB (or more) in following frequency range may indicate following probable faults:
<table><tr><td>Frequency Range</td><td>Probable Fault (assuming no other failure modes exist)</td></tr><tr><td>20 Hz – 10 kHz</td><td>Winding turn-to-turn short circuit (affected winding show the greatest change), Core defects (OC test)</td></tr><tr><td>5 kHz – 100 kHz</td><td>Axial winding deformation, Bulk winding movement, Contact resistance, Open circuit winding</td></tr><tr><td>50 kHz – 1 MHz</td><td>Radial winding deformation</td></tr><tr><td>100 kHz-500 kHz</td><td>Floating shield with local insulation carbonization (detectable response with</td></tr></table></td><td>SOS</td></tr>
</table>

			changes in peaks and valleys)	
		1 MHz- 5 Mhz	Winding looseness due to transportation (Difference will be greater for the most affected windings), Floating shield with local insulation carbonization (largest differences in peaks and valleys)	
15.	Insulation Condition	% Moisture by dry weight in paper (Wp)	% Water saturation of oil	SOS
	Dry (at commissioning)	<0.5%	<5%	
	Normal in operation	<0.5%	-	
	Wet	2-4%	6-20%	
	Extremely Wet	>4.5%	>30%	
16.	Short Circuit Impedance on transformer	± 3% of nameplate specifications		SOS
17.	DGA of tank oil & OLTC oil	As laid down under concerned clause		Half Yearly
18.	Oil parameters of tank oil	As laid down under concerned clause and Annexure-L		Yearly
19.	Thermo-vision Scanning	Temperature rise above ambient (°C)/Criticality		Half Yearly
		0-10	Minor	
		11-39	Intermediate	
		40-75	Serious	
		>76	Critical	
		Note: Comparison to be made with similar joints/items of the same transformer and values are to be nearly matching		
20.	Other maintenance checks:			
	(a)	Checking of bushing oil level		Monthly
	(b)	Checking of oil level in conservator		Monthly
	(c)	Checking of oil level in OLTC conservator		Monthly

	(d)	Checking of oil leaks	Monthly
	(e)	Checking condition of silica gel in breather	Monthly
	(f)	Checking of oil level in oil seal of breather	Monthly
	(g)	Manual actuation of cooler fans and oil pumps	Monthly
	(h)	External cleaning of all bushings	Yearly
	(i)	External cleaning of radiators	Yearly
	(j)	Checking of marshalling box/control cubicles: cleaning, tightening of terminations, checking of contactors, space heater, lamps etc.	Yearly
	(k)	Maintenance of OLTC driving mechanism	Yearly
	(l)	Checking/testing of buchholz relay by oil draining	Yearly
	(m)	Electrical checking/testing of PRD, buchholz relay, rapid pressure rise relay, OLTC surge relay, checking of alarm/trip	Yearly
	(n)	Checking of gaskets	Yearly
	(o)	Checking of OTI/WTI and tap position indicator and top up of oil in pockets, if required	Yearly

Note: ***The frequency of test needs to be increased based on the analysis of trend of the test results.***

Reference Documents for Transformer Condition Assessment:

1. **Operational Aspects**

   CIGRE Technical Brochures:

   170-2000 Static Electrification

   228-2002 Aging Process

   323-2007 Ageing of Cellulose

   349-2008 Moisture equilibrium and migration in insulation system

   393-2009 Thermal Performance of Transformers

   IEC Standards

   60076-7ed2.0 2018-Loading guide for Oil immersed Transformers

   60076-12 -2008 Loading Guide for Dry Type transformers

   60076-8-1997 Application Guide – Paralleling

   IEEE Standards

   C57.91-2011 Loading guide for Oil Immersed Transformers

   C57.96-2013 Loading guide For Dry Type Transformers

   C57.153-2015 Paralleling

2. **Monitoring**

   CIGRE Technical Brochures

   248-2004 Economics of Management

   298-2006 LifeTime data Management

   343-2008 Condition Monitoring and Condition Assessment Facilities

   409-2010 Gas monitors

   445-2011 Transformer Maintenance Guide

   630-2015 Guide on Transformer Intelligent Monitoring

   761-2019 Condition Assessment of Power Transformers

   783-2019 DGA Monitoring system

   IEC Standards

   60442 ed4.0-2013 Maintenance of Oil

   60994-1988 Silicon Oil Maintenance

   61203-1992 Synthetic Ester Maintenance

   62975 (under preparation) – Natural Ester Maintenance

ISO 18095-2018 Condition Monitoring and diagnostics of Power Transformers

IEEE Standards

C57.106-2015 Maintenance of Oil

C57.125-2015 Site failure Investigation

C57.140-2017 Evaluation and Reconditioning of oil filled Transformers

C57.143- 2012 Monitoring Equipment for Transformers

3. Diagnostics

CIGRE Technical Brochures

254-2002 Dielectric Frequency Response (DFR)

296-2006 &771-2019 DGA Interpretation

323-2007 Aging of cellulose in mineral oil insulated transformers

342-2008 Sweep Frequency Response Analysis (SFRA)

443-2010- DGA for non-mineral oils & Tap-Changers

494-2012 Furanic Compounds for Diagnosis

676-2017 PD In Transformers

IEC Standards

60076-18-2012 SFRA

60567-2005 Sampling for DGA

60599-2015 DGA Interpretation

IEEE Standards

C57.104-2019 DGA Interpretation of Oil

C57.139-2015 DGA of OLTC oil

C57.149-2012 SFRA

C57.152-2013 Diagnostic Field Testing of Transformers

C57.155-2014 DGA of Esters

C57.161-2018 DFR

C57.200-2000 PD Detection by Acoustic Monitoring

4. Refurbishment

CIGRE Technical Brochures

227-2003 Life Management Techniques

413-2010 Oil Regeneration and Dehalogenation

537-2013 Guide for Fire Safety

673-2016 Guide on Transportation

765-2019 Understanding and mitigating corrosion

IEE Standards

C57.93-2019 Installation and Maintenance of Transformer

C57.140-2017 Evaluation and Reconditioning

C57.150-2012 Transportation

C57.637 -2015 Reclamation of Oil



Annexures

Annexure-A

SPECIFIC TECHNICAL REQUIREMENT

TRANSFORMERS

1.0 500 MVA, (765/√3)/ (400/√3)/ 33 kV 1-Ph Auto Transformer

S. No.	Description	Unit	Parameters
1.	Voltage ratio (Line to ground)	kV	(765/√3)/(400/√3)/33 kV
2.	Rated Capacity		
	HV	MVA	500
	IV	MVA	500
	LV (Tertiary)	MVA	5 MVA active loading
3.	No of phases		1 (Single)
4.	Vector Group		YNaOd11 (in 3-phase bank)
5.	Type of Transformer		Auto transformer
6.	Applicable Standard		IEC-60076 / IS 2026
7.	Cooling		ONAN / ONAF / OFAF (or) ONAN / ONAF/ ODAF (or) ONAN / ONAF1 / ONAF2
8.	Rating at different cooling	%	60 / 80 / 100
9.	Cooler Bank Arrangement		2 X 50%
10.	Frequency	Hz	50
11.	Impedance at 75°C at highest MVA base		
i)	**HV – IV**	%	14.0
ii)	**HV – LV**	%	195.0
iii)	**IV – LV**	%	180.0
12.	Tolerance on Impedance	%	As per IEC
13.	Service		Outdoor
14.	Duty		Continuous
15.	Overload Capacity		IEC-60076-7
16.	Max. temperature rise over 50°C ambient temperature	^{o}C	
i)	Top oil measured by thermometer	^{o}C	45
ii)	Average winding measured by resistance method	^{o}C	50
17.	Winding hot spot rise over yearly weighted temperature of 32°C	^{o}C	61
18.	Tank Hotspot Temperature	^{o}C	110
19.	Max. design Ambient temp	^{o}C	50
20.	Windings		

i)	Lightning Impulse Withstand Voltage		
	HV	kV_p	1950
	IV	kV_p	1300
	LV	kV_p	250
	Neutral	kV_p	170
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	2145
	IV	kV_p	1430
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1550
	IV	kV_p	1050
iv)	One Minute Power Frequency Withstand Voltage		
	HV	kV_{rms}	-
	IV	kV_{rms}	570
	LV	kV_{rms}	95
	Neutral	kV_{rms}	70
v)	Neutral		Solidly Earthed
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of windings at ambient Temperature	%	≤ 0.5
21.	Bushing		
i)	Rated voltage		
	HV	kV	800
	IV	kV	420
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	2500
	IV	A	2500
	LV	A	1250
	Neutral	A	3150
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	2100
	IV	kV_p	1425

	LV	kV_p	250
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1550
	IV	kV_p	1050
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	970
	IV	kV_{rms}	695
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	24800
	IV	mm	13020
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
22.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
23.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active		80
24.	**Maximum Permissible Losses of Transformers**		
i)	Max. No Load Loss at rated voltage and frequency	kW	**80**
ii)	Max. Load Loss at rated current and frequency and at 75°C for HV and IV windings, at principal tap position	kW	**450**
iii)	Max I^2R loss at rated current and frequency and at 75°C for HV and IV windings, at principal tap position	kW	**335**

iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**10**

2.0 (a) 500MVA, 400/220/33 kV 3-Ph Auto Transformer
(b) 500 MVA, 400/230/33 kV 3-Ph Auto Transformer

S. No.	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line-to-Line)	kV	(a) 400/220/33 (b) 400/230/33	
2.	Rated Capacity			
	HV	MVA	500	
	IV	MVA	500	
	LV (Tertiary)	MVA	5 MVA active loading	
3.	No of phases		3-phase	
4.	Vector Group		YNaOd11	
5.	Type of Transformer		Auto Transformer	
6.	Applicable Standard		IEC 60076 / IS 2026	
7.	Cooling		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Rating at different cooling	%	60 / 80 / 100	
9.	Cooler Bank Arrangement		2 X 50%	
10.	Frequency	Hz	50	
11.	Tap Changer (OLTC)		+10% to -10% in 1.25% steps on common end of series winding for 400kV side voltage variation	
12.	Impedance at 75°C, at highest MVA base		Constant Ohmic type	Constant percentage type
i)	**HV – IV**			
	Max. Voltage tap	%	10.3	12.5
	Principal tap	%	12.5	
	Min. Voltage tap	%	15.4	
ii)	**HV – LV**			
	At principal tap	%	60.0 (minimum)	45.0
iii)	**IV – LV**	%	45.0 (minimum)	30.0
13.	Tolerance on Impedance	%	As per IEC, unless specified otherwise	
14.	Service		Outdoor	
15.	Duty		Continuous	
16.	Overload Capacity		IEC-60076-7	
17.	Temperature rise over 50°C ambient temp			
i)	Top oil measured by thermometer	^{O}C	45	

ii)	Average winding measured by resistance method	^{o}C	50
18.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o}C	61
19.	Tank Hotspot Temperature	^{o}C	110
20.	Maximum design ambient temperature	^{o}C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	950
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	IV	kV_p	1045
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	395
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	245
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250

	IV	A	2000
	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	IV	kV_p	1050
	LV	kV_p	250
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	IV	kV_{rms}	505
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	IV	mm	7595
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
25.	**Maximum Permissible Losses of Transformers**		Same for constant ohmic and constant percentage type
i)	Max. No Load Loss at rated voltage and frequency	kW	**90**

ii)	Max. Load Loss at rated current and at 75°C for HV and IV windings, at principal tap position	kW	**500**
iii)	Max I^2R loss at rated current and at 75°C for HV and IV at principal tap position	kW	**375**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**15**

3.0 (a) 167 MVA, (400/√3)/ (220/√3) /33kV 1-Ph Auto Transformer
(b) 167 MVA, (400/√3)/ (230/√3) /33kV 1-Ph Auto Transformer

S. No.	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line to Ground)	kV	(a) (400/√3)/(220/√3)/33 (b) (400/√3)/(230/√3)/33	
2.	Rated Capacity			
	HV	MVA	167	
	IV	MVA	167	
	LV (Tertiary)	MVA	5 MVA active loading	
3.	No of phases		1-phase	
4.	Vector Group		YNaOd11 (in 3-phase bank)	
5.	Type of Transformer		Auto Transformer	
6.	Applicable Standard		IEC 60076 / IS 2026	
7.	Cooling		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Rating at different cooling	%	60 / 80 / 100	
9.	Cooler Bank Arrangement		2 X 50%	
10.	Frequency	Hz	50	
11.	Tap Changer (OLTC)		+10% to -10% in steps of 1.25% on common end of series winding for 400kV side voltage variation	
12.	Impedance at 75°C at highest MVA base		Constant Ohmic type	Constant percentage type
i)	**HV – IV**			
	Max. Voltage tap	%	10.3	12.5
	Principal tap	%	12.5	
	Min. Voltage tap	%	15.4	
ii)	**HV – LV**			
	At principal tap	%	60.0 (minimum)	45.0
iii)	**IV – LV**	%	45.0 (minimum)	30.0
13.	Tolerance on Impedance	%	As per IEC, unless specified otherwise	
14.	Service		Outdoor	
15.	Duty		Continuous	
16.	Overload Capacity		IEC-60076-7	
17.	Temperature rise over 50°C ambient temp			
i)	Top oil measured by thermometer	°C	45	
ii)	Average winding measured by resistance method	°C	50	

18.	Winding hot spot rise over yearly weighted temperature of 32°C	^{o}C	61
19.	Tank Hotspot Temperature	^{o}C	110
20.	Maximum design ambient temperature	^{o}C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	950
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	IV	kV_p	1045
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	395
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	245
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	IV	A	2000
	LV	A	1250

	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	IV	kV_p	1050
	LV	kV_p	250
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	IV	kV_{rms}	505
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	IV	mm	7595
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
25.	**Maximum Permissible Losses of Transformers**		Same for constant ohmic and constant percentage type
i)	Max. No Load Loss at rated voltage and frequency	kW	**45**
ii)	Max. Load Loss at rated current and at 75°C for HV and IV windings, at principal tap position	kW	**200**

iii)	Max I^2R loss at rated current and at 75°C for HV and IV at principal tap position	kW	**140**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**6**

4.0 (a) 315 MVA, 400/220/33kV 3-Ph Auto Transformer
(b) 315 MVA, 400/230/33kV 3-Ph Auto Transformer

S. No.	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line-to-Line)	kV	(a) 400/220/33 (b) 400/230/33	
2.	Rated Capacity			
	HV	MVA	315	
	IV	MVA	315	
	LV (Tertiary)	MVA	5 MVA active loading	
3.	No of phases		3-phase	
4.	Vector Group		YNaOd11	
5.	Type of Transformer		Auto Transformer	
6.	Applicable Standard		IEC 60076 / IS 2026	
7.	Cooling		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Rating at different cooling	%	60 / 80 / 100	
9.	Cooler Bank Arrangement		2 X 50%	
10.	Frequency	Hz	50	
11.	Tap Changer (OLTC)		+10% to -10% in 1.25% steps on common end of series winding for 400kV side voltage variation	
12.	Impedance at 75°C at highest MVA base		Constant Ohmic type	Constant percentage type
i)	**HV – IV**			
	Max. Voltage tap	%	10.3	12.5
	Principal tap	%	12.5	
	Min. Voltage tap	%	15.4	
ii)	**HV – LV**			
	At principal tap	%	60.0 (minimum)	45.0
iii)	**IV – LV**	%	45.0 (minimum)	30.0
13.	Tolerance on Impedance	%	As per IEC, unless specified otherwise	
14.	Service		Outdoor	
15.	Duty		Continuous	
16.	Overload Capacity		IEC-60076-7	
17.	Temperature rise over 50°C ambient temp			
i)	Top oil measured by thermometer	^{o}C	45	
ii)	Average winding measured by resistance method	^{o}C	50	

18.	Winding hot spot rise over yearly weighted temperature of 32°C	^{o}C	61
19.	Tank Hotspot Temperature	^{o}C	110
20.	Maximum design ambient temperature	^{o}C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	950
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	IV	kV_p	1045
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	395
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	245
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	IV	A	1250
	LV	A	1250

	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	IV	kV_p	1050
	LV	kV_p	250
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	IV	kV_{rms}	505
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	IV	mm	7595
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
25.	**Maximum Permissible Losses of Transformers**		Same for constant ohmic and constant percentage type
i)	Max. No Load Loss at rated voltage and frequency	kW	**75**
ii)	Max. Load Loss at rated current and at 75° C for HV and IV windings, at principal tap position	kW	**440**

iii)	Max I^2R loss at rated current and at 75° C for HV and IV at principal tap position	kW	**330**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**10**

5.0 (a) 105 MVA, (400/√3)/ (220/√3)/33kV 1-Ph Auto Transformer
(b) 105 MVA, (400/√3)/ (230/√3)/33kV 1-Ph Auto Transformer

S. No.	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line to Ground)	kV	(a) (400/√3)/(220/√3)/33 (b) (400/√3)/(230/√3)/33	
2.	Rated Capacity			
	HV	MVA	105	
	IV	MVA	105	
	LV (Tertiary)	MVA	5 MVA active loading	
3.	No of phases		1-phase	
4.	Vector Group		YNaOd11 (in 3-phase bank)	
5.	Type of Transformer		Auto Transformer	
6.	Applicable Standard		IEC 60076 / IS 2026	
7.	Cooling		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Rating at different cooling	%	60 / 80 / 100	
9.	Cooler Bank		2 X 50%	
10.	Frequency	Hz	50	
11.	Tap Changer (OLTC)		+10% to -10% in steps of 1.25% on common end of series winding for 400kV side voltage variation	
12.	Impedance at 75°C, at highest MVA base		Constant Ohmic type	Constant percentage type
i)	**HV – IV**			
	Max. Voltage tap	%	10.3	12.5
	Principal tap	%	12.5	
	Min. Voltage tap	%	15.4	
ii)	**HV – LV**			
	At principal tap	%	60.0 (minimum)	45.0
iii)	**IV – LV**	%	45.0 (minimum)	30.0
13.	Tolerance on Impedance	%	As per IEC, unless specified otherwise	
14.	Service		Outdoor	
15.	Duty		Continuous	
16.	Overload Capacity		IEC-60076-7	
17.	Temperature rise over 50°C ambient temp			
i)	Top oil measured by thermometer	^{o}C	45	
ii)	Average winding measured by resistance method	^{o}C	50	

18.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o}C	61
19.	Tank Hotspot Temperature	^{o}C	110
20.	Maximum design ambient temperature	^{o}C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	950
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	IV	kV_p	1045
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	395
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	245
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	IV	A	1250
	LV	A	1250

	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	IV	kV_p	1050
	LV	kV_p	250
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	IV	kV_{rms}	505
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	IV	mm	7595
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
24.	Maximum Noise level at rated voltage, principal tap & no load and all cooling active	dB	80
25.	**Maximum Permissible Losses of Transformers**		Same for constant ohmic and constant percentage type
i)	Max. No Load Loss at rated voltage and frequency	kW	**30**
ii)	Max. Load Loss at rated current and at 75°C for HV and IV windings, at principal tap position	kW	**140**

iii)	Max I^2R loss at rated current and at 75°C for HV and IV at principal tap position	kW	**105**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**6**

6.0 315 MVA, 400/132/33 kV 3-Phase Auto Transformer

S. No	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line-to-Line)	kV	400/132/33	
2.	Rated Capacity			
	HV	MVA	315	
	IV	MVA	315	
	LV (Tertiary)	MVA	5 MVA (active loading)	
3.	No of phases		3-phase	
4.	Vector Group		YNaOd11	
5.	Type of transformer		Auto transformer	
6.	Applicable Standard		IEC 60076 / IS 2026	
7.	Cooling type		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Rating at different cooling	%	60 / 80 / 100	
9.	Cooler Bank Arrangement		2 X 50%	
10.	Frequency	Hz	50	
11.	Tap Changer (OLTC)		+10% to -10% in steps of 1.25% for IV voltage variation using variable flux variation concept	
12.	Location of tap changer		At Neutral end	
13.	Impedance at 75°C, at highest MVA base		Constant Ohmic impedance type	Constant percentage impedance type
i)	HV – IV			
	Max. Voltage tap	%	10.3	12.5
	Principal tap	%	12.5	
	Min. Voltage tap	%	15.4	
ii)	HV – LV			
	Principal tap	%	45.0 (minimum)	40.0

iii)	IV – LV		
	Principal tap	%	30.0 (minimum) | 25.0
iv)	Tolerance on Impedance	%	As per IEC, unless specified otherwise
14.	Service		Outdoor
15.	Duty		Continuous
16.	Overload Capacity		IEC-60076-7 / IS 6600
17.	Temperature rise over 50°C ambient temp.		
i)	Top oil measured by thermometer	^{o}C	45
ii)	Average winding measured by resistance method	^{o}C	50
18.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o}C	61
19.	Tank Hotspot Temperature	^{o}C	110
20.	Maximum design ambient temperature	^{o}C	50
21.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	650
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1430
	IV	kV_p	715
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	540

iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	275
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤ 0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	145
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	IV	A	2000
	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	IV	kV_p	650
	LV	kV_p	250
	Neutral	kV_p	170

iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	IV	kV_{rms}	305
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	IV	mm	4495
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
25.	**Maximum Permissible Losses of Transformers**		Same for constant ohmic and constant percentage type
i)	Max. No Load Loss at rated voltage and frequency	kW	**75**
ii)	Max. Load Loss at rated current and at 75°C for HV and IV	kW	**440**

	windings, at principal tap position		
iii)	Max. I^2R Loss at rated current and at 75°C for HV and IV windings, at principal tap position	kW	**330**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**10**

7.0 (a) 200 MVA, 400/132/33 kV 3-Phase Auto Transformer
(b) 200 MVA, 400/110/33 kV 3-Phase Auto Transformer

S. No	Description	Unit	Technical Parameters	
1.	Voltage ratio (Line-to-Line)	kV	(a) 400/132/33 (b) 400/110/33	
2.	Rated Capacity			
	HV	MVA	200	
	IV	MVA	200	
	LV (Tertiary)	MVA	5 MVA (active loading)	
3.	No of phases		3-phase	
4.	Vector Group		YNaOd11	
5.	Type of transformer		Auto transformer	
6.	Applicable Standard		IEC 60076/ IS 2026	
7.	Cooling type		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Rating at different cooling	%	60 / 80 / 100	
9.	Cooler Bank Arrangement		2 X 50%	
10.	Frequency	Hz	50	
11.	Tap Changer (OLTC)		+10% to -10% in steps of 1.25% for IV voltage variation using variable flux variation concept	
12.	Location of tap changer		At Neutral end	
13.	Impedance at 75°C, at highest MVA base		Constant Ohmic impedance type	Constant percentage impedance type
i)	HV – IV			
	Max. Voltage tap	%	10.3	12.5
	Principal tap	%	12.5	
	Min. Voltage tap	%	15.4	

ii)	HV – LV			
	Principal tap	%	45.0 (minimum)	40.0
iii)	IV – LV			
	Principal tap	%	30.0 (minimum)	25.0
iv)	Tolerance on Impedance	%	As per IEC, unless specified otherwise	
14.	Service		Outdoor	
15.	Duty		Continuous	
16.	Overload Capacity		IEC-60076-7	
17.	Temperature rise over 50°C ambient temp.			
i)	Top oil measured by thermometer	^{o}C	45	
ii)	Average winding measured by resistance method	^{o}C	50	
18.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o}C	61	
19.	Tank Hotspot Temperature	^{o}C	110	
20.	Maximum design ambient temperature	^{o}C	50	
21.	Windings			
i)	Lightning Impulse withstand Voltage			
	HV	kV_p	1300	
	IV	kV_p	650 (132 kV) 550 (110 kV)	
	LV	kV_p	250	
	Neutral	kV_p	95	
ii)	Chopped Wave Lightning Impulse Withstand Voltage			
	HV	kV_p	1430	
	IV	kV_p	715 (132 kV)	

			605 (110 kV)
	LV	kV_p	275
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
	IV	kV_p	540 (132 KV) 460 (110 kV)
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	275 (132 kV) 230 (110 kV)
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vii)	Tertiary Connection		Ungrounded Delta
viii)	Tan delta of winding	%	≤ 0.5
22.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	145
	LV	kV	52
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	IV	A	1250

	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1425
	IV	kV_p	650
	LV	kV_p	250
	Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	695
	IV	kV_{rms}	305
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	IV	mm	4495
	LV	mm	1612
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10

23.	Maximum Partial discharge level at 1.58 * U_r / √3	pC	100
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
25.	**Maximum Permissible Losses of Transformers**		Same for constant ohmic and constant percentage type
i)	Max. No Load Loss at rated voltage and frequency	kW	**70**
ii)	Max. Load Loss at rated current and at 75°C for HV and IV windings at principal tap position	kW	**400**
iii)	Max. I^2R Loss at rated current and at 75°C for HV and IV windings, at principal tap position	kW	**320**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**8**

8.0 (a) 200 MVA and 160MVA, 220/132 kV 3-Phase Auto Transformer
(b) 200 MVA and 160MVA, 230/110 kV 3-Phase Auto Transformer
(c) 200 MVA and 160MVA, 220/110 kV 3-Phase Auto Transformer

Cl. No.	Description	Unit	TECHNICAL PARAMETERS	
1.	Voltage ratio (line to line)	kV	(a) 220/132 (b) 230/110 (c) 220/110	
2.	Rated Capacity			
	HV	MVA	200	160
	LV	MVA	200	160
3.	No of phases		3	
4.	Vector Group		YNa0	
5.	Type of transformer		Auto Transformer	
6.	Applicable Standard		IEC 60076 /IS 2026	
7.	Cooling type		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2	
8.	Frequency	Hz	50	
9.	Rating at different cooling	%	60 / 80 / 100	
10.	Cooler Bank Arrangement		2 X 50%	
11.	Tap changer			
i)	Type		OLTC	
ii)	Tap Range & steps		–5% to +15% in steps of 1.25% for 132 kV variation	
iii)	Location of Tap changer		On the 132 kV line end	
12.	HV-LV Impedance at 75 °C, at highest MVA base			
i)	Max. Voltage tap	%	9.5	
ii)	Principal tap	%	12.5	
iii)	Min. Voltage tap	%	14.0	
iv)	Tolerance on Impedance	%	As per IEC	

13.	Service		Outdoor
14.	Duty		Continuous
15.	Overload Capacity		IEC 60076-7
16.	Temperature rise over 50°C ambient Temp		
i)	Top oil measured by thermometer	^{o} C	45
ii)	Average winding measured by resistance method	^{o} C	50
17.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o} C	61
18.	Tank Hotspot Temperature	^{o} C	110
19.	Maximum design ambient temperature	^{o} C	50
20.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	950
	LV	kV_p	650 (132 kV) 550 (110 kV)
	Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1045
	LV	kV_p	715 (132 kV) 605 (110 kV)
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	750
	LV	kV_p	540 (132 KV) 460 (110 kV)
iv)	One Minute Power Frequency withstand Voltage		
	HV	kVrms	395

	LV	kVrms	275 (132 kV) 230 (110 kV)
	Neutral	kVrms	38
v)	Neutral Grounding		Solidly grounded
vi)	Insulation		
	HV & LV		Graded
vii)	Tan delta of winding	%	≤0.5%
21.	Bushings		
i)	Rated voltage		
	HV	kV	245
	LV	kV	145
	Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kVp	1050
	LV	kVp	650
	Neutral	kVp	170
iv)	Switching Impulse withstand Voltage on HV	kVp	850
v)	One Minute Power Frequency withstand Voltage		
	HV	$kVrm_s$	505
	LV	$kVrm_s$	305
	Neutral	$kVrm_s$	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5

vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)	
	HV	mm	7595	
	LV	mm	4495	
	Neutral	mm	1116	
viii)	Maximum Partial discharge level at U_m			
	HV	pC	10	
	LV	pC	10	
22.	Maximum Partial discharge level at 1.58*Ur/√3	pC	100	
23.	Maximum Noise level at rated voltage, principal tap & no load and all cooling active	dB	75	
24.	**Maximum Permissible Losses of Transformers**		**200 MVA**	**160 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**35**	**30**
ii)	Max. Load Loss at rated current and at 75°C for HV and LV windings at principal tap position	kW	**260**	**200**
iii)	Max. I^2R Loss at rated current and at 75°C for HV and LV windings, at principal tap position	kW	**190**	**145**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**8**	**6**

9.0 160 MVA, 220/66 kV 3-ph Power Transformer

Cl. No.	Description	Unit	TECHNICAL PARAMETERS
1.	Voltage ratio (Line to Line)	kV	220/66
2.	Rated Capacity		
	HV	MVA	160
	LV	MVA	160
3.	No of phases		3 (Three)
4.	Vector Group		YNyn0
5.	Type of Transformer		Power Transformer
6.	Applicable Standard		IEC 60076 /IS 2026
7.	Cooling type		ONAN / ONAF / OFAF or ONAN / ONAF / ODAF or ONAN / ONAF1 / ONAF2
8.	Rating at different cooling	%	60 / 80 / 100
9.	Frequency	Hz	50
10.	Cooler Bank Arrangement		2 X 50%
11.	Tap changer		
i)	Type		On load tap changer (CFVV)
ii)	Tapping range and steps		–15% to +5% in steps of 1.25% for HV variation
iii)	Location of tapping		at Neutral end of HV
12.	HV-LV Impedance at 75° C, at highest MVA base	%	
i)	Max. Voltage tap	%	16.2
ii)	Principal tap	%	15.0
iii)	Min. Voltage tap	%	14.0
iv)	Tolerance on Impedance	%	As per IEC
13.	Service		Outdoor
14.	Duty		Continuous

15.	Overload Capacity		IEC 60076-7
16.	Temperature rise over 50°C ambient Temp		
i)	Top oil measured by thermometer	^{o} C	45
ii)	Average winding measured by resistance method	^{o} C	50
17.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o} C	61
18.	Tank Hotspot Temperature	^{o} C	110
19.	Maximum design ambient temperature	^{o} C	50
20.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	950
	LV	kV_p	325
	HV Neutral	kV_p	95
	LV Neutral	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	1045
	LV	kV_p	358
iii)	Switching Impulse withstand Voltage		
	HV	kV_p	750
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	395
	LV	kV_{rms}	140
	HV Neutral	kV_{rms}	38
	LV Neutral		38
v)	Neutral Grounding		

	HV		Solidly grounded
	LV		Solidly grounded
vi)	Insulation		
	HV		Graded
	LV		Graded
vii)	Tan delta of winding	%	≤0.5%
21.	Bushings		
i)	Rated voltage		
	HV	kV	245
	LV	kV	72.5
	HV Neutral	kV	36
	LV Neutral	kV	36
ii)	Rated current		
	HV	A	1250
	LV	A	2000
	HV Neutral	A	2000
	LV Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1050
	LV	kV_p	325
	HV Neutral	kV_p	170
	LV Neutral	kV_p	170
iv)	Switching Impulse withstand Voltage		
	HV	kV_p	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	505
	LV	kV_{rms}	155

	HV Neutral	kV_{rms}	77
	LV Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	7595
	LV	mm	2248
	Neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
	LV	pC	10
22.	Maximum Partial discharge level at 1.58 *Ur/√3	pC	100
23.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	75
24.	**Maximum Permissible Losses of Transformers**		
i)	Max. No Load Loss at rated voltage and frequency	kW	**60**
ii)	Max. Load Loss at rated current and at 75°C for HV and LV windings at principal tap position	kW	**320**
iii)	Max. I^2R Loss at rated current and at 75°C for HV and LV windings at principal tap position	kW	**265**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**8**

10.0 (a) 100 MVA, 220/33 kV 3-ph Power Transformer
(b) 100 MVA, 230/33 kV 3-ph Power Transformer

Cl. No.	Description	Unit	Technical Parameters
1.	Voltage ratio (Line-to-Line)	kV	(a) 220/33 (b) 230/33
2.	Rated Capacity		
	HV	MVA	100
	LV	MVA	100
3.	No of phases		3 (Three)
4.	Vector Group		YNyn0
5.	Type of transformer		Power transformer
6.	Applicable Standard		IEC 60076 / IS 2026
7.	Cooling type		ONAN / ONAF / OFAF or ONAN/ONAF / ODAF or ONAN / ONAF1 /ONAF2
8.	Rating at different cooling	%	60 / 80 / 100
9.	Frequency	Hz	50
10.	Cooler Bank Arrangement		2 X 50%
11.	Tap Changer		
i)	Type		On-load tap changer
ii)	Tap range and steps		-15% to +5% in steps of 1.25% for HV variation
iii)	Location of tap changer		On HV neutral end
12.	Impedance at 75°C, at highest MVA base		
i)	Max. Voltage tap	%	16.2
ii)	Principal tap	%	15.0
iii)	Min. Voltage tap	%	14.0
iv)	Tolerance on Impedance		As per IEC
13.	Service		Outdoor
14.	Duty		Continuous
15.	Overload Capacity		IEC-60076-7
16.	Temperature rise over 50°C ambient Temp		
i)	Top oil measured by thermometer	^{o}C	45
ii)	Average winding measured by resistance method	^{o}C	50
17.	Winding hot spot rise over yearly weighted temperature of 32°C	^{o}C	61
18.	Tank Hotspot Temperature	^{o}C	110
19.	Maximum design ambient temperature	^{o}C	50

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

v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	505
	LV	kV_{rms}	77
	HV Neutral	kV_{rms}	77
	LV Neutral	kV_{rms}	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV bushing	mm	7595
	LV bushing	mm	1116
	HV neutral / LV neutral	mm	1116
viii)	Maximum Partial discharge level at U_m		
	HV	pC	10
22.	Maximum Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100
23.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	80
24.	**Maximum Permissible Losses of Transformers**		
i)	Max. No Load Loss at rated voltage and frequency	kW	**43**
ii)	Max. Load Loss at rated current and at 75°C for HV and LV windings at principal tap position	kW	**245**
iii)	Max. I^2R Loss at rated current and at 75°C for HV and LV windings at principal tap position	kW	**200**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**5**

11.0

(a) 80 MVA, 50 MVA and 31.5MVA, 132/33 kV, 3-Phase Power Transformer
(b) 80 MVA, 50 MVA and 31.5MVA, 110/33 kV, 3-Phase Power Transformer

S. No.	Description	Unit	TECHNICAL PARAMETERS		
1.	Voltage ratio (Line-to-Line)	kV	(a) 132/33 (b) 110/33		
2.	Rated capacity (HV and LV)	MVA	80	50	31.5
3.	No of phases		3 (Three)		
4.	Vector Group		YNyn0		
5.	Type of transformer		Power Transformer		
6.	Applicable Standard		IEC 60076 / IS 2026		
7.	Cooling type		ONAN/ONAF		
8.	Rating at different cooling	%	60 / 100		
9.	Cooler Bank Arrangement		1 X 100%		
10.	Frequency	Hz	50		
11.	Tap changer				
i)	Type		On-load tap changer (CFVV)		
ii)	Tapping range and steps		-15% to +5% in steps of 1.25% for HV variation		
iii)	Location of tap changer		On HV neutral end		
12.	HV-LV Impedance at 75 °C, at highest MVA base				
i)	Max. Voltage tap	%	13.2		
ii)	Principal tap	%	12.5		
iii)	Min. Voltage tap	%	11.8		
13.	Tolerance on Impedance	%	As per IEC		
14.	Service		Outdoor		
15.	Duty		Continuous		
16.	Overload Capacity		IEC 60076-7		
17.	Temperature rise over 50°C ambient temp.				

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

i)	Rated voltage				
	HV	kV	145		
	LV, LV Neutral & HV Neutral	kV	36		
ii)	Rated current (Min.)				
	HV	A	1250		
	LV	A	1250 (for 50 & 31.5 MVA) 2000 (for 80 MVA)		
	HV Neutral & LV Neutral	A	1250		
iii)	Lightning Impulse withstand Voltage				
	HV	kV_p	650		
	LV, HV Neutral and LV Neutral	kV_p	170		
iv)	One Minute Power Frequency withstand Voltage				
	HV	kV_{rms}	305		
	LV, HV Neutral and LV Neutral	kV_{rms}	77		
v)	Tan delta of bushing at ambient Temperature	%	≤ 0.5		
vi)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)		
	HV	mm	4495		
	LV, HV Neutral and LV Neutral	mm	1116		
	Maximum Partial discharge level at U_m on HV	pC	10		
23.	Maximum Partial discharge level at 1.58*Ur/√3	pC	100		
24.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	75 for 50 MVA 70 for 31.5 MVA		
25.	**Maximum Permissible Losses of Transformers**		**80 MVA**	**50 MVA**	**31.5 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**35**	**25**	**18**
ii)	Max. Load Loss at rated current and frequency and at 75°C at principal tap between HV & LV	kW	**200**	**125**	**110**

iii)	Max. I^2R Loss at rated current and frequency and at 75°C at principal tap between HV & LV	kW	**170**	**105**	**93.5**
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	**5**	**3**	**2**

12.0 31.5 MVA, 20 MVA, 12.5 MVA, 66/11 kV 3-ph Power Transformer

S. No.	Description	Unit	TECHNICAL PARAMETERS		
1.	Voltage ratio (Line-to-Line)	kV	66/11		
2.	Rated Capacity (HV and LV)	MVA	31.5	20	12.5
3.	No of phases		3 (Three)		
4.	Vector Group		Dyn11		
5.	Type of transformer		Power Transformer		
6.	Applicable Standard		IEC 60076 / IS 2026		
7.	Frequency	Hz	50		
8.	Cooling type		ONAN		
9.	Tap Changer				
i)	Type		On-load tap changer (CFVV)		
ii)	Tap Range and no. of steps		–5% to +15% of HV variation in the step of 1.25%		
iii)	Location of Tap changer		On HV neutral end		
10.	HV-LV Impedance at 75°C	%			
	Max. Voltage Tap		11.2		
	Principal Tap		10		
	Min. Voltage Tap		9		
11.	Tolerance		As per IEC		
12.	Service		Outdoor		
13.	Duty		Continuous		
14.	Overload Capacity		IEC 60076-7		
15.	Temperature rise over 50°C Ambient Temp				
i)	Top oil measured by thermometer	^{o}C	45		
ii)	Average winding measured by resistance method	^{o}C	50		
16.	Winding hot spot rise over yearly weighted temperature of 32 °C	^{o}C	61		
17.	Tank Hotspot Temperature	^{o}C	110		
18.	Maximum design ambient temperature	^{o}C	50		
19.	Windings				

i)	Lightning Impulse withstand Voltage		
	HV	kV_p	325
	LV & LV Neutral	kV_p	75
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	HV	kV_p	358
	LV	kV_p	83
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	140
	LV & LV Neutral	kV_{rms}	28
iv)	Insulation		Solidly grounded
	HV		Uniform
	LV		Uniform
v)	Tan delta of winding	%	≤0.5
20.	Bushings		
i)	Rated voltage		
	HV	kV	72.5
	LV & LV Neutral	kV	17.5
ii)	Rated current		
	HV	A	800
	LV & LV neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	325
	LV & LV Neutral	kV_p	95
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	155
	LV & LV Neutral	kV_{rms}	42
v)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vi)	Minimum total creepage distances		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	2248
	LV & LV Neutral	mm	543

vii)	Maximum Partial discharge level on HV bushing at U_m	pC	10		
21.	Maximum Partial discharge level at 1.58*Ur/√3	pC	100		
22.	Maximum Noise level at rated voltage, at principal tap & no load and all cooling active	dB	70		
23.	Maximum Permissible Losses of Transformers		**31.5 MVA**	**20 MVA**	**12.5 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**18.0**	**14.0**	**9.0**
ii)	Max. Load Loss at rated current and frequency and at 75°C, at principal tap position	kW	**110.0**	**80.0**	**56.0**
iii)	Max. I^2R Loss at rated current and frequency and at 75°C, at principal tap position	kW	**93.5**	**68.0**	**47.0**

Notes: (for all transformers ratings)

1. **For parallel operation with existing transformer, percentage impedance, OLTC connection and range, vector group and the winding configuration (if necessary) are to be matched.**

2. **No external or internal Transformers/ Reactors are to be used to achieve the specified HV/IV, HV/LV and IV/LV impedances.**

13.0 765 kV Generator Transformers for Thermal Power Plants

S. No	Description	Unit	Technical parameters	
1.	Rated capacity at highest cooling capacity (*)			
	HV	MVA	265	315
	LV	MVA	265	315
	(*) MVA rating in VWO (valve wide open) condition of turbine			
2.	Rated voltage on HV	kV	765/√3	
3.	Rated voltage on LV	kV	LV voltage shall be decided as per Generator voltage	
4.	Number of phases		Single	
5.	No of windings		Two	
6.	Type		Generator step-up application	
7.	Service		Outdoor	
8.	Duty		Continuous	
9.	Applicable standard		IEC 60076	
10.	Type of cooling		ODAF or OFAF	
11.	Connection on HV/ LV		Star/ Delta (after 3-phase bank formation)	
12.	Vector group symbol		Ynd11 (after 3-phase bank formation)	
13.	Rated frequency	Hz	50	
14.	No. of coolers		6x20% Tank mounted unit coolers	
15.	Tap changer			
i)	Type of tap changer		De-energized Tap Changer (Off-Circuit Tap Changer)	
ii)	Tapping range and tap steps		+5% to -5% in steps of 2.5%	
iii)	Tapping for variation		On HV neutral for HV variation	
16.	% impedance at 75°C, at highest MVA base		265MVA base	315MVA base
i)	At Principal tap position	%	15% (with +/-5% tolerance)	16% (with +/-5% tolerance)
ii)	Range at highest /lowest tap position	%	12.5 to 17.5%	14.4 to 17.6%
iii)	Permissible variation of impedance between single phase units		Shall be preferably identical as far as possible and variation of any single-	

			phase unit shall be within +/-5% of impedance with other two units.
17.	System earthing		
	HV		Solidly earthed
	LV		Unearthed
18.	Maximum temperature rise over 50°C ambient Temp		
i)	Top oil measured by thermometer	°C	35
ii)	Average winding measured by resistance method	°C	40
19.	Winding hot spot rise (over yearly weighted temperature of 32°C	°C	61
20.	Tank Hotspot Temperature	°C	110
21.	Maximum design ambient temperature	°C	50
22.	Short circuit withstand time	seconds	3
23.	Noise pressure level at full load with 100% coolers	dB	As per NEMA TR-1
24.	Type of insulations on HV		Graded
25.	Type of insulation on LV		Uniform
26.	Insulation level on windings		
i)	Lightning impulse withstand voltage		
	HV	kVp	2050
	LV	kVp	170
	HV Neutral	kVp	95
ii)	Chopped wave impulse withstand voltage		
	HV line end	kVp	2255
	LV line end	kVp	187
iii)	Switching impulse withstand voltage on HV winding line end		
	HV	kVp	1700
iv)	One-minute power frequency withstand voltage of windings		
	LV	kV rms	70
	HV neutral	kV rms	38
27.	Bushings		
i)	Rated voltage		
	HV	kV	800
	LV & HV Neutral	kV	36
ii)	Rated current		
	HV	A	2500
	LV	A	16000 A for 265MVA

			20000 A for 315MVA
	HV neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	2100
	LV	kV_p	170
	HV neutral	kV_p	170
iv)	Switching impulse withstand voltage		
	HV	kV_p	1550
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	970
	LV	kV_{rms}	77
	HV neutral		77
vi)	Max Partial discharge level on HV bushing at U_m	pC	10
vii)	Minimum total creepage distance of bushings		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	24800
	HV neutral and LV	mm	1116
28.	Terminal arrangement		
	HV line end		Condenser bushing (Oil to air or Oil to SF6 or Oil to Oil) as per specification
	LV line end		Isolated phase bus duct flange
	HV neutral		Outdoor oil communicating type bushing (36kV)
29.	Minimum phase spacing of the LV isolated bus duct		LV Terminal shall match approx. 1800mm bus duct spacing. Exact value will be communicated to successful bidder during detailed engineering
30.	Bushing Current Transformers		As specified by the utility
31.	De-rating considering busduct temperature for bushing current selection		The temperature inside the bus duct enclosure may be of the order of 90 to 100°C. The bus duct conductor temperature may be as high as 105°C & temperature in

			the bus duct enclosure will be of the order of 80°C.	
32.	**Maximum Permissible Losses of Transformers**		**265 MVA**	**315 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**105**	**135**
ii)	Max. Load Loss at rated current and frequency and at 75°C, at principal tap position	kW	**330**	**420**
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW	**20**	**21**

14.0 420 kV Generator Transformers for Thermal Power Plants

S. No	Description	Unit	Technical parameters		
1.	Rated capacity at highest cooling capacity (*)				
	HV	MVA	200	265	315
	LV	MVA	200	265	315
	(*) MVA rating in VWO (valve wide open) condition of turbine				
2.	Rated voltage on HV	kV	420/√3		
3.	Rated voltage on LV	kV	LV voltage shall be decided as per Generator voltage		
4.	Number of phases		Single		
5.	No of windings		Two		
6.	Type		Generator step-up application		
7.	Service		Outdoor		
8.	Duty		Continuous		
9.	Applicable standard		IEC 60076		
10.	Type of cooling		ODAF or OFAF		
11.	Connection on HV/LV		Star/ Delta (after 3-phase bank formation)		
12.	Vector group symbol		Ynd11 (after 3-phase bank formation)		
13.	Rated frequency	Hz	50		
14.	No. of coolers		6x20% Tank mounted unit coolers		
15.	Tap changer				
i)	Type of tap changer		De-energized Tap Changer (Off-Circuit Tap Changer)		
ii)	Tapping range and tap steps		+10% to -10% in steps of 2.5% for 200MVA; +5% to -5% in steps of 2.5% for 265 MVA and 315MVA		
iii)	Tapping for variation		On HV neutral for HV variation		
16.	% impedance at 75°C, at highest MVA base		200MVA base	265MVA base	315MVA base
	At Principal tap position	%	13.5% (with +/-5% tolerance)	15% (with +/-5% tolerance)	16% (with +/-5% tolerance)

i)	Range at highest /lowest tap position	%	12 to 15%	12.5 to 17.5%	14.4 to 17.6%
ii)	Permissible variation of impedance between single phase units		Shall be preferably identical as far as possible and variation of any single-phase unit shall be within +/-5% of impedance with other two units.		
17.	System earthing				
	HV		Solidly earthed		
	LV		Unearthed		
18.	Maximum temperature rise over 50°C ambient temperature				
i)	Top oil measured by thermometer	°C	35		
ii)	Average winding measured by resistance method	°C	40		
19.	Winding hot spot rise (over yearly weighted temperature of 32°C	°C	61		
20.	Tank Hotspot Temperature	°C	110		
21.	Maximum design ambient temperature	°C	50		
22.	Short circuit withstand time	seconds	3		
23.	Noise pressure level at full load with 100% coolers	dB	As per NEMA TR-1		
24.	Type of insulations on HV		Graded		
25.	Type of insulation on LV		Uniform		
26.	Insulation level on windings				
i)	Lightning impulse withstand voltage				
	HV	kVp	1425		
	LV	kVp	170 (for 265 MVA & 315 MVA) or 125 (for 200 MVA)		
	HV Neutral	kVp	95		
ii)	Chopped wave impulse withstand voltage				
	HV line end	kVp	1570		
	LV line end	kVp	187 (for 265 MVA & 315 MVA) or 138 (for 200 MVA)		
iii)	Switching impulse withstand voltage on HV winding line end				
	HV	kVp	1175		
iv)	One-minute power frequency withstand voltage of windings				
	HV	kV rms	630		

	LV	kV rms	70 (for 265 MVA & 315 MVA) or 50 (for 200 MVA)
	HV neutral	kV rms	38
27.	Bushings		
i)	Rated voltage		
	HV	kV	420
	LV & HV Neutral	kV	36
ii)	Rated current		
	HV	A	1250 A for 200MVA 1600 A for 265MVA 2000 A for 315MVA
	LV	A	12500 A for 200MVA 16000 A for 265MVA 20000 A for 315MVA
	HV neutral	A	1250 A for 200MVA 2000 A for 265 or 315MVA
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	1550
	LV	kV_p	170
	HV neutral	kV_p	170
iv)	Switching impulse withstand voltage		
	HV	kV_p	1175
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	750
	LV	kV_{rms}	77
	HV neutral		77
vi)	Max Partial discharge level on HV bushing at U_m	pC	10
vii)	Minimum total creepage distance of bushings		(Specific creepage distance: 31mm/kV corresponding to the line to line highest system voltage)
	HV	mm	13020
	HV neutral and LV	mm	1116
28.	Terminal arrangement		
	HV line end		Condenser bushing (Oil to air or Oil to SF6 or Oil to Oil) as per specification
	LV line end		Isolated phase bus duct flange

	HV neutral		Outdoor oil communicating type bushing (36kV)		
29.	Minimum phase spacing of the LV isolated bus duct		LV Terminal shall match approx. 1800mm bus duct spacing. Exact value will be communicated to successful bidder during detailed engineering		
30.	Minimum external air clearance from live part to earth	mm	3500 for altitude <1000m above MSL for 420kV side		
31.	Bushing Current Transformers		As specified by the utility		
32.	De-rating considering bus duct temperature for bushing current selection		The temperature inside the bus duct enclosure may be of the order of 90 to 100°C. The bus duct conductor temperature may be as high as 105°C & temperature in the bus duct enclosure will be of the order of 80°C.		
33.	**Maximum Permissible Losses of Transformers**		**200 MVA**	**265 MVA**	**315 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	**98**	**97**	**108**
ii)	Max. Load Loss at rated current and frequency and at 75°C, at principal tap position	kW	**308**	**370**	**455**
iii)	Max. Auxiliary Loss at rated voltage and frequency	kW	**19**	**21**	**23**

15.0 420kV Generator Transformers for Hydro Power Stations

S. No.	Description	Unit	Technical parameters
1.	Rated continuous capacity at max ambient temperature		As specified by the utility
	HV	MVA	
	LV	MVA	
2.	Rated voltage on HV	kV	420/√3
3.	Rated voltage on LV	kV	as per Generator supply voltage
4.	Number of phases		Single
5.	No of windings		Two
6.	Highest voltage of equipment (Um) for		
	HV winding	kV	420/√3
	LV winding	kV	as per Generator supply voltage
7.	Type		Generator step-up application
8.	Applicable standard		IEC 60076
9.	Type of cooling		OFWF or ODWF
10.	No. of coolers		2x 100% (oil to water heat exchangers) No of oil pumps: 2 x 100%
11.	Connection on HV / LV		Star/ Delta (after 3-phase bank formation)
12.	Vector group symbol		Ynd11 (after 3-phase bank formation)
13.	Rated frequency	Hz	50
14.	% impedance at 75°C		As per IEC 60076-5
15.	Maximum temperature rise at rated power		
i)	Top oil measured by thermometer	°C	55
ii)	Average winding measured by resistance method	°C	60
16.	Winding hot spot temperature rise over yearly weighted average temperature of 32 °C	°C	61
17.	Max. tank surface temperature	°C	110
18.	Noise pressure level at full load with 100% coolers	dB	As per NEMA TR-1 standard
19.	System earthing		
	HV		Solidly earthed

	LV		Unearthed
20.	Type of insulations on HV		Class A, Graded insulation
21.	Type of insulation on LV		Class A, Uniform insulation
22.	Insulation level of windings		
i)	Lightning impulse withstand voltage		
	HV	kVp	1425
	LV	kVp	As specified
	HV Neutral	kVp	95
ii)	Chopped wave impulse withstand voltage		
	HV	kVp	1570
	LV	kVp	As specified
iii)	Switching impulse withstand on HV winding line end	kVp	1175
iv)	One-minute power frequency withstand voltage of winding		
	HV	kV rms	630
	LV	kV rms	As specified
	HV neutral	kV rms	38
23.	Bushings		
i)	Rated voltage of bushings		
	HV	kV	420kV
	LV	kV	As specified
	HV neutral	kV	36kV
ii)	Lightning impulse withstand voltage of bushing		
	HV	kVp	1550
	LV	kVp	As specified
	HV Neutral	kVp	170
iii)	Switching impulse withstand on HV bushing	kVp	1175
iv)	One-minute power frequency withstand voltage of bushing		
	HV	kV rms	750
	LV	kV rms	As specified
	HV neutral	kV rms	70
v)	Max partial discharge level of bushings at Um on HV bushing	pC	10
vi)	Total specific creepage distance of bushings	mm/kV (Highest line to line voltage)	25 or 31 (based on location – as specified)

24.	Terminal arrangement		
	HV terminal		Oil to air or Oil to SF6 or Oil to Oil depending upon the connection arrangement
	LV terminal		Oil to air bushing
	HV neutral terminal		Oil to air bushing
25.	Transportation restriction if any		As specified by the utility

REACTORS

16.0 80 MVAr & 110 MVAr, 765/√3kV, 1-phase Shunt Reactor

S. No.	Description	Unit	Technical Parameters	
1.	Rated capacity at 765/√3 kV	MVAr	80	110
2.	Rated Voltage (Ur)	kV	765/√3	
3.	Maximum continuous operating voltage (Um) (1p.u.)	kV	800/√3	
4.	Winding connection		Star with neutral (in 3 Phase Bank)	
5.	Cooling type		ONAN	
6.	Frequency	Hz	50	
7.	No of Phases		1 (Single)	
8.	Reference standard		IEC 60076-6	
9.	Service		Outdoor	
10.	Duty		Continuous at 800/√3kV	
11.	Permissible unbalance current among phases		±1%	
12.	Crest value of third harmonic component in phase current when reactor is energised at rated voltage with sinusoidal wave form		≤ 3% of the crest value of fundamental	
13.	Range of constant impedance (Linearity)		Up to 1.25 p.u. (However, complete saturation characteristics of the Reactors upto 1.5 p.u. Voltage shall be furnished)	
14.	Tolerance on current		(i) 0 to +5% for a single-phase unit (ii) ±1% for between units	
15.	Ratio of zero sequence reactance to positive reactance (X0/X1)		Between 0.9 & 1.0.	
16.	Temperature rise over 50 °C Ambient Temp. and at 800/√3 kV			
i)	Top oil measured by thermometer	°C	40	
ii)	Average winding measured by resistance method	°C	45	
17.	Winding hot spot temperature rise over yearly weighted average temperature of 32 °C	°C	61	
18.	Max. tank surface temperature	°C	110	
19.	Max design ambient temperature	°C	50	

20.	Windings		
i)	Lightning Impulse withstand Voltage		
	Line end	kV_p	1950
	Neutral	kV_p	550
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	Line end	kV_p	2145
iii)	Switching Impulse withstand Voltage at Line end	kV_p	1550
iv)	Power Frequency withstand Voltage		
	Line end	kV_{rms}	830kV rms (Ph to Earth) for 5 min (to be tested)
	Neutral	kV_{rms}	230 (for one minute)
21.	Neutral earthing		Solidly Earthed
22.	Whether neutral is to be brought out		Yes (through 145kV class bushing)
23.	Tan-delta of windings at ambient Temperature		< 0.005
24.	Bushing		
i)	Rated voltage		
	Line bushing	kV	800
	Neutral bushing	kV	145
ii)	Rated current		
	Line bushing	A	2500
	Neutral bushing	A	1250
iii)	Lightning Impulse withstand Voltage		
	Line bushing	kV_p	2100
	Neutral bushing	kV_p	650
iv)	Switching Impulse withstand Voltage of Line bushing	kV_p	1550
v)	One minute power frequency withstand Voltage of bushings (dry)		
	Line bushing	kV rms	970

	Neutral bushing	kV rms	305	
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5	
vii)	Minimum creepage distance		(Specific Creepage Distance: of 31mm/kV corresponding to highest line to line voltage)	
	Line bushing	mm	24800	
	Neutral bushing	mm	4495	
viii)	Partial discharge of bushings at Um (line end and neutral)	pC	< 10	
25.	Vibration and tank stress at Um		Max. Amplitude ≤200microns (peak to peak) Average amplitude ≤ 60microns (peak to peak) Tank stress: ≤2.0kg/sq.mm at any point of tank	
26.	Maximum Partial discharge level at 1.58 Ur/√3	pC	100	
27.	Maximum noise level at rated voltage & frequency	dB	80	
28.	**Maximum Permissible Losses of Reactor**		**80MVAr**	**110MVAr**
i)	Max. Total loss at rated current and frequency and at 75°C	kW	**98**	**120**
ii)	Max. I^2R Loss at rated current and frequency and at 75°C	kW	**52**	**60**

17.0 50MVAR, 63 MVAr, 80 MVAr & 125 MVAr, 3-phase, 420 kV Shunt Reactor

S. No	Description	Unit	Technical Parameters		
1.	Rated Capacity at 420kV	MVAr	**63**	**80**	**125**
2.	Rated Voltage (Ur) (1.0 pu)	kV	420		
3.	Number of phases		3 (three)		
4.	Connection		Star		
5.	Cooling type		ONAN		
6.	Frequency	Hz	50		
7.	Reference standard		IEC 60076-6		
8.	Service		Outdoor		
9.	Permissible unbalance current among phases	%	±2%		
10.	Crest value of third harmonic content in phase current when reactor is energised at rated voltage with sinusoidal wave form	%	≤ 3% of the crest value of fundamental		
11.	Range of constant impedance (Linearity)		Up to 1.5 p.u voltage (However, complete saturation characteristics of the Reactors upto 2.5 p.u. Voltage shall be furnished)		
12.	Tolerance on current	%	0 to +5%		
13.	Ratio of zero sequence reactance to positive reactance (X0/X1)		Between 0.9 & 1.0.		
14.	Temperature rise over 50 °C ambient temperature at 420 kV				
i)	Top oil measured by thermometer	°C	40		
ii)	Average winding measured by resistance method	°C	45		
15.	Winding hot spot temperature rise over yearly weighted average temperature of 32 °C	°C	61		
16.	Max. tank surface temperature	°C	110		
17.	Max design ambient temperature	°C	50		
18.	Windings				
i)	Lightning Impulse withstand Voltage				
	Line end	kV_p	1300		
	Neutral	kV_p	550		

ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	Line end	kV_p	1430
iii)	Switching Impulse withstand Voltage at Line end	kV_p	1050
iv)	One Minute Power Frequency withstand Voltage		
	Line end	kV_{rms}	570
	Neutral	kV_{rms}	230
19.	Tan-delta of windings		< 0.005
20.	Neutral earthing		Solidly Earthed
21.	Whether neutral brought out		Yes (through 145kV class bushing)
22.	Bushing		
i)	Rated voltage		
	Line bushing	kV	420
	Neutral bushing	kV	145
ii)	Rated current		
	Line bushing	A	1250
	Neutral bushing	A	1250
iii)	Lightning Impulse withstand Voltage		
	Line bushing	kV_p	1425
	Neutral bushing	kV_p	650
iv)	Switching Impulse withstand Voltage of Line bushing	kV_p	1050
v)	1minute power frequency withstand voltage of bushings (dry)		
	Line bushing	kV rms	695
	Neutral bushing	kV rms	305
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum creepage distance		(Specific Creepage Distance: of 31mm/kV corresponding to highest line to line voltage)
	Line bushing	mm	13020
	Neutral bushing	mm	4495

viii)	Partial discharge of bushings at Ur (line end and neutral)	pC	< 10	
23.	Maximum partial discharge level at 1.58Ur/√3	pC	100	
24.	Vibration and tank stress at rated voltage		Max. amplitude ≤200microns (peak to peak) Average amplitude ≤ 60microns (peak to peak) Tank stress: ≤2.0kg/sq.mm at any point of tank	
25.	Maximum noise pressure level at rated voltage & frequency	dB	80	
26.	**Maximum Permissible Losses of Reactor at rated current and frequency and at 75°C**		**Total loss**	**I^2R Loss**
i)	**50 MVAr**	kW	**85**	**45**
ii)	**63 MVAr**	kW	**100**	**57**
iii)	**80 MVAr**	kW	**115**	**65**
iv)	**125 MVAr**	kW	**160**	**90**

18.0 25 MVAr & 50 MVAr, 245 kV 3-phase Shunt Reactor

S. No.	Description	Unit	Technical Parameters	
1.	Rated Voltage, U_r (1p.u)	kV	245	
2.	Rated Capacity at 245 kV	MVAr	25	50
3.	Connection		Star with neutral brought out	
4.	Cooling System		ONAN	
5.	Frequency	Hz	50	
6.	No of Phases		3 (Three)	
7.	Reference Standard		IEC 60076-6	
8.	Service		Outdoor	
9.	Permissible un-balance current among phases	%	± 2	
10.	Crest value of Third Harmonic content in phase current when reactor is energised at rated voltage with sinusoidal waveform	%	≤ 3% of the crest Value of fundamental	
11.	Range of constant Impedance (Linearity)		Up to 1.5 p.u. voltage (However, complete saturation characteristics of the Reactors up to 2.5 p.u. Voltage shall be furnished)	
12.	Tolerance on current	%	0 to +5%	
13.	Ratio of zero sequence reactance to positive reactance (X0/X1)	Range	0.9 – 1.0	
14.	Temperature rise over 50°C Ambient Temp at rated voltage and at 245 kV			
i)	Top oil measured by thermometer	^{O}C	40	
ii)	Average winding measured by resistance method	^{O}C	45	
iii)	Winding hot spot rise	^{O}C	61	
15.	Max. design Ambient temp	^{O}C	50	
16.	Windings			
i)	Lightning Impulse withstand Voltage			
	Line end	kV_p	950	
	Neutral	kV_p	170	
ii)	Chopped Wave Lightning Impulse Withstand Voltage Line end	kV_p	1045	
iii)	Switching Impulse withstand Voltage at line end	kV_p	750	

iv)	Power Frequency withstand Voltage on Neutral		
	Line end	kVrms	395
	Neutral	kVrms	70
v)	Tan delta of windings		< 0.005
17.	Bushing		
i)	Rated voltage		
	Line end	kV	245
	Neutral end	kV	36
ii)	Rated current		
	Line end	A	1250
	Neutral end	A	800
iii)	Lightning Impulse withstand Voltage		
	Line end	kVp	1050
	Neutral end	kVp	170
iv)	Switching Impulse withstand Voltage on line end	kVp	850
v)	1 min power frequency withstand voltage (dry)		
	Line end	kVrms	505
	Neutral end	kVrms	77
vi)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
vii)	Minimum total creepage distance		(Specific Creepage Distance: of 31mm/kV corresponding to highest line to line voltage)
	Line end	mm	7595
	Neutral end	mm	1116
viii)	Partial discharge of line bushings at Um	pC	< 10
18.	Vibration and tank stress at rated voltage		Max. amplitude ≤200microns (peak to peak) Average amplitude ≤ 60microns (peak to peak) Tank stress: ≤2.0kg/sq.mm at any point of tank
19.	Max. Partial discharge level at 1.58 Ur / √3	pC	100
20.	Maximum noise level at rated voltage & frequency	dB	75

21.	**Maximum Permissible Losses of Reactor**		**25 MVAr**	**50 MVAr**
i)	Max. Total loss at rated current and frequency and at 75°C	kW	**50**	**80**
ii)	Max. I^2R Loss at rated current and frequency and at 75°C	kW	**28**	**45**

19.0 Technical Parameters of Oil filled Neutral Grounding Reactor (NGR)

S. No.	Description	Unit	Parameters
1.	Rated voltage from insulation	kV	145
2.	Connection		Between neutral of reactor and ground
3.	Cooling System		ONAN
4.	Cooling medium		Insulating oil
5.	Frequency	Hz	50
6.	No of Phases		1 (Single)
7.	Service		Outdoor
8.	Insulation		Graded
9.	Max. continuous current (rms)		10 A
10.	Rated short time current (rms)		60 A for 10 seconds
11.	Rated impedance at rated short time and continuous current		To be specified by the utility as per requirement
12.	Max. temperature rise over ambient temperature of 50°C at rated voltage		
i)	Top oil measured by thermometer	°C	45
ii)	Winding measured by resistance	°C	50
13.	Insulation level for winding		
i)	Lightning Impulse withstand Voltage		
	Line side	kV_p	550
	Ground side	kV_p	95
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	Line end	kV_p	605
iii)	One min Power Frequency withstand Voltage		
	Line side	kV_{rms}	230
	Ground side	kV_{rms}	38
14.	**Bushing**		
i)	Rated Voltage		
	Line side	kV	145
	Ground side	kV	24
ii)	Lightning Impulse withstand Voltage		
	Line side	kV_p	650
	Ground side	kV_p	125
iii)	One Minute Power Frequency withstand Voltage		
	Line side	kV_{rms}	305

	Ground side	kV_{rms}	55
iv)	Total minimum Creepage distance of bushing		31mm/kV
	Line side	mm	4495
	Ground side	mm	744
v)	Tan delta of bushing at ambient Temperature	%	≤ 0.5
15.	Method of grounding		Solidly connected between neutral of shunt reactor and earth
16.	Whether neutral is to be brought out		Yes (through 24kV bushing)

20.0 Technical Parameters of Air Core Neutral Grounding Reactor (NGR)

S. No.	Description	Unit	Parameters
1.	Rated voltage from insulation	kV	145
2.	Connection		Between neutral of reactor and ground
3.	Cooling System		AN
4.	Cooling medium		Insulating oil
5.	Frequency	Hz	50
6.	No of Phases		1 (Single)
7.	Service		Outdoor
8.	Insulation		Uniform
9.	Max. continuous current (rms)		20 A
10.	Rated short time current (rms) for 60 secs.		240A
11.	Rated mechanical short circuit current		600 A (shall be verified during design review)
12.	Rated impedance at rated short time and continuous current		To be specified by the utility as per requirement
13.	Insulation level for winding		
i)	Lightning Impulse withstand Voltage		
	Line side	kV_p	550
	Ground side	kV_p	550
ii)	Chopped Wave Lightning Impulse Withstand Voltage		
	Line end	kV_p	605
iii)	One min Power Frequency withstand Voltage		
	Line side	kVrms	230
	Ground side	kVrms	230
14.	Mounting of NGR		Pedestal insulator
i)	Type		Porcelain/Silicon Rubber
ii)	minimum Creepage distance	mm	4495
iii)	Lightning Impulse withstand Voltage	kV_p	650
iv)	One Minute Power Frequency withstand Voltage	kVrms	305
15.	Mounting structure		Non magnetic material

NOTE: ***The rating of Surge Arrester for NGR of 765kV reactor need to be decided based on proper study in view of failure of NGR.***

Annexure-B

TECHNICAL PARAMETERS OF BUSHING CURRENT TRANSFORMERS & NEUTRAL CURRENT TRANSFORMERS

1.0 Parameters of Current Transformer for 500MVA (1-ph), (765/√3)/ (400/√3)/33kV Auto-Transformers

Description	**Current Transformer Parameters**			
	HV Side	**IV Side**	**Neutral Side**	**Outdoor type Neutral Current Transformer(NCT) in common neutral side** (for each bank of three 1-ph units)
Ratio				
CORE 1	3000/1	3000/1	3000/1	3000/1
CORE 2	1500/1	3000/1	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	3000V, PX/PS	3000V, PX/PS	3000V, PX/PS	3000V, PX/PS
CORE 2	0.2S Class 20VA ISF≤5	0.2S Class 20VA ISF≤5	-	-
Maximum CT Secondary Resistance				
CORE 1	12.0 Ohm	12.0 Ohm	12.0 Ohm	12.0 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	Metering	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	20 mA	20 mA	20 mA	20 mA
CORE 2	-	-	-	-

Notes:

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

2.0 Parameters of Current Transformer for (a) 500MVA (3-ph), 400/220/33 kV; (b) 167 MVA (1-ph), (400/√3)/(220/√3)/33 kV Auto-Transformers

Description	**Current Transformer Parameters**			
	HV Side	**IV Side**	**Neutral Side**	**Outdoor type Neutral Current Transformer (NCT) in common neutral side** (for each bank of three 1-ph units)
Ratio				
CORE 1	1600/1	1600/1	1600/1	1600/1
CORE 2	1000/1	1600/1	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	1600V, PX/PS	1600V, PX/PS	1600V, PX/PS	1600V, PX/PS
CORE 2	0.2S Class 20VA ISF≤5	0.2S Class 20VA ISF≤5	-	-
Maximum CT Secondary Resistance				
CORE 1	4.0 Ohm	4.0 Ohm	4.0 Ohm	4.0 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	Metering	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	25 mA	25 mA	25 mA	25 mA
CORE 2	-	-	-	-

Notes:

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

3.0 Parameters of Current Transformer for
(a) 315 MVA(3-ph), 400/220/33kV;
(b) 105 MVA(1-ph), (400/√3)/(220/√3)/33kV
(c) 200 MVA (3-ph), 400/132/33 kV Auto-Transformers

Description	**Current Transformer Parameters**			
	HV Side	**IV Side**	**Neutral Side**	**Outdoor type Neutral Current Transformer (NCT) in common neutral side** (for each bank of three 1-ph units)
Ratio				
CORE 1	1000/1	1000/1	1000/1	1000/1
CORE 2	600/1	1000/1	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	1000V, PX/PS	1000V, PX/PS	1000V, PX/PS	1000V, PX/PS
CORE 2	0.2S Class 20VA ISF≤5	0.2S Class 20VA ISF≤5		
Maximum CT Secondary Resistance				
CORE 1	2.5 Ohm	2.5 Ohm	2.5 Ohm	2.5 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	Metering	-	-
a) Maximum magnetization current (at knee point voltage)				
CORE 1	60 mA	60 mA	60 mA	60 mA
CORE 2	-	-	-	-

Notes:

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

4.0 Parameters of Current Transformer for 315 MVA (3-ph), 400/132/33 kV Auto-Transformers

Description	Current Transformer Parameters		
	HV Side	**IV Side**	**Neutral Side**
Ratio			
CORE 1	1600/1	1600/1	1600/1
CORE 2	600/1	1600/1	-
Minimum knee point voltage or burden and accuracy class			
CORE 1	1600V, PX/PS	1600V, PX/PS	1600V, PX/PS
CORE 2	0.2S Class 20VA ISF≤5	0.2S Class 20VA ISF≤5	-
Maximum CT Secondary Resistance			
CORE 1	4.0 Ohm	4.0 Ohm	4.0 Ohm
CORE 2	-	-	-
Application			
CORE 1	Restricted Earth Fault (REF)	REF	REF
CORE 2	Metering	Metering	-
Maximum magnetization current (at knee point voltage)			
CORE 1	25 mA	25 mA	25 mA
CORE 2	-	-	-

Notes:

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

5.0 Parameters of Current Transformers for (a) 200 MVA(3-ph), 220/132 kV; (b) 160MVA(3-ph), 220/132 kV Auto-Transformers

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

Notes:

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

6.0 Parameters of Current Transformer for 160 MVA (3-Ph), 220/66 kV Transformers

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	600/1	600/1	1600/1	1600/1
CORE 2	600/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	600V, PX/PS	600V, PX/PS	1600V, PX/PS	1600V, PX/PS
CORE 2	0.2S Class 20VA ISF≤5	-	-	-
Maximum CT Secondary Resistance				
CORE 1	1.5 Ohm	1.5 Ohm	4 Ohm	4 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	25 mA	25 mA
CORE 2	-	-	-	-

Notes:

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

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

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	600/1	600/1	2000/1	2000/1
CORE 2	600/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	600V, PX/PS	600V, PX/PS	2000V, PX/PS	2000V, PX/PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	-	-
Maximum CT Secondary Resistance				
CORE 1	1.5 Ohm	1.5 Ohm	4 Ohm	4 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	25 mA	25 mA
CORE 2	-	-	-	-

Notes:

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

8.0 Parameters of Current Transformer for 80 MVA (3-ph), 132/33kV Transformers

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	400/1	400/1	1600/1	1600/1
CORE 2	400/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	400V, PX/PS	400V, PX/PS	1600V, PX/PS	1600V, PX/PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	-	
Maximum CT Secondary Resistance				
CORE 1	1.5 Ohm	1.5 Ohm	4 Ohm	4 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	25 mA	25 mA
CORE 2	-	-	-	-

Notes:

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

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

Description	Current Transformer Parameters			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
Ratio				
CORE 1	300/1	300/1	1000/1	1000/1
CORE 2	300/1	-	-	-
Minimum knee point voltage or burden and accuracy class				
CORE 1	300V, PX / PS	300V, PX/PS	1000V, PX/PS	1000V, PX/PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	-	
Maximum CT Secondary Resistance				
CORE 1	1.5 Ohm	1.5 Ohm	4 Ohm	4 Ohm
CORE 2	-	-	-	-
Application				
CORE 1	Restricted Earth Fault (REF)	REF	REF	REF
CORE 2	Metering	-	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	25 mA	25 mA
CORE 2	-	-	-	-

Notes:

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

10.0 Parameters of Current Transformers for, 80 MVAR (1-ph) & 110 MVAR (1-ph), 765 kV Shunt Reactors

Description	**Current Transformer Parameters**	
	Line Side	Neutral Side
Ratio		
CORE 1	300/1A	To be decided by manufacturer for WTI
CORE 2	300/1A	3000-2000-500/1A
CORE 3	300/1A	3000-2000-500/1A
CORE 4	300/1A	300/1A
Minimum knee point voltage or burden and accuracy class		
CORE 1	300V, PX/PS Class	Suitable for WTI
CORE 2	300V, PX/PS Class	3000V, PX/PS Class
CORE 3	300V, PX/PS Class	3000V, PX/PS Class
CORE 4	10VA, Class 1.0	300V, PX/PS Class
Maximum CT Secondary Resistance		
CORE 1	1 Ohm	-
CORE 2	1 Ohm	12-8-2 Ohm
CORE 3	1 Ohm	12-8-2 Ohm
CORE 4	-	1 Ohm
Application		
CORE 1	Reactor Differential	Winding Temperature Indicator
CORE 2	Restricted earth fault	Line Protection (Main-I)/T zone differential Protection/spare
CORE 3	Reactor Backup	Line Protection (Main-I)/T zone differential Protection/spare
CORE 4	Metering	Reactor Differential

Technical Parameters of Neutral Current Transformer (NCT) for Common Neutral Side (for each bank of three 1-phase units) & NGR

(a)	Ratio	300/1 A
(b)	Minimum knee point voltage	300 V
(c)	Accuracy class	PX / PS
(d)	Maximum CT Resistance	1 Ohms
(e)	Application	Earth fault protection
(f)	Maximum magnetization current at $V_k/4$ (V_k= knee-point voltage)	40 mA

Notes:

1. The secondary excitation current of Class PX/PS shall not be more than 4% of rated secondary current at 25% of knee point voltage.
2. For PX/PS Class CTs, dimension parameter "K", secondary VA shall be considered 1.5 and 20 respectively.
3. Rated continuous thermal current rating shall be 200% of rated primary current.
4. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
5. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
6. In case of 1-phase reactor, common Neutral side shall be out door type.

11.0 Technical Parameters of Current Transformers for 125 MVAR (3-ph), 80 MVAR (3-ph) & 63 MVAR (3-ph), 420 kV Shunt Reactor & Neutral Grounding Reactor (NGR)

Description	**Shunt Reactor**			NGR
	Line Side	Neutral Side	Common Neutral side	Earth Side
Ratio				
CORE 1	200/1A	200/1A	200/1	200/1A
CORE 2	200/1A	To be decided by manufacturer for WTI		-
CORE 3	200/1A	3000-2000-500/1A		-
CORE 4	200/1A	3000-2000-500/1A		-
Minimum knee point voltage or burden and accuracy class				
CORE 1	200V, PX/PS Class	200V, PX/PS Class	200V, PX/PS Class	200V, PX/PS Class
CORE 2	200V, PX/PS Class	To be decided by manufacturer for WTI		-
CORE 3	200V, PX/PS Class	3000-2000-500V, PX/PS Class		-
CORE 4	10VA, Class 1.0	3000-2000-500V, PX/PS Class		-
Maximum CT Secondary Resistance				
CORE 1	1 Ohm	1 Ohm	1 Ohm	1 Ohm
CORE 2	1 Ohm	-	-	-
CORE 3	1 Ohm	15-10-2.5 Ohm	-	-
CORE 4	-	15-10-2.5 Ohm	-	-
Exciting current (max.) @$V_k/4$				
CORE 1	250mA	250mA		-
CORE 2	250mA	-		-
CORE 3	250mA	20mA @3000/1 30mA @ 2000/1 120mA @ 500/1		-

CORE 4	-	20mA @3000/1 30mA @ 2000/1 120mA @ 500/1		-
Application				
CORE 1	Reactor Differential	Reactor Differential	-	REF
CORE 2	REF	Temperature Indicator (on one phase only)	-	-
CORE 3	Reactor Backup	Line Protection (Main-I)/T-zone differential Protection/spare	-	-
CORE 4	Metering	Line Protection (Main-II)/T-zone differential Protection/spare	-	-

Notes:

1. For PX/PS Class CTs, dimension parameter "K", secondary VA shall be considered 1.5 and 20 respectively.
2. Rated continuous thermal current rating shall be 200% of rated primary current.
3. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
4. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
5. In case of 1-phase reactor, common Neutral side shall be out door type.

12.0 Technical Parameters of Current Transformers for 25 MVAR (3-ph), 50 MVAR (3-ph), 245 kV Shunt Reactor

Description	**Shunt Reactor** NGR		
	Line Side	Neutral Side	Common Neutral Side
Ratio			
CORE 1	200/1A	200/1A	200/1
CORE 2	200/1A	200/1	-
CORE 3	200/1A	200/1A	-
CORE 4	-	To be decided by manufacturer for WTI	-
Minimum knee point voltage or burden and accuracy class			
CORE 1	200V, PX/PS Class	10VA, Class 1.0	200V, PX/PS Class
CORE 2	200V, PX/PS Class	200V, PX/PS Class	-
CORE 3	200V, PX/PS Class	200V, PX/PS Class	-
CORE 4		To be decided by manufacturer for WTI	-
Maximum CT Secondary Resistance			
CORE 1	1 Ohm	-	1 Ohm
CORE 2	1 Ohm	1 Ohm	-
CORE 3	1 Ohm	1 Ohm	-
CORE 4	-	-	-
Exciting current (max.) @$V_k/4$			
CORE 1	60mA	-	60mA
CORE 2	60mA	60mA	-
CORE 3	60mA	60mA	-
CORE 4	-	-	-
Application			
CORE 1	Reactor Differential	Metering	Restricted earth fault
CORE 2	Restricted earth fault	Restricted earth fault	-

CORE 3	Reactor Impedance Protection	Differential Protection	-
CORE 4	-	Winding Temperature Indication (on one phase only)	-

Notes:

1. For PX/PS Class CTs, dimension parameter "K", secondary VA shall be considered 1.5 and 20 respectively.
2. Rated continuous thermal current rating shall be 200% of rated primary current.
3. Parameters of WTI CT for each winding shall be provided by the manufacturer / contractor.
4. The CTs used for REF protection must have the identical parameters in order to limit the circulating current under normal condition for stability of protection.
5. In case of 1-phase reactor, common Neutral side shall be out door type.

Annexure-C

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

A. GENERAL

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	General Information i) Supplier ii) Name of Manufacturer iii) Place of Manufacture (Country & City) iv) Type of transformer (Core/Shell)			
2.	Applications i) Indoor/Outdoor ii) 2wdg/3wdg/Auto iii) GT/Step-down/ICT/Station Start-up/ Auxiliary/ Rail Trackside Supply			
3.	Corrosion Level at Site i) Light ii) Medium iii) Heavy iv) Very Heavy			
4.	Site altitude above mean sea level	m		--
5.	Seismic zone and ground acceleration at site (both in horizontal & vertical direction)			--

6.	Maximum and minimum ambient temperature at site			
7.	Applicable Standards i) IEC: 60076 ii) IS : 2026 iii) Any other, please specify			
8.	Rated Capcity / Full load rating (HV/IV/LV)	MVA		
9.	3-Phase/Bank of Three Single Phase (A,B,C)			
10.	Rated No Load Voltages (HV/IV/LV)	kV		
11.	Currents at normal tap (HV/IV/LV)	Amp		
12.	Rated Frequency	Hz		
13.	Connections and phase displacement symbols (Vector Group)			
14.	Weight Schedules (Minimum with no negative tolerance)			
	i) Active part (Core + coil)	kg		
	ii) Insulating Oil (excluding mass of extra oil)	kg		
	iii) Tank and Fittings	kg		
	iii) Total weight	kg		
	iv) Transportaion Weight	kg		
	v) Overall dimensions L x B x H	mm		
	vi) Size of heaviest package L x B x H	mm		
	vii) Weight of heaviest package	kg		
	viii) Weight of 5% extra oil	kg		
	ix) Weight of core	Kg		
	x) Weight of copper (HV/IV/LV/ Regulating)	kg		

	xi) Insulating Oil volume (excluding 5% extra oil)	Ltrs		
	xii) Quantity of oil in OLTC	Ltrs		
15.	Transport limitation			
16.	LV Winding i) Stabilizing tertiary (Yes/No) ii) Loaded (Yes/No)			
17.	Tappings i)Type (OLTC/OCTC) and make of tap changer ii)Position of Tapping on the winding iii)Variation on iv)Range of variation v)No. of Steps vi) Whether control suitable for : • Remote/local operation • Auto/manual operation vi)Parallel Operation Requirements	 % 		
18.	Impedance and Losses			
	i) Guaranteed No load loss at rated voltage and frequency	kW		
	Tolerance (to be considered for loss evaluation)	%		
	ii) Guranteed I^2R Loss at rated current & frequency (at 75^0C) at principal tap	kW		
	Tolerance (to be considered for loss evaluation)	%		
	iii) Eddy current and stray loss at rated current & frequency (at 75^0C) at principal tap	kW		
	iv) Load Loss(I^2R+Eddy and Stray) at rated current & frequency (at 75^0C) at principal tap	kW		

	v) Guaranteed Auxiliary loss at rated voltage and frequency	kW		
	Tolerance (to be considered for loss evaluation)	%		
	vi) Calculated Fan Loss	kW		
	vii) Calculated Pump Loss	kW		
	viii) Air core reactance of HV winding	%		
	ix) Guaranteed Impedance (at Highest MVA base)	%		
	(a) HV-IV (at Pricipal tap) (b) HV-LV(at Pricipal tap) (c) IV-LV(at Pricipal tap)			
	Tolerance			
	x) Impedance at extreme tappings at Highest MVA base [for HV-IV for 3 winding transformer (or) HV-LV for two winding transformer] a) Max. Voltage tap b) Min. Voltage tap	%		
	Tolerance	%		
	xi) Zero sequence impedance at principal tap (for 3-phase transformers)			
19.	Capacitance to earth for HV/IV/LV	pF		
20.	Regulation at full load at 75 ^{0}C winding temperature at: a) upf b) 0.8 pf			
21.	Guaranteed maximum Magnetizing Current at rated Voltage	%		

22.	Efficiency : At 100% load upf 0.8 lead 0.8 lag At 75% load upf 0.8 lead 0.8 lag At 50% load upf 0.8 lead 0.8 lag	%		
23.	Load at Maximum efficiency	%		
24.	Any limitations in carrying out the required test? If Yes, State limitations			
25.	Fault level of system (in kA) and its duration (in sec)	kA (sec)		
26.	Calculated short Circuit current (in kA) withstand capability for 2 seconds (3 seconds for generator transformers) without exceeding temperature limit (i.e. Thermal ability to withstand SC current)	kA		
27.	Test current (in kA) and duration (in ms) for short Circuit current test (i.e. Dynamic ability to withstand SC)	kA & msec		
28.	Over fluxing withstand time (due to combined voltage & frequency fluctuations): 110% 125% 140% 150% 170%	msec		
29.	Free space required above the tank top for removal of core			
30.	Maximum Partial discharge level at 1.58 Ur/√3	pC		

B. MAGNETIC SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufa-cturer
1.	Core Type: i) 3 Phase 3 Limb (3 wound limbs) ii) 3 Phase 5 Limb (3 wound limbs) iii) 1 Phase 2 Limb (2 wound limbs) iv) 1 Phase 3 Limb (1 wound limb) v) 1 Phase 4 Limb (2 wound limbs) vi) 1 Phase 5 Limb (3 wound Limbs)			
2.	Type of Core Joint: i) Mitred ii) Step Lap			
3.	CRGO : i) Make & Country of Origin ii) Thickness, mm iii) Max. Specific loss at 1.7 T, 50Hz, in Watts/kg iv) Grade of core as per BIS v) Insulation between core lamination vi) BIS certified (Yes/No)			
4.	Minimum Gross & Net Area of: i) Core ii) Limb iii) Yoke iv) Unwound limb (May be verified during manufacturing stage – at the discretion of buyer)	cm^2		
5.	Stacking Factor	%		
6.	Voltage per turn	V		

7.	Apparent Core Density for Weight Calculation			
8.	Minimum Net Weight of Silicon Steel Lamination CRGO (may be verified during manufacturing stage by calculation)	kg		
9.	Maximum Flux density at 90%, 100% and 110% voltage and frequency (may be verified during manufacturing stage by calculation)	T		
10.	W/kg at working flux density			
11.	Building Factor Considered			
12.	Calculated No Load Loss at rated voltage and Frequency (Net Weight x W/kg x Building factor)	kW		
13.	Magnetizing inrush current	Amp		
14.	No load current at normal ratio and frequency for : 85% of rated voltage 100% of rated voltage 105% of rated voltage	Amp		
15.	Core Isolation test	kV		
16.	Core bolt in limb / yoke	Yes/No		
17.	Core bolt insulation withstand voltage for one minute	kV		
18.	Maximum temperature rise of any part of core or its support structure in contact with oil	^{0}C		

C. CONDUCTING SYSTEM

Sl. No.	**Description**	**Unit**	**Offered by manufacturer**			
			HV	**IV**	**LV**	**Regulating**
1.	Type of Winding Helical/Disc/Layer/inter wound					

2.	Type of Conductor PICC/CTC/CTCE/CTCEN/BPICC					
3.	Minimum Yield Strength of Conductor for 0.2% elongation	N/mm^2				
4.	Maximum Current density at CMR and conductor area at any tap: i) HV ii) IV iii) LV	A/mm^2 & sq. mm				
5.	Maximum current density under short circuit: i) HV ii) IV iii)LV	A/mm^2				
6.	Bare Weight of copper without paper insulation and lead (Minimum)	Kg				
7.	Per Phase Maximum resistance of winding at rated tap at 75 ^{O}C	ohm				
8.	Number of Turns/Phase					
9.	Insulating material used for HV/IV/LV winding					
10.	Insulating material used between : i) HV and IV winding ii) IV and LV winding iii) LV winding and core iv) Regulating winding and adjacent winding/core					
11.	Details of special arrangement provided to improve surge voltage distribution in the winding					

12.	Dielectric Shielding used: i) Interleaved winding ii) Wound in Shield iii) Others					
13.	Magnetic Shielding used: i) Yoke Shunt on core clamp ii) Magnetic shunt on tank iii) Electromagnetic (Copper/Aluminum) shield on tank iv) Others					
14.	Noise level when energized at normal voltage and frequency without load	dB				

D. COOLING SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	Type of Cooling [ONAN (or) ONAN/ONAF (or) ONAN / ONAF / OFAF (or) ONAN / ONAF/ ODAF (or) ONAN / ONAF1 / ONAF2 etc.]			
2.	Percentage Rating Corresponding to Cooling Stages (HV/IV/LV)			
3.	No. of Cooler banks (2x50% / 2x100% / 1x100% etc.)			
4.	Temperature gradient between windings and oil			
5.	Time in minutes for which the transformer can run at full load without exceeding maximum permissible temperature at reference ambient temperature when supply to fans and / or pumps is cut off	min		

6.	Guaranteed Maximum Temperature rise at 1000 mts. altitude and at actual altitude at site at ambient temperature at cooling specified at sl. No. 1: i) Top Oil by thermometer ii) Average Winding by resistance iii) Winding hot spot	^{0}C		
7.	Type of Cooler: i) Radiator Bank ii) Oil to Air Heat Exchanger (Unit Cooler) iii) Oil to Water Cooler (Single Tube) iv) Oil to Water Cooler (Double Tube) v) Tank Mounted vi) Header Mounted vii) Separately Mounted viii) Degree of Protection of terminal box			
8.	Cooling Fans: i) Type ii) Size iii) Rating (kW) iv) Supply voltage v) Quantity (Running + Standby) per cooler bank vi) Whether fans are suitable for continuous operation at 85% of their rated voltage calculated time constant: • natural cooling • forced air cooling vii) Degree of Protection of terminal box			

9.	Oil Pumps: i) Type ii) Size iii) Rating (lpm and kW) iv) Supply voltage v) Quantity (Running + Standby) per cooler bank vi) Efficiency of motor at full load vii) Temperature rise of motor at full load viii) BHP of driven equipment			
10.	Coolers (Oil to Air): i) Quantity (Running + Standby) ii) Type and Rating			
11.	Coolers (Oil to Water): i) Quantity (Running + Standby) ii) Type and Rating iii) Oil flow rate (lpm) iv) Water flow rate (lpm) v) Nominal Cooling rate (kW) vi) Material of tube			
12.	Radiators: i) Width of elements (mm) ii) Thickness (mm) iii) Length (mm) iv) Numbers			
13.	Cooler loss at rated output, normal ratio, rated voltage, rated frequency at ambient temperature of 50°C	kW		

E. DIELECTRIC SYSTEM

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

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

F. ACCESSORIES

Sl. No.	Description	Unit	Offered by manufacturer	Specified by Buyer
1.	Tap Changers			
	i) Control a-Manual b-Automatic c-Remote d-Local			
	ii) Voltage Class and Current Rating of Tap Changers			
	iii) Make and Model			
	iv) Make and Type of Automatic Voltage Regulator (AVR)			
	v) Tie-in resistor requirement (to limit the recovery voltage to a safe value) and its value			
	vi) OLTC control and monitoring to be carried out through Substation Automation System	Y/N		
	vii) Power Supply for control motor (No. of Phases/Voltage/Frequency)			
	viii) Rated Voltage for control circuit (No. of Phases/Voltage/Frequency)	V		
2.	Tank			
	i) Tank Cover: Conventional/Bell/Bottom Plate			
	ii) Material of plate for tank			

	iii) Plate thickness : side, bottom, cover	mm						
	iv) Rail Gauge	mm						
	v) Minimum Clearance height from rail for lifting Active Part	mm						
	vi) Wheels : Numbers/Plane/Flanged/Uni-Directional/Bi-Directional/Locking Details							
	vii) Vacuum withstand Capability (a) Tank (b) Radiators/Conservator/Accessories	mm of Hg						
	viii) High Pressure withstand Capability (a) Tank (b) Radiators/Conservator/Accessories	mm of Hg						
	ix) Radiator fins/ conservator plate thickness	mm						
	x) Tank Hot spot temperature	^{o} C						
3.	Bushings:		HV	IV	LV	HV-N LV-N		
	i) Termination Type a-Outdoor b-Cable Box (oil/Air/SF_6) c-Plug in Type							
	ii) Type of Bushing: OIP/RIP/RIS/oil communicating							
	iii) Bushing housing - Porcelain / polymer							
	iv) Rated Voltage Class	kV						
	v) Rated Current	A						
	vi) Lightning Impulse withstand voltage (1.2/50µs)	kV_p						

	vii) Switching Impulse withstand voltage (250/2500µs)	kV_p					
	viii) One minute Power frequency withstand voltage (dry & wet)	kV_{rms}					
	ix) Minimum Creepage Distance	mm					
	x) Quantity of oil in bushing and specification of oil used						
	xi) Make and Model						
	xii) Tan delta of bushings	%					
	xiii) Max Partial discharge level at Um	pC					
	xiv) Terminal Pad details						
	xv) Weight of assembled bushings	kg					
	xvi) Whether terminal connector for all bushings included in the scope of supply						
4.	Minimum clearances between bushings (for HV, IV and LV) (a) Phase to phase (b) Phase to ground						
5.	Indicator / Relay						
	i) Winding temperature thermometer/ indicator: Range Accuracy						
	ii) Oil temperature thermometer/ indicator: Range Accuracy						
	iii) Temperature sensors by fiber optic (if provided)						
	iv) Oil actuated/gas operated relay						

	v) Oil level Indicators: Main Conservator OLTC Conservator			
	vi) Oil Sight Window: Main Tank Main Conservator OLTC Conservator			
6.	Conservator: i) Total volume ii) Volume between highest and lowest visible oil levels			
7.	Conservator Bag (air cell) i) Material of air cell ii) Continuous temperature withstand capacity of air cell			
8.	Air cell rupture relay provided	Yes / No		
9.	Pressure Relief Device: i) Number of PRDs provided ii) Location on the tank iii) Operating pressure of relief device			
10.	Sudden Pressure Relay / Rapid Pressure rise relay provided; if yes, i) Location on the tank ii) Operating pressure	Y/N		
11.	Dehydrating Breathers(Type & No. of breathers) (a) For main Conservator tank (b) For OLTC conservator			
12.	Flow sensitive Conservator Isolation Vlave Provided	Y/N		
13.	Tap Changer protective device			
14.	Type and material of gaskets used at gasketed joints			

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

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

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

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

A. GENERAL

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	General Information i) Supplier ii) Name of Manufacturer iii) Place of Manufacture (Country & City) iv) Type of Reactor (Shunt reactor/ Bus reactor) v) Type of NGR (oil filled/air core)			
2.	Applications (Indoor/Outdoor)			
3.	Corrosion Level at Site i) Light ii) Medium iii) Heavy iv) Very Heavy			
4.	Site altitude above mean sea level	m		
5.	Seismic zone and ground acceleration at site (both in horizontal & vertical direction)			
6.	Maximum and minimum ambient temperature at site			
7.	Applicable Standards (IEC: 60076/IS : 2026/Any other, please specify)			
8.	Rated Capcity / Power	MVAR		
9.	Single Phase / 3-Phase			
10.	Rated Voltages	kV		
11.	Maximum Operating Voltage	kV		
12.	Rated Current	Amp		
13.	Rated Continuous current (For NGR)	Amp		

14.	Rated short time current (10 sec / 60 sec) (For NGR)	Amp		
15.	Permissible unbalance current among phases	%		
16.	Crest value of third harmonic content in phase current at rated voltage with sinusoidal wave form	%		
17.	Vibration and tank stress at rated voltage			
18.	Rated Frequency	Hz		
19.	Winding Connection			
20.	Weight Schedules (Minimum with no negative tolerance)			
	i) Active part (Core + coil)	kg		
	ii) Insulating Oil (excluding mass of extra oil)	kg		
	iii) Tank and Fittings	kg		
	iv) Total weight	kg		
	v) Transportaion Weight	kg		
	vi) Overall dimensions L x B x H	mm		
	vii) Size of heaviest package L x B x H	mm		
	viii) Weight of heaviest package	kg		
	ix) Weight of 5% extra oil	kg		
	x) Weight of core	Kg		
	xi) Weight of copper	kg		
	xii) Insulating Oil volume (excluding 5% extra oil)	Ltrs		
21.	Transport limitation			
22.	Impedance and Losses			
	i) Guaranteed Max. Total loss at rated current and frequency (at 75^0C)	kW		
	Tolerance	%		
	ii) Guranteed I2R Loss at rated current & frequency (at 750C)	kW		

	iii) Tolerance	%		
	iv) Reactance at rated voltage & frequency	ohms		
	v) Range of constant impedance			
	vi) Ratio of zero sequence reactance to positive reactance (X0/X1)			
23.	Any limitations in carrying out the required test? If Yes, State limitations			
24.	Over voltage withstand time (without exceeding winding hotspot temperature of 140^0C): 105% (foe 420 kV and above reactor) 110% (for 245 kV reactor) 125% 150%	msec		
25.	Maximum partial discharge level at 1.58Ur/√3			
26.	Free space required above the tank top for removal of core	mm		

B. MAGNETIC SYSTEM

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

2.	Type of Core Joint: i) Mitred ii) Step Lap			
3.	Gapped core	Yes/No		
4.	CRGO : i) Make & Country of Origin ii) Thickness, mm iii) Max. Specific loss at 1.7 T, 50Hz, in Watts/kg iv) Grade of core as per BIS v) Insulation between core lamination vi) BIS certified (Yes/No)			
5.	Minimum Gross Area of: i) Core ii) Limb iii) Yoke iv) Unwound limb (May be verified during manufacturing stage – at the discretion of buyer)	cm^2		
6.	Stacking Factor	%		
7.	Voltage per turn	V		
8.	Apparent Core Density for Weight Calculation			
9.	Minimum Net Weight of Silicon Steel Lamination CRGO (may be verified during manufacturing stage by calculation)	kg		
10.	W/kg at working flux density			
11.	Building Factor Considered			
12.	Magnetizing inrush current	Amp		
13.	Core Isolation test	kV		
14.	Core bolt in limb / yoke	Yes/No		

15.	Core bolt insulation withstand voltage for one minute	kV		
16.	Maximum temperature rise of any part of core or its support structure in contact with oil	^{0}C		

C. CONDUCTING SYSTEM

Sl. No.	**Description**	**Unit**	**Offered by manufacturer**
1.	Type of Winding Helical/Disc/Layer/inter wound		
2.	Type of Conductor PICC/CTC/CTCE/CTCEN/BPICC		
3.	Minimum Yield Strength of Conductor for 0.2% elongation	N/mm^2	
4.	Maximum Current density at CMR and conductor area:	A/mm^2 & sq. mm	
5.	Maximum current density under short circuit	A/mm^2	
6.	Bare Weight of copper without paper insulation and lead (Minimum)	Kg	
7.	Per Phase Maximum resistance of winding at rated tap at 75 ^{O}C	ohm	
8.	Number of Turns/Phase		
9.	Insulating material used for winding		
10.	Insulating material used between winding and core		
11.	Details of special arrangement provided to improve surge voltage distribution in the winding		

12.	Dielectric Shielding used: i) Interleaved winding ii) Wound in Shield iii) Others		
13.	Magnetic Shielding used: i) Yoke Shunt on core clamp ii) Magnetic shunt on tank iii) Electromagnetic shield on tank (Copper/Aluminum) iv) Others		
14.	Noise level when energized at normal voltage and frequency without load	dB	
15.	Vibration level		

D. COOLING SYSTEM

Sl. No.	Description	Unit	Specified by Buyer	Offered by manufacturer
1.	Type of Cooling			
2.	No. of Cooler banks (2x50% / 2x100% / 1x100% etc.)			
3.	Temperature gradient between windings and oil			
4.	Guaranteed Maximum Temperature rise at 1000 mts. altitude and at actual altitude at site at ambient temperature for cooling specified at sl. No. 1: i) Top Oil by thermometer ii) Average Winding by resistance iii) Winding hot spot	^{0}C		
5.	Type of Cooler			

6.	Radiators: i) Width of elements (mm) ii) Thickness (mm) iii) Length (mm) iv) Numbers			

E. DIELECTRIC SYSTEM

Sl. No.	Description	Unit	Offered by manufacturer	
1	Insulation Levels of windings		HV end	Neutral end / ground end
	i) Lightning Impulse withstand voltage (1.2/50µs)	kV_p		
	ii) Chopped wave Lightning Impulse withstand voltage	kV_p		
	iii) Switching Impulse withstand voltage (250/2500µs)	kV_p		
	iv) Power frequency withstand voltage (one minute / 5 minutes)	kV_{rms}		
2	Tan delta of windings at ambient Temperature	%		

F. ACCESSORIES

Sl. No.	Description	Unit	Offered by manufacturer	Specified by Buyer
1.	Tank			

	i) Tank Cover: Conventional/Bell/Bottom Plate				
	ii) Material of plate for tank				
	iii) Plate thickness : side, bottom, cover	mm			
	iv) Rail Gauge	mm			
	v) Minimum Clearance height from rail for lifting Active Part	mm			
	vi) Wheels : Numbers/Plane/Flanged/Uni-Directional/Bi-Directional/Locking Details				
	vii) Vacuum withstand Capability (a) Tank (b) Radiators/Conservator/Accessories	mm of Hg			
	viii) High Pressure withstand Capability (a) Tank (b) Radiators/Conservator/Accessories	mm of Hg			
	ix) Radiator fins / conservator plate thickness	mm			
	x) Tank Hot spot temperature	^{o}C			
	xi) Tank suitable for plinth mounting	Yes/No			
2.	Bushings:		HV side	Neutral end / ground end	
	i) Termination Type a-Outdoor b-Cable Box (oil/Air/SF_6) c-Plug in Type				
	ii) Type of Bushing: OIP/RIP/RIS/oil communicating				

	iii) Bushing housing - Porcelain / polymer				
	iv) Rated Voltage Class	kV			
	v) Rated Current	A			
	vi) Lightning Impulse withstand voltage (1.2/50µs)	kV_p			
	vii) Switching Impulse withstand voltage (250/2500µs)	kV_p			
	v) One minute Power frequency withstand voltage (dry & wet)	kV_{rms}			
	viii) Minimum Creepage Distance	mm			
	ix) Quantity of oil in bushing and specification of oil used				
	x) Make and Model				
	xi) Tan delta of bushings				
	xii) Terminal Pad details				
	xiii) Weight of assembled bushings	kg			
	xiv) Whether terminal connector for all bushings included in the scope of supply				
	xv) Max Partial discharge level at U_m	pC			
3.	Minimum clearances between bushings (a) Phase to phase (b) Phase to ground				
4.	Indicator / Relay				
	i) Winding temperature thermometer/ indicator: Range Accuracy				

	ii) Oil temperature thermometer/ indicator: Range Accuracy			
	iii) Temperature sensors by fiber optic (if provided)			
	iv) Oil actuated/gas operated relay			
	v) Oil level Indicators:			
	vi) Oil Sight Window:			
5.	Conservator: i) Total volume ii) Volume between highest and lowest visible oil levels			
6.	Conservator Bag (air cell) i) Material of air cell ii) Continuous temperature withstand capacity of air cell			
7.	Air cell rupture relay provided	Yes / No		
8.	Pressure Relief Device: i) Number of PRDs provided ii) Location on tank iii) Operating pressure of relief device			
9.	Sudden Pressure Relay / Rapid Pressure rise relay provided; if yes, i) Location on the tank ii) Operating pressure	Y/N		
10.	Dehydrating Breathers(Type & No. of breathers)			
11.	Flow sensitive Conservator Isolation Vlave Provided	Y/N		
12.	Sudden Pressure Relay / Rapid Pressure rise relay provided	Y/N		

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

	viii) Tan delta (Dielectric Dissipation Factor) at 90oC ix) Resistivity (Ω-cm)) x) Breakdown Voltage (before and after treatment) (kV) xi) Interfacial tension at 20 oC (N/m) xii) Pour point (oC) xiii) Flash point(oC) xiv) Acidity (mg KOH/gm) xv) Inhibitors (for inhibited oil) (%) xvi) Oxidation Stability			
17.	Press Board: i) Make ii) type			
18.	Conductor Insulating Paper i) Kraft paper ii) Thermally upgraded Kraft paper iii) Nomex			
19.	Provision for fire protection system (as per spec), if yes, provide details	Y/N		
20.	Insulation of core bolts, washers, end plates etc.			
21.	Weights and Dimensions: i) Weights: a. Core b. Windings c. Tank d. Fittings e. Oil f. Total weights of complete transformers with oil and fittings ii) Dimensions;			

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

Annexure-D

TEST PLAN AND PROCEDURES

Tests for Transformers

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

		Um≤170 kV)	
12.	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
13.	Lightning impulse test for the neutral terminals (LIN)	Type	Type
14.	Switching impulse test for the line terminal (SI) (Not applicable for Um≤72.5 kV)	Type	Routine
15.	Applied voltage test (AV)	Routine	Routine
16.	Line terminal AC withstand voltage test (LTAC) (Not applicable for Um≤72.5 kV)	Routine	Type
17.	Induced voltage withstand test (IVW)	Routine	-
18.	Induced voltage test with PD measurement (IVPD)	Routine*	Routine
19.	Measurement of transferred surge on Tertiary due to HV lightning impulse and IV lighting impulse	–	Type
20.	Measurement of transferred surge on Tertiary due to HV Switching impulse and IV Switching impulse	-	Type
21.	Test on On-load tap changer (Tap changer fully assembled on the transformer)	Routine	Routine
22.	Measurement of dissolved gasses in dielectric liquid	Routine	Routine
23.	Check of core and frame insulation	Routine	Routine
24.	Leak testing with pressure for liquid immersed transformers (tightness test)	Routine	Routine
25.	Appearance, construction and dimension check	Routine	Routine
26.	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.	Routine	Routine
27.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine	Routine
28.	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine	Routine
29.	Tank vacuum test	Routine	Routine
30.	Tank pressure test	Routine	Routine
31.	Check of the ratio and polarity of built-in current transformers	Routine	Routine

32.	Temperature rise test	Type	Type
33.	Overload testing in short-circuit method (applicable for 765 kV transformer only)	-	Type
34.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)	Routine	Routine
35.	Over excitation test (applicable for 765 kV transformer only)	-	Routine
36.	Measurement of Zero seq. reactance (for three phase Transformer only)	Type	Type
37.	Measurement of harmonic level in no load current	Type	Type
38.	Determination of acoustic sound level	Type	Type
39.	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)	Type	Type
40.	Dynamic Short circuit withstand test	as specified in the specification	

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

Tests for Reactors

S. No.	Test	Test Category
1.	Measurement of winding resistance	Routine
2.	Reactance and loss measurement (Measured in Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units)	Routine
3.	Measurement of insulation resistance & Polarization Index	Routine
4.	Measurement of insulation power factor and capacitance between winding and earth	Routine
5.	Measurement of insulation power factor and capacitance of bushings	Routine
6.	Tan delta of bushing at variable frequency (Frequency Domain Spectroscopy)	Routine
7.	Core assembly dielectric and earthing continuity test	Routine
8.	High voltage with stand test on auxiliary equipment and wiring after assembly	Routine
9.	Chopped wave lightning impulse test for the line terminals (LIC)	Routine
10.	Lightning impulse test on Neutral (LIN)	Routine
11.	Switching impulse test	Routine
12.	Separate source voltage withstand test	Routine
13.	Short time over voltage Test (830kVrms) (applicable for 765 kV Reactor only)	Routine
14.	Induced over voltage test with Partial Discharge measurement (IVPD)	Routine
15.	Measurement of dissolved gasses in dielectric liquid	Routine
16.	2-Hour excitation test except type tested unit	Routine
17.	Vibration & stress measurement at Um/√3 level Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units. (Measurement shall also be carried out at 1.05Um/√3 level for reference purpose)	Routine
18.	Temperature rise test	Type
19.	Measurement of harmonic content of current (Measured in Cold state)	Type
20	Measurement of acoustic sound/noise level (Measured in Cold and Hot state of temperature rise test)	Type

21.	Knee point voltage measurement of reactor (Measured in Cold and Hot state of temperature rise test)	Type
22.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine
23.	Oil leakage test on Reactor tank	Routine
24.	Appearance, construction and dimension check	Routine
25.	Measurement of mutual reactance on 3-phase reactor	Routine
26.	Measurement of zero-sequence reactance on 3-phase reactor	Routine
27.	Tank vacuum test	Routine
28.	Tank pressure test	Routine

Tests for Oil Filled Neutral grounding Reactors (NGR) (as applicable)

1.	Measurement of winding resistance	Routine
2.	Measurement of Impedance at rated continuous current	Routine
3.	Measurement of insulation resistance	Routine
4.	Measurement of Capacitance & Tan delta of winding insulation to earth and bushing	Routine
5.	Lightning impulse test	Routine
6.	Separate source voltage withstand test	Routine
7.	Isolation Test	Routine
8.	Oil leakage test	Routine
9.	Appearance, construction and dimension check	Routine
10.	High voltage with stand test on auxiliary equipment and wiring after assembly	Routine
11.	Tank vacuum test	Routine
12.	Tank pressure test	Routine
13.	Temperature rise test	Type Test
14.	Measurement of vibration at rated continuous current	Routine
15.	Measurement of loss	Routine
16.	Short time current test and measurement of impedance at short time current	Type Test
17.	Measurement of acoustic sound / noise level	Type Test

Tests on Air Core NGRs (as applicable)

1.	Measurement of winding resistance	Routine
2.	Measurement of Impedance at rated continuous current	Routine
3.	Measurement of loss	Routine
4.	Lightning impulse test	Routine
5.	Appearance, construction and dimension check	Routine

Note: All routine tests (for transformer/reactor/NGR) shall be carried out on all the units and type tests mentioned in above tables shall be conducted on one unit.

Test Procedures (for Transformer)

General

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

1. Core assembly dielectric and earthing continuity test

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

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

2. Measurement of winding resistance

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

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

3. No-load loss and current measurement

As per IEC 60076-1:2011 clause 11.5

4. Measurement of short-circuit impedance and load loss

The short-circuit impedance and load loss for a pair of windings shall be measured at rated current & frequency with voltage applied to the terminals of one winding, with the terminals of the other winding short-circuited, and with possible other windings open circuited. The difference in temperature between the top and bottom liquid shall not exceed 5 K. To obtain this result

more rapidly, the liquid may be circulated by a pump. Loss measurement for all combinations (HV-IV, HV-LV, IV-LV and at Normal and extreme taps).

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

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

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

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

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

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

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

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

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

6. Over excitation test (for 765kV class trasformer)

A routine over excitation test at 1.05 p.u voltage for 12 hours shall be done on the tap position giving the highest flux. This test shall be carried out immediately after the routine short-term heat run test on the transformer. The rate of gas development during the test shall be evaluated using IEEE/IEC/CIGRE guidelines.

7. Temp. Rise Test as per IEC: 60076

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

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

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

The Contractor before carrying out such test shall submit detailed calculations showing losses on various taps and for the three types of ratings of the transformer and shall recommend the combination that results in highest temperature rise for the test.

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

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

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

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

i. Test conditions for temperature rise test:

- This test shall be generally carried out in accordance with IEC 60076-2

- For each cooling combination with cooler bank, tests shall be done on the maximum current tap for a minimum of 12 hours for ONAN/ONAF or ONAF1 and 24 hours for ODAF or OFAF or ONAF2 with saturated temperature for at least 4 hours while the appropriate power and current for core and load losses are supplied.
- The total testing time, including ONAN heating up period, steady period and winding resistance measurements is expected to be about 48 hours.
- DGA tests shall be performed before and after heat run test and DGA results shall generally conform to IEC/IEEE/CIGRE guidelines.

ii. Test records:

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

iii. General:

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

iv. Top oil temperature rise test:

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

- time
- Voltage between phases
- Current in each phase and total power
- Power in each phase and total power
- Ambient temperature
- Top oil temperature
- Cooler inlet and outlet oil temperatures
- Hot spot temperatures (make use of probes) (if applicable)

- Colour photographs of the four sides and top of the transformer together with the corresponding series of thermal images (colour) during starting of the test then after every four hours till the temperature stabilised and finally during temperature stabilised for each rating (ONAN/ONAF/OFAF or ONAN/ONAF1/ONAF2).

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

v. Winding temperature rise test

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

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

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

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

8. Overload testing in short-circuit method (for 765kV class transformer)

The test shall be carried out on the tapping position that will cause the highest current under normal conditions. Hot spot temperature measurement shall be done by using temperature probes or sensors in approved locations.
The transformer shall be fully erected as for service with all cooling equipment.

i. Testing option 1:

Pre-load the unit with 100% of full load current for a period long enough to stabilise the top oil temperature with cooling as for service conditions.

- Increase the loading to 120% overload rating. Forced cooling shall be activated as per service conditions.
- Scan and record infra-red images of all four sides and the top of the transformer at the interval of every one hour.
- Hold the overload current for a period of 4 hours.
- Measure and record the hotspot temperatures.

ii. **Testing option 2**:

Pre-load the unit with 100% of full load current for a period long enough to stabilise the top oil temperature with 100% cooling as per service conditions.

- Increase the loading to 130% overload rating.
- Scan and record infra-red images of all four sides and the top of the transformer every 30 minutes.
- Hold the current at 130% for a period of 2 hours.
- Measure and record the hotspot temperature.

iii. Acceptance criteria:

Winding hotspot temperatures shall not exceed 130°C for option 1 and 135 °C for option 2.

The temperature rise recorded by infra-red shall be not more than 10°K above top oil temperature or 15°K above the local oil temperature.

The rate of gas development as determined from oil samples shall be determined. Samples shall be taken before and after the test and acceptance criteria shall be in accordance with IEC/IEEE guidelines.

iv. Test records:

Full details of the test arrangements, procedures and conditions shall be supplied with the test certificates and shall include the following:

- Purchaser's reference number and site designation
- Manufacturer's name and transformer serial number
- MVA rating and voltage ratio
- Vector group
- Altitude of test bay
- Designation of terminals supplied and terminals strapped
- Colour photographs of the four sides and top of the transformer.

v. Overload test:

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

- time
- voltage between phases
- current in each phase
- power in each phase and total power
- ambient temperature
- top oil temperature
- cooler inlet and outlet temperatures
- average winding temperatures
- hot spot temperatures (make use of probes)

Notes:
Measurement methods for hot spots, their location and the number of sensors shall be agreed with Purchaser prior to the test. The probes may be left in position provided the reliability and integrity of the unit will not be jeopardized during its long life expectancy.

9. Dielectric Tests

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

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

10. Measurement of transferred surge on LV or Tertiary due to HV & IV Lightning impulse

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

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

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

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

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

Acceptance criteria

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

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

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

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

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

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

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

14. Dynamic short circuit withstand test

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

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

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

15. Routine test on bushings shall be done as per IEC 60137.

Test Procedures (for Reactor)

1. Measurement of winding resistance

After the Reactor has been under oil without excitation for at least 3 h, the average oil temperature shall be determined and the temperature of the winding shall be deemed to be the same as the average oil temperature. The average oil temperature is taken as the mean of the top and bottom oil temperatures.

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

2. Reactance and loss measurement

- The type tested unit shall be measured in the cold and hot state.
- In other units, measurement shall be carried out in the cold state and corrected as per factors derived from the type tested unit.
- Measurement shall also be carried out during 2-hour excitation test.

The following details shall be recorded under the heading of losses on the test certificate:

- Voltage reading
- Current reading
- CT & PT Ratio
- Tan delta
- the power reading
- total losses measured
- Total losses corrected to 75°C winding temperature
- the frequency reading
- the instrument constants and corrections (if any)
- The magnetization curve of the reactor (Type Tested unit)

3. Measurement of insulation resistance & Polarization Index

Measurement of D.C. insulation resistance between each winding to earth and between windings shall be carried out at 5000V DC. The polarisation index is a ratio of insulation resistance value at the end of 10 min test to that at the end of 1 min test at a constant voltage. It is recommended that PI value shall be better than 1.3.

4. Measurement of insulation power factor and capacitance between winding and earth

Reactor shall be tested in GST mode only between winding to tank for the measurement of capacitance & tan delta of winding to earth by applying 2kV and 10kV. Tan delta of winding shall not exceed 0.5% at ambient temperature. No temperature correction factor shall be applied.

5. Measurement of insulation power factor and capacitance of bushings

Bushing shall be tested in UST mode by applying 10kV and 2kV. Tan delta of bushing shall not exceed 0.5% if measured between 10° C and 40° C temperature. If tan delta is measured at a temperature beyond the abovementioned limit, necessary correction factor as per IEEE shall be applicable.

6. Core assembly dielectric and earthing continuity tests.

The insulation of the magnetic circuit and between the magnetic circuit and the core clamping structure, including core-bolts, bands and/ or buckles shall withstand the application of a test voltage of either 2 kVac or 3 kV dc for 60 seconds.

The insulation of core to tank, core to yoke clamp (frame) and yoke clamp (frame) to tank shall be able to withstand a voltage of 2.5 kV (DC) for 1 minute. Insulation resistance shall be minimum 1 GΩ for all cases mentioned above.

The continuity of the single-point earthing shall be verified before despatch. The results of the works tests shall be recorded on the test certificate, and shall include the resistance reading obtained from a measurement made between the core and core clamping structure by means of at least 1.5 kV ac or 2 kV dc. During erection, the contractor shall repeat this measurement at site. The records of these tests shall also be included in the test report.

7. Dielectric Tests

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

a) Lightning impulse tests (LIC, LIN)
b) Switching impulse (SI)
c) Applied voltage test (AV)
d) Induced voltage test with partial discharge measurement

Testing shall be performed in line with IEC. DGA tests shall be performed before and after Dielectric Tests.

8. Two hours excitation test

- Each reactor to be excited at 1 p.u. for 2 hours except type tested unit.
- Measure reactance, loss and vibration
- DGA rate interpretation shall be as per IEC/ CIGRE/ IEEE guidelines
- Test shall be performed before partial discharge test

9. Vibration & Stress measurement

After all dielectric test reactor shall be energised at rated voltage and mark atleast 4 points on each side wall where vibration is more. Stress will be measured on the same points. Similar process shall be followed for 1.05Ur voltage.

10. Temperature rise test (As per IEC-60076)

Temperature rise shall be guaranteed and tested at rated voltage (1 p.u). The tests shall be done for a minimum of 24 hours with saturated temperature for at least 4 hours. DGA tests shall be performed before and after heat run test and DGA results shall generally conform to IEC61181.
During this test the following shall be measured.

- Voltage
- Current
- Reactance and loss
- Audible sound
- Vibration
- Colour photographs of the four sides and top of the reactor together with the corresponding series of thermal images (colour) during starting and end of the test. It is also recommended to take thermal images 4 more times to take care of any unforeseen situation.
- Temperature measurement with internal probes during test.

The heat run type test results shall serve as a “finger print” for the other units to be routine tested.

Specified winding hotspot temperatures shall not be exceeded.

The temperature rises recorded by infra red shall not be more than 10°C above top oil temperature or 15°C above the local oil temperature.

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

- Employer's order number and reactor site designation.
- Manufacturer's name and reactor serial number.
- Ratings of reactor:
- MVA
- Voltage:
- Frequency
- Rated currents:
- Class of cooling
- Measured load losses at 75° C.
- Altitude of test bay.

Top oil temperature rise test

A log of the following parameters taken at 30 minute intervals:

- time
- Voltage
- Current
- Total power
- Ambient temperature measured on not less than three thermometers
- Top oil temperature: and
- Cooler inlet and outlet oil temperatures.
- Infra red pictures during the heating up phases

Winding temperature rise test

- Record the weight of conductor in each winding, and the losses in watts per kilogram, the 'cold' resistance of each winding and the simultaneous top oil and ambient air temperatures, together with the time required for the effect to disappear.

- Record the thermal time constant of the winding.
- Log the half–hourly readings of the parameters as for the top oil temperature rise test.
- Provide a table of readings, after shut-down of power, giving the following information ;
  - Time after shut- down:
  - Time increment:
  - Winding resistance: Record the resistance values for minimum 20 minutes.
  - Resistance increment:

- X, where x is the time after shut-down divided by the thermal time constant of the winding: and
- Y, where Y = 100 (1-e –x)

(Any graphical/computer method used to determine the temperature of a winding by extrapolation to the instant of power shut-down shall produce a linear curve.)

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

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

11. Measurement of harmonic content of current (Measured in Cold state)

The harmonics of the current in all three phases are measured at rated voltage, by means of a harmonic analyser. The magnitude of the relevant harmonics is expressed as a percentage of the fundamental component. For more information on the magnetic characteristic, see Annex B of IEC 60076-6. The harmonics of the applied voltage shall be adequately measured at the same time.

12. Measurement of acoustic noise level (Measured in Cold and Hot state of temperature rise test)

Test shall be performed as per clause 7.8.12 of IEC 60076-6 and IEC 60076-10. The measured value shall not be exceeded the limit as specified at Annexure-A of this specification.

13. Knee point voltage measurement of reactor (Measured in Cold state)

The test shall be carried out as per IEC 60076-6 clause B.7.1 “DC current charging – discharging method (theory)” or applying AC voltage from 0.7p.u, 0.8p.u, 0.9p.u and so on upto the level as per specification and measure the current at various voltages and calculate the tolerance of reactance as per annexure-A of this specification.

14. Measurement of zero-sequence reactance (Applicable for three phase shunt reactor only)

The test shall be generally performed as per IEC 60076-1. This measurement shall be carried out at a voltage corresponding to a neutral current equal to the rated phase current.

15. Frequency Response analysis

The test shall be performed on each phase of the Reactor by taking open circuit response of complete winding as HV to neutral terminal and vice versa. The response shall be compared with other units of same design for reference.

FRA shall also be carried out without oil in main tank for reference purpose.

16. Routine tests on Neutral Grounding Reactor

In addition to the routine tests listed in the IEC-60076 the volt-current characteristics test shall also be carried out on each neutral grounding reactor preferably at least upto short time rated current. Calculated value of hot spot temperature shall be furnished by the Contractor. Further, Lighting impulse voltage withstand test and ohmic value measurement shall be carried out.

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

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

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

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

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

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

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
				Test Method IS 3024/ IS 649				
		(k) Compliance to Quality Control Order of DHI		IS 3024		P	V	V
	(ii) Core Cheese (Packets) Applicable only for Reactors	(a) Visual Check	100%	Drawing/ Specifications	No damages	P	P	V
		(b) Surface flatness check – Mechanical			Drawing/Specifications			
		(c) Placement of Ceramic Spacers - Measurement						
		(d) Total Height & Diameter						
5.	Pre-compressed Press Board/ Laminated pre-compressed pressboard	(a) Visual & dimensional check, thickness, width and length	One sample of each size (thickness) per lot of pressboard	IEC 60641-3-1 IEC60763-3-1 IEC 60641-2, IEC60763-2 Methods of Test	No surface defects	P	V	V
		(b) Apparent Density (g/cm^3)			Up to 1.6 mm TK - 1.0-1.2 >1.6-3 mm - 1.1-1.25 >3-3.6 mm - 1.15-1.30 >6-8 mm - 1.2-1.3			
		(c) Compressibility in air (C) (in %)			Up to 1.6 TK- 10 % >1.6-3 mm - 7.5 % >3-3.6 mm - 5 % >6-8 mm - 4 %			
		(d) Reversible part Compressibility in air (C_{rev}) (in %)			Up to 1.6 TK- 45 %; >1.6-3 mm - 50 % >3-3.6 mm - 50 %; >6-8 mm - 50 %			
		(e) Oil Absorption			Up to 1.6 mm TK - 11 min > 1.6-3 mm - 9 min > 3 - 3.6 mm - 7 min > 6-8 mm - 7 min			
		(f) Moisture Content			6% max. / As per relevant std. & Manufacturer's std. practice			
		(g) Shrinkage in air (MD, CD & PD)			MD - 0.5 % max, CD- 0.7 % max, Thick – 5 % max			
		(h) pH of aqueous extract			6-9 for solid boards			
		(i) Conductivity of aqueous extract			Up to 1.6 - 5 max (mS/m) > 1.6-3 mm- 6 max, > 3-3.6 mm - 8 max > 6-8 mm TK - 8-10 max			
		(j) Dielectric Strength in Air			Up to 1.6 - 12 kV/ mm > 1.6-3 mm - 11 kV/mm > 3-3.6 mm - 10 kV / mm > 6-8 mm TK - 9 kV/mm			
		(k) Dielectric Strength in Oil			Up to 1.6 - 40 kV/ mm > 1.6-3 mm - 35 kV/mm			

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
					> 3-3.6 mm - 30 kV / mm > 6-8 mm TK - 30 kV/mm			
		(l) Ash Content (%)			1 % maximum			
		(m) Elongation (MD, CD)			MD CD Up to 1.6 - 3 % 4 % >1.6-3 mm - 3 % 4 % >3-3.6 mm - 3 % 4 % >6-8 mm TK - 3 % 4 %			
		(n) Tensile strength (MD, CD)			As per relevant std./ Manufacturer's std. practice			
		(o) Internal Ply Bond strength (for laminated pre compressed boards) • Dried (tested at 23°C) • Dried (tested at 120°C retention) • Oil impregnated (tested at 23°C) • Aged for 1 week at 120°C in oil (tested at 23°C retention)			As per relevant std./ Manufacturer's std. practice			
		(p) Flexural strength (MD, CD) (for Laminated pre compressed Boards) (MPa)			As per relevant std./ Manufacturer's std. practice			
		(q) Contamination Dielectric Liquids (for laminated pre compressed press boards) • Neutralization value (mg KOH/g) • Sludge content (mg/l) • Dissipation factor			As per relevant std./ Manufacturer's std. practice			
6.	Perma-wood	(a) Visual & dimensional check, thickness, width & length	One sample of each size per lot	IS 3513 IS 1708 IS 1736 IS 1998 IEC 61061 Approved document	Shall be free from surface defect	P	V	V
		(b) Density			0.8 to 1.3 gm/cc			
		(c) Moisture content			IS 3513/IS 1708			
		(d) Oil Absorption at 90 °C			Min 5%			
		(e) Dielectric Strength at 90 °C			Min 60 KV			
		(f) Tensile strength			Min for LD - 700 KV /cm^2			
		(g) Compressive strength test			Min for LD - 1400 KV /cm^2			
		(h) Shear strength age-wise			Min for LD - 450 KV /cm^2			
		(i) Thickness			Thickness (mm) Tolerance (±mm) 10 to 25 - 1.2 26 to 50 - 1.4 51 to 150 - 2.0			
		(j) Shrinkage (MD, CD)			IEC 61061/Plant standard			
		(k) pH Value						

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(l) Breakdown voltage, parallel to the laminations						
7.	Porcelain Bushings (Hollow)	(a) Visual & dimensional check.	10% Sample per lot As per IS/ IEC	IS 3347 IS 8603 IEC 60137	As per approved drawing, IS 3347/IS 8603	P	V	V
		(b) Power frequency voltage withstand test			As per IS 3347/IS 8603/ IEC 60137			
8.	Polyester Resin Impregnated Glass Fiber Tape	(a) Visual Check	One sample per lot per size	IS 15208	Free from visual defect	P	V	--
		(b) Verification of shelf life			To be used within self-life period not to be used after expiry of period			
		(c) Dimensional Check • Thickness • Width			• 0.25 to 0.35 mm (± 0.07) / as per manufacturer's design • 20 to 50 mm (± 2)			
		(d) Tensile Strength			200 N/mm (min)			
		(e) Resin Content			27 (± 3%)			
		(f) Softening point of resin			Max 200 °C			
		(g) Storage Condition			As per cl. 15.3 of IS 15208			
		(h) Elongation			4% (Max)			
9.	Lacquer (in case it is used)	Manufacturer's std. practice			As per Manufacturer's std. practice	P	V	--
10.	Condenser Bushing (OIP/RIP/RIS)	**Routine Test**	100%	IEC 60137				
		(a) Visual and Dimensional check			No visible damage	P	W	W
		(b) Lightening impulse withstand test (if applicable)			As per IEC 60137			
		(c) Measurement of dielectric dissipation factor and capacitance at room temperature			Tan Delta - 0.5%		P	V
		(d) Dry power frequency voltage withstand test			As per approved GTP	P	W	V
		(e) Measurement of Partial Discharge (PD)			As per IEC - No flash-over/ puncture		W	V
		(f) Pressure Test (for OIP condenser bushing)			No leakage	P	W	V
		(g) Test tap insulation test			As per IEC 60137			

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						Sub-Vendor	Manufacturer	Customer
		(h) Tightness test			No leakage	P	W	V
		(i) Creepage distance			As per approved GTP	P	W	W
		(j) Test of oil before carrying out routine test on bushing (for OIP bushing) • BDV • Water content • Tan delta at 90°C • IFT at 27°C			• BDV: Min 70 kV • Water content: Max 5 ppm • Tan Delta at 90^0C Max:0.0025 • IFT at 27^0C: Min 0.04 N/m	P	W	V
		Method & Positioning of Storage			As per bushing manufacturer's guideline		P	--
11.	Buchholz Relay	**Routine test**	100%	IS 3637		P	W	V
		(a) Type & make			As per approved drawing			
		(b) Porosity			No leakage			
		(c) High voltage			2 KV for 1 min. withstand			
		(d) Insulation resistance			Minimum 10 MΩ by 500 V DC megger			
		(e) Element test			No leakage at 1.75 Kg /cm^2 oil pressure for 15 mins			
		(f) Gas volume test at 5° ascending towards conservator			GOR - 1: 90 to 165 CC GOR - 2: 175 to 225 CC GOR - 3: 200 to 300 CC			
		(g) Loss of oil & Surge test			GOR - 1: 70 to 130 CC GOR - 2: 75 to 140 CC GOR - 3: 90 to 160 CC			
12.	Bimetallic Terminal Connector	**Routine test**	100%	IS 5561		P	W	V
		(a) Dimensional			As per approved drawing			
		(b) Visual check			Free form defects			
		(c) Tensile strength			As per type test report			
		(d) Resistance			As per type test report			
		(e) Galvanizing test (if required)			As per type test report			
13.	Marshalling Box/ Cooler Control Cabinet	(a) Dimensional & Visual check (workmanship, clearances, ferruling, labeling, accessories, earthing terminals, mounting/ lifting details, 20% spare TBs etc.)	100%	Approved drawing and specification	As per approved drawing	P	P/W	W/V
		(b) Verification of paint shade, thickness & adhesion			As per approved drawing			
		(c) All Functional Check at max & min rated operating voltage, electrical control			As per approved drawing			

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						Sub-Vendor	Manufacturer	Customer
		operations, alarms, interlocks and sequential operations						
		(d) BOM check for Component type, make & rating			As per approved drawing			
		(e) DOP check by thin paper insertion method			As per technical specification			
		(f) Degree of Protection (IP Class) verification			As per type test report / approved drawing			
		(g) Check for sealing gasket (EPDM rubber for outdoor/ neoprene rubber for indoor)			Free form defects			
		Routine test						
		a. HV test at 2kV (for 1 min) for auxiliary winding			1 min withstand			
		b. Verification of wiring and its routing			Firm and aesthetic			
		c. IR test at 500 V for 1 min			1 min withstand			
14.	Remote Tap Changer Control Panel (if applicable)	(a) Dimension & Visual Check	100%	Approved drawing and specification	As per approved drawing	P	P/W	W/V
		(b) 2kV test for Auxiliary wiring			1 min withstand			
		(c) Paint shade & Thickness			As per approved drawing			
		(d) Wiring routing check			Firm and aesthetic			
		(e) Functional Check			As per approved drawing			
		(f) Verification of BOQ			As per approved drawing			
15.	Air cell (Flexi Air Separator)	Make, Visual check of surface finish of complete air cell & Dimensions	100%	IS 3400	No surface defects. As per approved drawing	P	W	V
		Routine test						
		(a) Pressure test at 0.105 Kg /cm^2 (10Kpa) for 24 hrs			No leakage for 24 hours	P	W	V
		(b) 10 times inflation and deflation test at 0.105 Kg /cm^2			No deformation	P	W	V
		Type tests on basic fabric i. Oil side coating compound ii. Air side inner/outer coating iii. Rubber coating (inner/outer) iv. Coated fabric	One sample per lot of raw material		Tensile strength & elongation at break: ISO 1421 Tear resistance: ISO 4674-1 Coating adhesion: ISO 2411 Gas permeability: ISO 7229	P	W	V
16.	Roller Assembly	(a) Visual & Dimensions.	One sample per lot	IS 5517 IS 2004	Free from surface defect	P	V	--

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						Sub-Vendor	Manufacturer	Customer
		(b) Mechanical Properties & Chemical composition of raw material used for shaft & roller forging	One sample per melt/heat treatment batch	IS 28 IS 2026	For shaft as per MS EN8, BS 970-1 For roller wheel of cast iron IS 210 For roller wheel of Cast steel IS 1030			
17.	Oil & Winding Temperature Indicator	(a) Type & make	100%	--	As per approved drawing	P	P/W	V
		(b) Accuracy			± 1.5% of FSD			
		(c) HV test at 2kV for 1 min between all terminals & earth			Withstand for 1 min			
		(d) Switch contact operation test			Operation within ± 2.5° C of setting			
		(e) Contact Rating			As per Manufacturer's std.			
18.	Pressure Relief Device	(a) Type & Make	100%	As per specification	As per approved drawing & free from defect	P	P/W	W/V
		(b) Air Pressure Test			Operate at Specified pressure ± 0.07 kg/cm^2			
		(c) Liquid Pressure Test			Satisfactory operation at pressure release			
		(d) Switch/contact testing			No leakage for 24 hrs			
		(e) Leakage test at 75% operating pressure			2 kV withstand for 1 min			
		(f) HV test			As per Manufacturer's std.			
		(g) Functional test/Calibration						
		(h) Contact Rating						
19.	Magnetic Oil Level Gauge (MOG)	(a) Type & make	100%	--	As per approved drawing & free from defect	P	P/W	W/V
		(b) Dial Calibration for level			Check pointer position for Max, Min and center level (within tolerance as per specifications)			
		(c) 2kV HV test for 1 min between all terminal & earth			Withstand for 1 minute			
		(d) Leak test with air for 6 Hours			No leakage at 4 kg /cm^2			
		(e) Switch/contact operation test			Operate at Min level indication			
		(f) Contact Rating			As per Manufacturer's std.			
20.	Valves (Gate, Globe & Butterfly)	(a) Type, make & visual check for material of valve body, gate wedge, spindle and gland	100%	IS 778	As per approved drawing & no visible defect	P	W	V
		(b) Dimension check						
		(c) For Gate & Globe Valve: (i) Body test at 1.5 MPa (2 minutes) (ii) Seat test at 1.0 MPa (2 minutes) (iii) Seepage test at 2 kg/cm^2 for 12 hrs.			No leakage			

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference/ Standard	Acceptable Value	Category of Responsibility*		
						Sub-Vendor	Manufacturer	Customer
		(d) For Butterfly valve: (i) Pressure test through body and spindle (ii) Pressure test for diaphragm (iii) Oil seepage test (oil 105± 5 °C, pressure of 1.5 kg/cm² for 24 hrs.)			(i) No leakage at 5 kg/cm² for 10 minutes (ii) Max 6 drops/min at 1.5 kg/cm² (iii) No leak in body and spindle Max 6 drops/min through disc			
21.	Transformer Oil	Routine Test	100%	IS: 335 IEC 60296 IS 6855	As per technical specification	P	W	W
22.	Tank, Tank-cover, Turret, Conservator & Accessories	(a) Visual check of welding joints including earthing connection, matching of tank with cover& Dimensional check after final welding	100% One per design	CBIP Manual on Transformer 2013	Free from defect	P	W	V
		(b) Visual Check for a fit up for butt welds on tank walls, base & cover			Check for proper welding			
		(c) DP test on Butt welds after fit up & load bearing welds (lifting logs, bollards, jacking pads)			Check for proper welding			
		(d) Air leakage test on assembled tank with turrets & on conservator			No leakage			
		(e) Visual check of paint shade, paint film thickness (inside & outside) & film adhesion, primer application			Paint thickness Outside: 155 micron Inside: 30 micron No peel-off Or As per approved drawing			
		(f) WPS (Weld procedure specification) approval			Details to be furnished As per Specification/ASME Sec IX			
		(g) PQR (Process Qualification Record)			Details to be furnished As per Specification/ASME Sec IX			
		(h) Welders Qualification			Details to be furnished As per Specification/ASME Sec IX	P	W	V
		(i) UT (Ultrasonic test) of tank MS Plate of thickness >12mm.			Details to be furnished As per Specification/ASME Sec IX			
		(j) RT (Radiography test) of butt weld in bottom plate of tank after fit up (if any)			Details to be furnished As per Specification/ASME Sec IX			
		(k) Verification of PWHT (Post weld heat treatment)			Details to be furnished As per Specification/ASME Sec IX			
		(l) Surface cleaning by Shot/sand blasting			Details to be furnished as per Specification			
		(m) Tank - i. Pressure test (PT)			i. Withstand-Twice the normal head of oil or normal head+ 35	P	W	V

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						Sub-Vendor	Manufacturer	Customer
		ii. Vacuum test (VT) iii. Adhesion test iv. Visual Inspection inside transformer tank before PT & VT test			KN/m^2 whichever is lower, maintained at base of bank for 8 hrs. ii. Withstand- 3.33 KN/ m^2 for 1 hr. ii. Details to be furnished as per manufacturer's standard. iv. Inputs required as per specification			
		(n) Chemical composition & mechanical property of steel (for tank, tank-cover, conservator, turrets and accessories)		IS 2062 BS 4360	As per relevant standards	P	W	V
23.	Radiators	(a) Chemical composition & mechanical property of raw material	100%	BS EN 50216-1 IS513 Manufcaturer's drawing	As per relevant standards	P	W	W/V
		(b) DP test on lifting lugs welds			No welding defect			
		(c) Surface cleaning of header support and bracing details by sand/shot blasting			Free from surface defect			
		(d) Air pressure test on elements			As per relevant standards /CBIP			
		(e) Dimensional check after final welding			As per approved drawing			
		(f) Air pressure test on radiator assembly by water dipping method			2 kg /cm^2 for 30 minutes - no leakage			
		(g) Visual check of paint shade, paint film thickness & film adhesion			As per tech spec, coating thickness more than 70 micron			
		(h) WPS (Weld Procedure Specification) approval			Details to be furnished, if applicable as per Specification/ASME Sec IX			
		(i) PQR (Process Qualification Record)			Details to be furnished, if applicable as per Specification/ASME Sec IX			
		(j) Welders Qualification			As applicable As per Specification/ ASME Sec IX			
24.	OLTC (as applicable)	(a) HV test on Auxiliary circuit (2kV for 1min).	100%	IS 8468 IEC 60214	To Withstand for 1 min	P	P/W	V
		(b) Operational test of complete OLTC including functional check of driving mechanism			Satisfactory operation			
		(c) Pressure test on diverter switch oil compartment			No leakage at 10 Psi for 1 hour			
		(d) Mechanical Operation test of diverter switch (endurance test)			No defect after 5000 operations			
		(e) Mechanical test of tap selector motor drive			500 satisfactory operations between extreme taps			
		(f) Sequence test			Switching time within permissible limit			
		(g) Visual & Dimensional check			Free from defects, dimensions as per drawing			

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

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						Sub-Vendor	Manufacturer	Customer
	EPDM Gasket for Marshalling Box	(b) Dimensional check (Thickness & Width)	1 sample / Lot		Within tolerance			
		(c) Tensile Strength			As per IS 11149			
		(d) Elongation at break			As per IS 11149			
		(e) Shore Hardness check as per DIN-53505			As per IS 11149			
		(f) Compression test (in air) as per DIN, ISO 815			As per IS 11149			
29.	Bushing CT	Dimensions (Visual check for ID/OD, thickness)	100%	IS 16227 IEC 61869-2	As per approved drawing			
		Routine test						
		(a) Verification of terminal marking & polarity			As per IS 16227/ IEC 61869-2			
		(b) Overvoltage inter-turn test			Rated current withstand for 1 min			
		(c) Determination of error			As per IS 16227/ IEC 61869-2			
		(d) HV Test (Dry power frequency withstand test on secondary winding)			3 kV AC for 1 min withstand			
		(e) Accuracy Ratio			As per IS 16227/ IEC 61869-2			
		(f) Secondary winding resistance for PS/PX class			As per IS 16227/ IEC 61869-2			
		(g) Knee point voltage & excitation current for PS/PX class						
30.	Oil circulating pump (as applicable)	(a) Visual check	100%	IS 9137	no visual damage/ defect	P	P/W	V
		(b) No load running test (rpm, input power and current)			Satisfactory performance & no load losses within limit			
		(c)						
		(d) HV test (2kV power frequency withstand voltage test for 1 min)			Should withstand			
		(e) Oil pressure test on pumps at 5kg/cm^2 for 30 min			No leakage			
		(f) Locked rotor test			Satisfactory operation of protection			
31.	Oil flow Indicator (as applicable)	(a) Type, Make & Visual check (b) Dial & Calibration (c) Contact Rating (d) Dielectric Test between terminals and earth (e) Leak test at 7 kg/cm2 for 2 min (f) Alarm & trip operation check (g) Full flow check	100%	--	(a) As per standard document, no visual damage/defect (b) As per standard document (c) As per standard document (d) Shall withstand 2 kV for 1 min (e) No leak	P	P/W	V
32.	Power/Control Cable	Review of Supplier's TC for physical & electrical tests as per specification/drawing.	Random	--	As per standard document	P	P	V

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						Sub-Vendor	Manufacturer	Customer
33.	Silica Gel Breather	(a) Dimension, Type and model check (b) Check of healthiness & colour of Silica gel (c) Pressure test by blanking oil cup end	100%	-	(a) Within tolerance, Type and model as per drg (b) No visible defect, Gel colour is blue/Orange (c) No leak at 0.35 kg/cm^2 (for 30 Min)	P	W	-
34.	Drum for insulating oil	(a) Visual check of inside cleanliness and outside coat	100%	IS 1783 –1	As per specifications/ IS 1783-1			
		(b) Dimensional check (thickness, height & diameter)						
		(c) Leakage test on drum						
		(d) Drop test						
		(e) Hydraulic test						

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

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

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

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

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

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

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

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

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Sr. No.	Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
					Manufacturer	**Customer**
	normal tap (Soft copy of test report to be submitted to site along with test reports)					
26.	High voltage withstand test on auxiliary equipment and wiring after assembly				P	W
27.	Tank vacuum test (at tank supplier premises during tank manufacturing)				P	W
28.	Tank pressure test (at tank supplier premises during tank manufacturing)				P	W
29.	Check of the ratio and polarity of built-in current transformers				P	W
30.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)				P	W
31.	Over excitation test (applicable for 765 kV transformer only)					
For Shunt Reactors :						
1.	Measurement of winding resistance	100%	Specification/ IS:2026 / IEC 60076/other applicable standard	As per Specification/ IS: 2026/ IEC 60076/ other applicable standard	P	W
2.	Reactance and loss measurement (Measured in Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units)				P	W
3.	Measurement of insulation resistance & Polarization Index				P	W
4.	Measurement of insulation power factor and capacitance between winding and earth				P	W
5.	Measurement of insulation power factor and capacitance of bushings				P	W
6.	Tan delta of bushing at variable frequency (Dielectric frequency response)				P	W
7.	Core assembly dielectric and earthing continuity test				P	W
8.	High voltage with stand test on auxiliary equipment and wiring after assembly				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
	9.	Chopped wave lightning impulse test for the line terminals (LIC)				P	W
	10.	Lightning impulse test on Neutral (LIN)				P	W
	11.	Switching impulse test				P	W
	12.	Separate source voltage withstand test				P	W
	13.	Short time over voltage Test (830kVrms) (applicable for 765 kV Reactor only)				P	W
	14.	Induced over voltage test with Partial Discharge measurement (IVPD)				P	W
	15.	Measurement of dissolved gasses in dielectric liquid				P	W
	16.	2-Hour excitation test except type tested unit				P	W
	17.	Vibration & stress measurement at Um/√3 level Cold and Hot state for the unit on which temperature rise test is performed & in Cold state for all other units. (Measurement shall also be carried out at 1.05Um/√3 level for reference purpose)				P	W
	18.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)				P	W
	19.	Oil leakage test on Reactor tank				P	W
	20.	Appearance, construction and dimension check				P	W
	21.	Measurement of mutual reactance on 3-phase reactor				P	W
	22.	Measurement of zero-sequence reactance on 3-phase reactor				P	W
	23.	Tank vacuum test				P	W
	24.	Tank pressure test				P	W
D.	**Type Tests/Special test**		One from Lot	Specification/ IS:2026 / IEC 60076/other applicable standard	Specification/ IS:2026 / IEC 60076/other applicable standard		
	For Transformers:						
	1.	Measurement of transferred surge on Tertiary due to HV lightning impulse and IV lighting impulse				P	W

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
	2.	Measurement of transferred surge on Tertiary due to HV switching impulse and IV switching impulse				P	W
	3.	Full wave lightning impulse test for the line terminals (LI) (for Um<= 72.5kV)				P	W
	4.	Chopped wave lightning impulse test for the line terminals (LIC) (for transformer with Um≤170 kV)				P	W
	5.	Lightning impulse test for the neutral terminals (LIN)					
	6.	Switching impulse test for the line terminal (SI) (applicable for Um>72.5 kV & ≤170 kV)				P	W
	7.	Temperature rise test				P	W
	8.	Measurement of Zero seq. reactance (for three phase Transformer only)				P	W
	9.	Measurement of harmonic level in no load current				P	W
	10.	Determination of sound level				P	W
	11.	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)				P	W
	12.	Short circuit withstand capability test (Dynamic)				P	W
	For Shunt Reactors:						
	1.	Temperature rise test				P	W
	2.	Measurement of harmonic content of current (Measured in Cold state)				P	W
	3.	Measurement of acoustic noise level (Measured in Cold and Hot state of temperature rise test)				P	W
	4.	Knee point voltage measurement of reactor (Measured in Cold and Hot state of temperature rise test)				P	W
E.	**Packing & Dispatch – Main Tank**						
	1	Pipes and headers	100%	Manufacturer's Standard	Manufacturer's Standard	P	--
	2	Radiators				P	--

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Sr. No.	Test		Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
	3	Verification of Completeness of accessories & fittings				P	--
	4	Bushings				P	--
	5	Conservator tank				P	--
	6	Transformer Oil				P	--
	7	Internal inspection of unit before dispatch for any dust, foreign metal elements, etc.			No foreign elements, metal parts should be present		
	8	Check Dry air pressure after filling			0.15 to 0.2 kg/cm^2 above ATM Pr.	P	--
	9	Measurement of dew point of dry air before and after filling in tank before dispatch			Manufacturer's Standard	P	--
	10	Check proper blanking of all openings and leakage, if any				P	--
	11	Provision of impact recorder and tracking system				P	--
	12	Check for soundness of packing				P	--
	13	Dew point Measurement of Dry air after 24 hrs. of filing in tank			Manufacturer's Standard	P	-
	14	Measurement of Paint DFT			Manufacturer's Standard	P	-
	15	Check mounting of dry air cylinder			Manufacturer's Standard	P	-

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Annexure–F

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

Calculation of flux density, core quantity, no-load loss and weight of copper for a specific transformer has been given below. Similar calculations for any rating of transformer can be carried out and relevant data may be obtained from the manufacturer.

Example: 75 MVA, 220/11, YNd11, 3 Phase, Power transformer,
Tap Range: -2.5% to +7.5% , Off-circuit Switch (Linear) connection

Measured data of core step width and thickness:

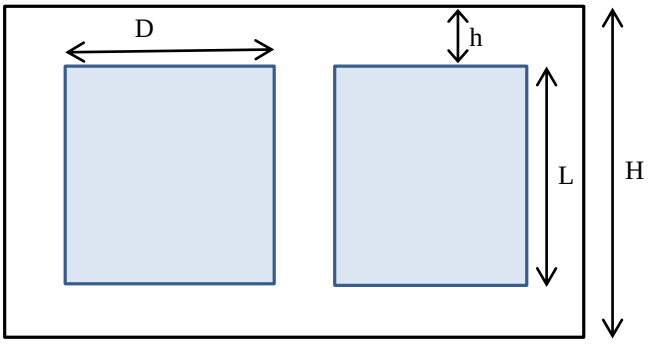
STEP NO.	**WIDTH**	**THICKNESS**	**THICKNESS**	**AREA OF STEP**	**AREA OF STEP**	**SUM OF STEP AREA**
	(mm)	**(mm)**	**(mm)**	**(mm^2)**	**(mm^2)**	**(mm^2)**
1	260	8.25	8.25	2145.00	2145.00	4290.00
2	300	8.41	8.41	2523.00	2523.00	5046.00
3	320	8.17	8.17	2614.40	2614.40	5228.80
4	360	8.48	8.48	3052.80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

CALCULATION OF FLUX DENSITY:

Phase voltage = 4.44 f x B_{max} x A x N x 10^{-4}
Where,

Phase voltage = 11 kV
Frequency (f) =50 Hz
A= 4056.52 cm^2
N= No. of turns on 11 kV side =72
Maximum flux density, B_{max} = (11000)/(4.44*50*4056.52*72*10^{-4}) = 1.696 T

CALCULATION OF WEIGHT OF CORE:



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

There are 3 core heights and 4 window widths

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

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

Guaranteed weight as per GTP= 42000 kg

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

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

Weight of core lamination = **42452.3 kg**

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

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

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

Guaranteed No Load Loss = 39.0kW

Calculated No load loss < (Guaranteed loss figure)

Estimation of copper quantity during stage Inspection

A. Weight of bare copper by ID/OD METHOD

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

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

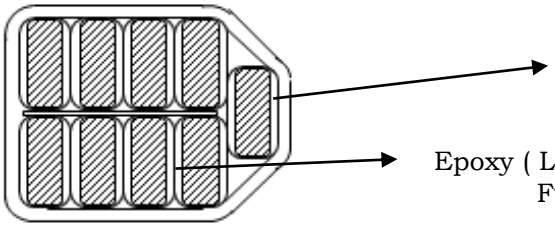
Type of Conductor in LV winding – Continuously Transposed Cable (CTC)
No. of Coils in LV Winding =1
No. of Cables parallel in LV Winding =2
No. of strands per cable in LV Winding = 77

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

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

No. of phases = 3

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



Bare Size of HV strand = 9.880 x 1.792 mm
Bare Size of Tap strand = 7.845x 3.012 mm
Area of each LV Cable = Strand area x No of strands/Cable
= [(4.967x1.789)-0.363)] x 77 = 656.27 mm^2
Area of each HV Cable = Strand area x No of strands/Cable
= [(9.88x1.792)-0.363)] x 2 = 34.68 mm^2
Area of each Tap Cable = Strand area x No of strands/Cable
= [(7.845x3.012)-0.55] x 1 = 23.08 mm^2

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

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

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

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

B. WEIGHT OF BARE COPPER BY PER UNIT LENGTH METHOD

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

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

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

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

Bare Cu Weight of HV winding

= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length x No. of parallel Coils

= 3x3.142x1290x811x2x309.3x2x 10^{-6} = 12200 kg

Bare Cu Weight of Tap winding

= 3 x π x Mean Diameter x No. of Turns x No. of cables per turn x weight of unit length x No. of parallel Coils

= 3 x3.142 x 1290x 84 x 3 x 214.8 x2x 10^{-6} = 1316 kg

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

C. WEIGHT OF BARE COPPER BY RESISTANCE METHOD

Measured Ambient temperature = 31 ^{o}C

Measured Resistance of each strand of LV = 0.42760 ohm

Measured Resistance of each LV cable = 0.42760/77
= 0.005553ohm

Measured Resistance per strand of each HV coil (46 disc from HV center)
= 3.121 ohm

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

So Total Measured Resistance per Stand of each HV coil (50 disc from HV centre)
= 3.121 + 0.26834
=3.38934 ohm

So Total Measured Resistance per Cable of each HV coil (50 disc from HV centre)
= 3.38934/2 = 1.69467 ohm

Measured Resistance per cable of each Tap coil (2 disc of Tap coil) = 0.067465 ohm

So, Total Measured Resistance per cable of each Tap coil (8 disc of Tap coil)
= 0.067465 x 8/2 =0.26986

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

Resistance Conversion factor at 20 ^{o}C = (235+20)/(235+31)= 0.95865

Resistance of LV Winding at 20 ^{o}C = Resistance of LV Winding x Resistance Conversion factor
= 0.005553 x 0.95865 = 0.005324 ohm

Resistance per cable of each HV coil at 20 ^{o}C = Resistance of HV cable x Resistance Conversion factor
=1.69467 x 0.95865 =1.6246 ohm

Resistance per cable of each Tap coil at 20 ^{o}C = Resistance of Tap cable x Resistance Conversion factor
= 0.26986 x 0.95865
= 0.2587 ohm

$R = \rho (L/A)$

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

Length of each LV cable = (R x A)/ ρ = 0.005324x 656.27/ 0.017241
= 202.27 x10^3 mm
Length of each HV cable = 1.6246 x 34.68/ 0.017241
= 3267.86 x10^3 mm
Length of each Tap cable = 0.2587 x 23.08/ 0.017241
= 346.31 x10^3 mm

Bare Cu Weight of LV winding
= 3 x length of per cable x area of each cable x no. of parallel cables x Cu density
= 3 x 202.27 x10^3 x 656.27 x 2 x 8.89x 10^{-6}
= 7081 kg

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

Bare Cu Weight of Tap winding
= 3 x length of per cable x area of all parallel conductors x Cu density x No. of parallel Coils
= 3 x 346.31 x 10^3 x 23.08 x 3 x 8.89x 10^{-6} x 2
= 1279 kg

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

D. CURRENT DENSITY CALCULATION:

LV winding:
Current = 2272.73 A; Conductor area = 656.27x2= 1312.54 mm^2
Current density = 2272.73 / 1312.54 = 1.73 A/mm^2

HV winding: (Minimum Tap)
Current = 201.88 A; Conductor area = 34.68 x2x2= 138.72 mm^2
Current density = 201.88 / 138.92 = 1.46 A/mm^2

Tap Winding: **(Minimum Tap)**
Current = 201.88 A; Conductor area = 23.08 x3x2= 138.48 mm^2
Current density = 201.88 / 138.92 = 1.46 A/mm^2

Annexure-G

BASIC MANUFACTURING FACILITY & MANUFACTURING ENVIRONMENT

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

Basic manufacturing facility

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

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

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

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

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

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

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

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

Annexure- H

LIST OF DRAWINGS/DOCUMENTS TO BE SUBMITTED BY THE MANUFACTURER

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

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

(a) Guaranteed Technical Particulars (GTPs) and other Technical particulars
(b) Rating and Diagram Plate giving details of terminal marking and connection diagram
(c) General Arrangement (GA) drawing (as built drawing) of transformer/reactor showing Plan, Elevation, End view (left side & right side view looking from HV side) and 3D view identifying various fittings & accessories, dimensions, weight, clearances, quantity of insulating oil, centre of gravity etc.
(d) View showing maximum lifting height of core-coil assembly and maximum clearance over tank top required for taking out the bushing.
(e) List of all accessories, description, make, weight and quantity
(f) Bill of Materials (BoM) with description, make & quantity
(g) Drawing relating to Neutral formation of 1-phase units of three phase bank
(h) Drawing relating to Delta formation of 1-phase units of 3-phase bank
(i) Foundation Plan (combined foundation drawing for 1-phase transformers/ reactors) showing Rail gauge, fixing details of foundation bolts, clamping arrangement to restrict movement during earthquake & location of jacking pads and loading details
(j) Bushing Drawing showing dimensions, electrical & mechanical characteristics, mounting details and test tap details (as applicable)
    i) HV Bushing

ii) IV Bushing
iii) LV Bushing
iv) Neutral Bushing

(k) Transport Dimension Drawing indicating transport weight, transport condition (oil filled/gas filled), lifting bollards, jacking pads, pulling eyes, quantity and location of impact recorder etc.

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

(m) GA drawing for bus duct termination (if applicable) indicating position of bus duct mounting flanges

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

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

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

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

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

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

(t) Alarm/Trip Indication Scheme

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

(v) Technical literature of all fittings and accessories

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

(x) Calculation of hot spot temperature

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

(z) Magnetisation Characteristics of bushing CTs and neutral CTs

(aa) Hysteresis Characteristics of iron core

(bb) Over fluxing withstand duration curve

(cc) Typical heating and cooling curves

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

(ee) Twin bi-directional roller assembly drawing

(ff) Oil Flow Diagram

(gg) List of spares

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

(ii) Insulating oil storage tank drawing
(jj) Oil sampling Bottle details
(kk) Customer inspection schedule
(ll) Test procedure of transformer/reactor
(mm) Manufacturer Quality Program (MQP) and Field Quality Plan (FQP)
(nn) Field Welding Schedule for field welding activities (if applicable)
(oo) Type test reports
(pp) O&M manual (hard copy and soft copy) of transformer/reactor inter-alia including instructions for Aircell, Oil filling, Bushing removal and Core Coil Assembly un-tanking etc.

Annexure – I

SCOPE OF DESIGN REVIEW

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

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

Annexure-J

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

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

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

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

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

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

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

<table>
<tr>
<td>4</td>
<td>Conceptual design
e.g. Dry / oil-immersed type ; Core type with concentric windings / sandwich type, shell type, Circular coils / non-circular coils</td>
<td></td>
<td>OIL-IMMERSED, CORE TYPE, CONCENTRIC WINDINGS, CIRCULAR COILS</td>
<td>Yes/No</td>
<td>Reference:
1. Rating & Diagram plate
2. Approved GTP</td>
</tr>
<tr>
<td>5</td>
<td>Arrangement and geometrical sequence of main windings
e.g.; Core-LV-HV-T</td>
<td></td>
<td>CORE - LV (TER) – REG – IV - HV</td>
<td>Yes/No</td>
<td>Reference:
1. Winding assembly drawing in Short circuit test report if available
2. *Or Representative Coil assembly drawing reference</td>
</tr>
<tr>
<td>6</td>
<td>Type of conductors for each winding
e.g aluminium / aluminium alloy, annealed or work-hardened Copper; metal foil / wire / flat conductor / Continuously Transposed conductor; Epoxy bonding (Yes/No); work hardened Proof stress (min) N/mm²</td>
<td></td>
<td>
<table>
<tr><td></td><td>LV</td><td>Tap</td><td>IV</td><td>HV</td></tr>
<tr><td>Conductor</td><td>COPPER</td><td>COPPER</td><td>COPPER</td><td>COPPER</td></tr>
<tr><td>Type</td><td>CTC</td><td>CTC</td><td>CTC</td><td>CTC</td></tr>
<tr><td>Epoxy coated</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Proof stress N/mm (min)</td><td></td><td></td><td></td><td></td></tr>
</table>
</td>
<td>Yes/No</td>
<td>Reference:
1. *Test Certificates submitted by the conductor Vendor for each winding
2. Approved GTP</td>
</tr>
<tr>
<td>7</td>
<td>Type of each windings</td>
<td></td>
<td>
<table>
<tr><td>Winding</td><td>LV</td><td>Tap</td><td>IV</td><td>HV</td></tr>
</table>
</td>
<td>Yes/No</td>
<td>Reference:
1. In case Short ckt. test report is inclusive of detail on</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td>
<table>
<tr><td>5a</td><td>e.g. Helical-/Layer-/ Disc- type / pancake coils</td></tr>
<tr><td>5b</td><td>e.g. Line lead entry (top, bottom , Center, Edge)</td></tr>
</table>
</td>
<td></td>
<td>
<table>
<tr><td>Type</td><td>Layer /Disc</td><td>Multi-start Layer</td><td>Disc</td><td>Disc</td></tr>
<tr><td>Line Lead entry</td><td>Top/Bottom</td><td>Top/Bottom</td><td>Top/Bottom</td><td>Center entry</td></tr>
</table>
</td>
<td></td>
<td>

Winding type
Lead entry detail

2. Representative Coil assembly drawing reference
</td>
</tr>
<tr>
<td>8</td>
<td>Absorbed power at Short Circuit
(= Rated Power/per unit short circuit impedance)
[The ratio shall be between 70 % to 130% of that rating of the reference transformer]</td>
<td></td>
<td>
<table>
<tr><td>Sc. Tested Transformer</td><td>Max Voltage Tap</td><td>Min Voltage Tap</td><td>Nor Voltage Tap</td></tr>
<tr><td>Rated MVA</td><td>315</td><td>315</td><td>315</td></tr>
<tr><td>Impedance measured after sc. test</td><td>10.4%</td><td>12.5%</td><td>15.4%</td></tr>
<tr><td>Absorbed power (MVA)</td><td>3028.85</td><td>2520.00</td><td>2045.45</td></tr>
</table>
</td>
<td>Yes/No</td>
<td>Reference:
1. Short ckt test report inclusive of Routine test Impedance values</td>
</tr>
</table>

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

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

*To be made part of short circuit test report document

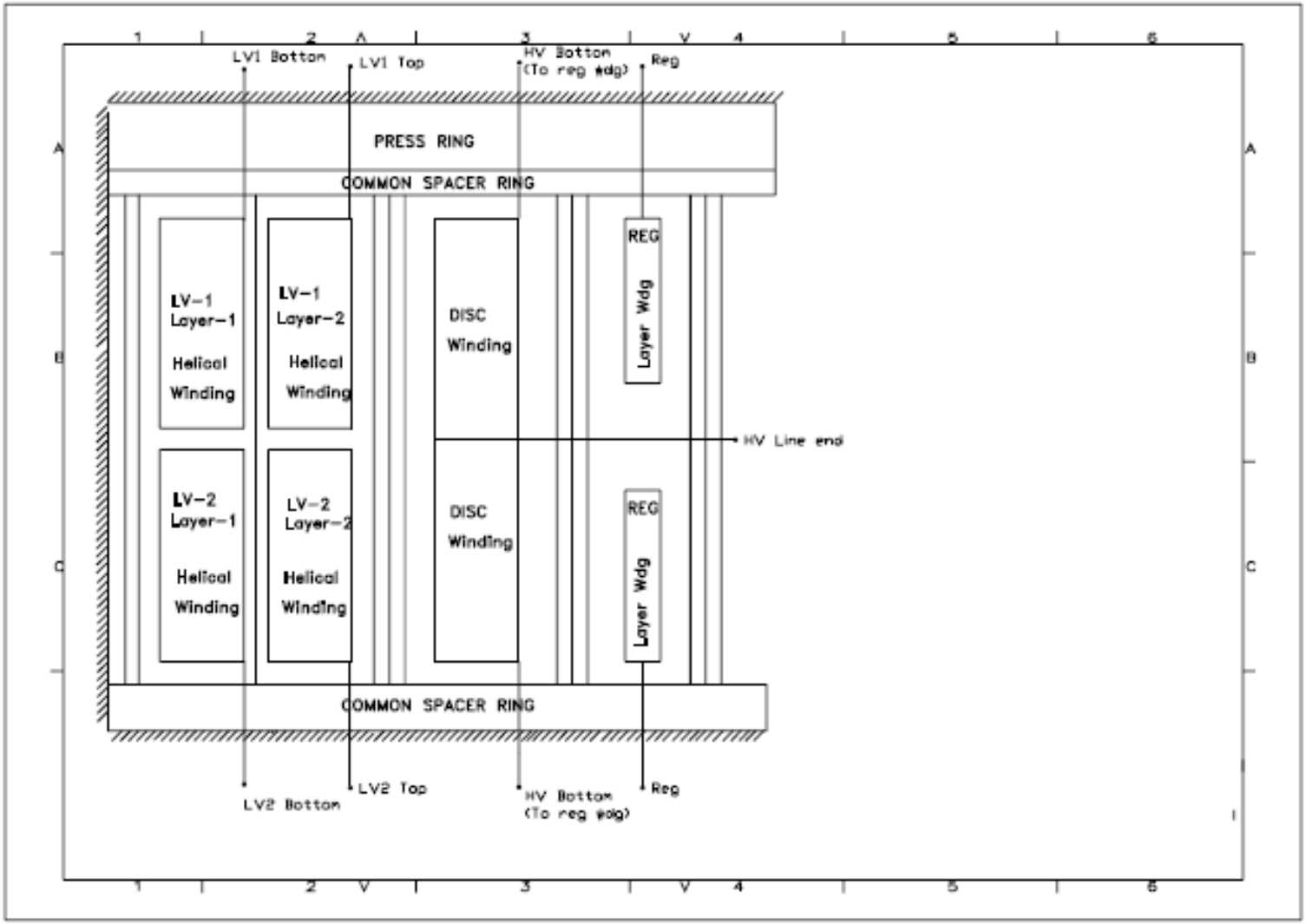
(For design to be similar every criteria specified above should match)

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

Manufacturer Signature

Purchaser's Signature

Representative Coil assembly reference Winding Arrangement



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

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

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

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
4.02	Winding	40 Deg C	50 Deg C
4.03	Winding hot spot rise	66 Deg C	61 Deg C
4.04	Core hot spot rise	61 Deg C	55 Deg C
5.00	Guaranteed losses at Principle tap, rated voltage & frequency (Mentioned measured values in DSC tested unit)	Guaranteed/Measured/Designed	Designed/Guaranteed
5.01	Load Loss, kW	444.5/425.78/429.39	495/500
5.02	No Load loss, kW	104.5/84.27/84.18	88.4/90
5.03	Aux Loss, kW	8.5/6.76/8.28	15/15
6.00	**System Fault Level (HV / IV / LV)**		
6.01	If System fault level is higher than SC tested T/F please submit calculation of short circuit impedance variation.	50/40/-kA	63/50/-kA
7.00	Winding connection (HV/IV/LV)	Auto Star/Delta	Auto Star/Delta
8.00	Insulation (HV/IV/LV)	Graded/Graded/Uniform	Graded/Graded/Uniform
8.01	HV (LI/LIC/SI/PF/AC)	1300kVp/1430kVp/1050kVp/570kVrms /38kVrms	1300kVp/1430kVp/1050kVp/570kVrms /38kVrms
8.02	IV (LI/LIC/SI/PF/AC)	950kVp/1045kVp/750kVp/395kVrms/3 8kVrms	950kVp/1045kVp/750kVp/395kVrms/3 8kVrms

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
8.03	LV (LI/LIC/AC)	250kVp/275kVp/95kVrms	250kVp/275kVp/95kVrms
8.04	N (LI/AC)	170kVp/38kVrms	170kVp/38kVrms
9.00	**Bushing Ratings**		
9.01	HV	420kV/2000A, OIP Condenser	420kV/1250A, RIP Condenser
9.02	LV	245kV/1250A, OIP Condenser	245kV/2000A, RIP Condenser
9.03	TV	72.5kV/3150A, OIP Condenser	52kV/3150A, RIP Condenser
9.04	Neutral	36kV/2000A, Oil Communicating	36kV/2000A, Oil Communicating
9.05	Impulse level (HV/IV/LV/N)	1425kVp/1050kVp/250kVp/170kVp	1425kVp/1050kVp/250kVp/170kVp
9.06	Switching impulse level (HV/IV)	1050kVp/850kVp	1050kVp/850kVp
9.07	Power Frequency (Dry) (HV/IV/LV/N)	695kVrms/505kVrms/105kVrms/77 kVrns	695kVrms/505kVrms/105kVrms/77 kVrns
10.00	**CORE**		
10.01	Flux Density at Rated Voltage	1.722 T	1.72 T
10.02	Core Construction [main limb / return limb]	3 Main Limbs / 2 Return Limbs	3 Main Limbs / 2 Return Limbs
10.03	Cross-section ratio - Main & Return limb Main limb & Yoke	100% & 53% 100% & 53%	100% & 53% 100% & 53%
10.04	Core Diameter	815	1015

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

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
12.01	LV	Epoxy Bonded CTC, 1.5 x 7.8//23, 0.5 PI	Epoxy Bonded CTC, 2|| (1.3 x 5.4//31), 0.5 PI
12.02	REG	Epoxy Bonded CTC, 1.25 x 4.8//25, 1.5 PI (ZNO elements used)	Epoxy Bonded CTC, 1.36 x 6.5//27, 1.5 PI (ZNO elements used)
12.03	IV	Epoxy Bonded CTC, 1.4x 6.45//23, 1.1 PI	Epoxy Bonded CTC, 2|| (1.1 x 6.4//25), 1.1 PI
12.04	HV	Epoxy Bonded CTC, 2 X (1.4 x 5.5//17), 1.5 PI	Epoxy Bonded CTC, 2 X (1.1 x 5.7//35), 1.5 PI
13.00	**Proof Stress Value in Mpa**		
13.01	LV	180	200
13.02	REG	160	200
13.03	IV	200	200
13.04	HV	160	200
13.00	**ID / OD / Height**		
13.01	LV	875/955/1900	1075/1160/1780
13.02	REG	1115/1155/1780	1320/1365/1700
13.03	IV	1305/1575/1950	1515/1845/1790
13.04	HV	1755/2100/1950	2069/2430/1790

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
14.00	**No of Turns (Max / Nor / Min) Voltage Tap**		
14.01	LV	165	115
14.02	REG	112/0/112	80/0/80
14.03	IV	635	450
14.04	HV	520	368
15.00	**Winding weight**	Bare Copper	Bare Copper
15.01	LV	3440 kg	4300 kg
15.02	REG	2100 kg	2300 kg
15.03	IV	16450 kg	20700 kg
15.04	HV	22400 kg	27500 kg
16.00	**Current Density (Max / Nor / Min) Voltage Tap (A/mm²)**		
16.01	LV	4.02	3.99
16.02	REG	2.85/3.14/3.49	2.81/3.1/3.44
16.03	IV	2.03/1.83/1.58	1.92/1.73/1.49

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
16.04	HV	1.62/1.78/1.98	1.54/1.7/1.89
17.00	**Loss at Max / Nor / Min Voltage Tap (kW)**		
17.01	I^2R	385 / 344 / 415	441 / 394 / 471
17.02	Stray	39/ 45 / 56	47 / 54 / 117
17.03	Eddy	30/ 37 / 55	37 / 47 / 67
17.04	Stray+Eddy	69 / 82 / 111	84 / 101 / 184
17.05	Total Load Loss	454 / 426 / 526	525 / 495 / 655
17.06	% (Stray+Eddy) of Load loss	15.2 / 19.3 / 21	16 / 20.5 / 28
17.07	Core loss	84.5	88.4
18.00	**GAP (mm)**		
18.01	CORE - LV or CORE-TV	30	30
18.02	LV - REG	80	80
18.03	REG - IV	75	75
18.04	IV-HV	90	112
18.05	PH - PH	175	177
18.06	PH - RETURN LIMB	160	166

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
19.00	**Spacers / Circle (Nos. x Width)**		
19.01	LV	24 x 35W	36 X 30W
19.02	REG	24 x 45W	36 X 40W
19.03	IV	36 X 40W	36 X 45W
19.04	HV	36 X 50W	36 X 60W
20.00	**Supporting Area ((No of spacer x width) *100/Mean dia)**		
20.01	LV	29.20%	31.0%
20.02	REG	30.3%	34.1%
20.03	IV	32.0%	31.0%
20.04	HV	30.0%	30.5%
21.00	**Top Ring Thickness & Material**	100 mm & Laminated Press Board	130 mm & Laminated Press Board
22.00	**Bottom Ring Thickness & Material**	80 mm & Laminated Press Board	90 mm & Laminated Press Board
23.00	**Oil Quantity during first filling**	100 kL	115 kL
24.00	**Tank Thickness**		
24.01	**Side**	12 mm	12 mm
24.02	**Top**	25 mm	25 mm

Technical parameter of Offered & Short circuit tested Transformer			
Sr. No	**Technical Parameters**	**Short Circuit Tested Unit Rating**	**Offered Transformer**
24.03	**Bottom**	20 mm + Box Stiffener	20 mm + Box Stiffener
25.00	Change of Solid Insulation & Oil duct for above GAP (Sr. No – 18.0) YES / NO	-	Similar/No change w.r.t short circuit tested unit.
26.00	Active Part arrangement (Core & Coil Assembly) Change YES / NO	-	Similar/No change w.r.t short circuit tested unit.
27.00	Internal clearance in oil (Active part - Tank) Change (Yes / No)	-	Similar/No change w.r.t short circuit tested unit.
28.00	Cooling System (Radiator, Fans, Pumps) Change (Yes / No), If yes, submit detailed design calculation for supporting documents)	-	Same / Fans & pumps are suitably considered to dissipate total losses

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

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

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

Comparison of forces and stresses of 500MVA,400/220/33kV,3-Phase Auto Transformer with SC tested 315MVA,400/220/33kV, 3-Phase Auto Transformer as per IEC-60076-5													**Doc. No: _____; Rev_____**			
Type of force/ Stress	Tertiary Winding				Tap Winding				Common Winding				Series Winding			
	Actual	Reference	Allowable	Critical	Actual	Reference	Allowable	Critical	Actual	Reference	Allowable	Critical	Actual	Reference	Allowable	Critical
Mean hoop tensile stress on disc-, helical-, and layer type windings (Mpa)	Not Applicable				16.41	10.99	160	-	21.95	14.18	200	-	100.25	86.14	200	-
Mean hoop compressive stress on disc, helical, single layer type windings (Mpa)	47.5	57.05	160	-	75.16	56.06	160		69.56	61.93	200		Not Applicable			
Equivalent mean hoop compressive stress on multi layer type windings (Mpa)	Not applicable															

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

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

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

Annexure-K

PAINTING PROCEDURE

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

Radiator and pipes up to 80 NB (Internal surfaces)	Chemical cleaning, if required	Hot oil proof, low viscosity varnish or Hot oil resistant, non-corrosive Paint	--	--	--	--
Digital RTCC Panel	Seven tank process as per IS:3618 & IS:6005	Zinc chromate primer (two coats)	--	EPOXY paint with PU top coat or POWDER coated	Minimum 80μm / for powder coated minimum 100μm	RAL 7035 shade for exterior and Glossy white for interior
Control cabinet / Marshalling Box - No painting is required.						

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

Annexure–L

I. UNUSED INHIBITED HIGH GRADE INSULATING OIL PARAMETERS

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

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

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

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

II. UNUSED UNINHIBITED INSULATING OIL PARAMETERS

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

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

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

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

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

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

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

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

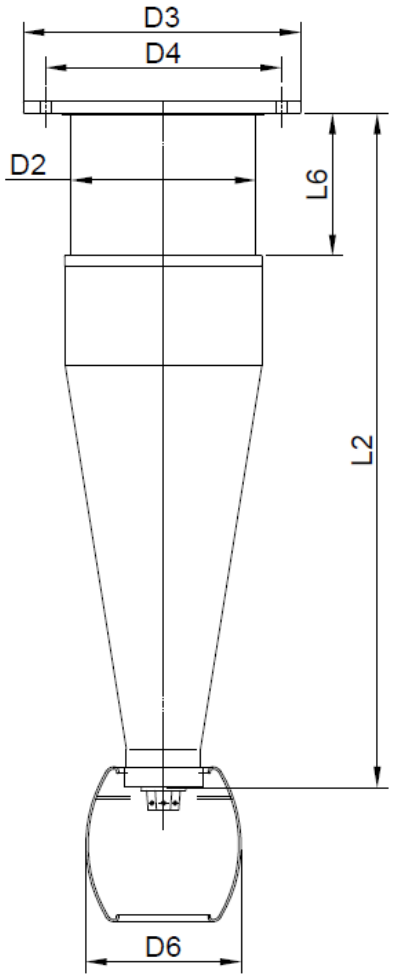
V. After filtration & settling and prior to energization at site oil shall be tested for following:

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

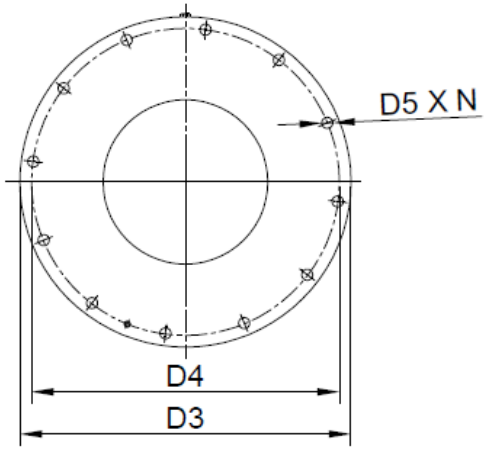
	c) Tan delta at 90 °C	-	0.05 (Max.) - For Inhibited Oil 0.5 (Max.) - For Uninhibited Oil
6	Total PCB content*		Not detectable (< 2 mg/kg)
	* Separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of the utility		

STANDARD DIMENSIONS FOR LOWER PORTION OF CONDENSER BUSHINGS

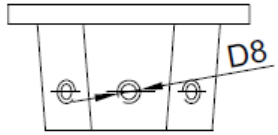
(For 2500 A, 800 kV and 420 kV voltage class Bushings)



Bushing Mounting Flange Details



Bottom Connection Details

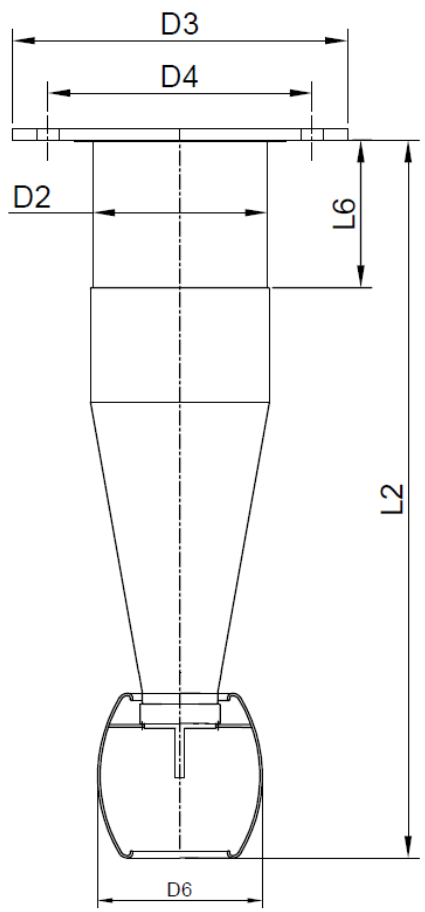


Symbol	Description
L2	Length between bottom seat of flange and bottom of the oil end shield/ stress relieving electrode/ oil end terminal whichever is the longest
L6	Length for accommodating Bushing Current Transformer (BCT)
D2	Maximum diameter of oil immersed end
D3	Outside diameter of fixing flange
D4	Pitch Circle Diameter of fixing holes of flange
D5	Diameter of fixing hole
N	Number of fixing holes
D6	Maximum diameter of oil end shield/stress relieving electrode
D8	Diameter of hole for oil end terminal

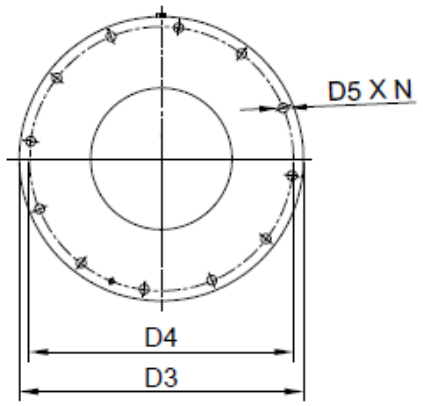
Voltage Rating (kV)	**800**	**420**
BIL kVp	2100	1425 1550 (for GT)
Creepage Distance (mm) (min.)	24800	13020
Current Rating (A)	**2500**	**2500**
Type of lead	Solid Stem (SS)	SS
L2 ±5	1955 (excluding bottom terminal end shield)	1335
L6 (min.)	600	600
D2 (max.)	528	350
D3±2	780	480
D4±1 (PCD)	711	430
D5xN	32x12	20x8
D6 (max.)	420	350
D8	Φ12	Φ12
No. of holes and depth of bolt for oil end terminal	6; 20	6; 20
Length & Diameter of Air End Terminal	125 & Φ 60	125 & Φ 60

STANDARD DIMENSION FOR LOWER PORTION OF CONDENSER BUSHINGS

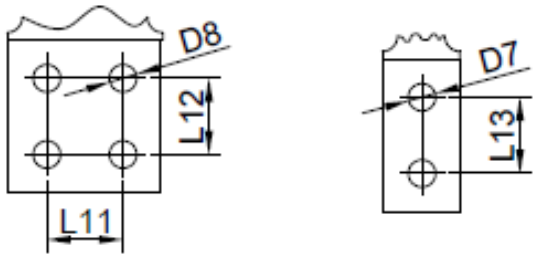
(For 420 kV and below voltage class Bushings)



Bushing Mounting Flange Details



Bottom Connection Details



Symbol	Description
L2	Length between bottom seat of flange and bottom of the oil end shield/ stress relieving electrode/ oil end terminal whichever is the longest
L6	Length for accommodating Bushing Current Transformer (BCT)
D2	Maximum diameter of oil immersed end
D3	Outside diameter of fixing flange
D4	Pitch Circle Diameter of fixing holes of flange
D5	Diameter of fixing hole
N	Number of fixing holes
D6	Maximum diameter of oil end shield/stress relieving electrode
L11	Horizontal Distance between holes for bushing bottom connection for 4 hole connection
L12	Vertical Distance between holes for bushing bottom connection for 4 hole connection
L13	Vertical Distance between holes for bushing bottom connection for 2 hole connection
D7	Diameter of hole for bushing bottom connection for 2 hole connection
D8	Diameter of hole for bushing bottom connection for 4 hole connection

Voltage Rating (kV)	**420**	**245**		**145**		**72.5**		**52**
BIL kVp	1425 1550(for GT)	1050		650		325		250
Creepage Distance (mm)	13020	7595		4495		2248		1612
Current Rating (A)	**1250**	**1250**	**2000**	**1250**	**2000**	**800**	**2000**	**1250**
Type of lead	Solid Stem (SS)	SS	SS	SS	SS	SS		SS
L2 ±5	1640	1130	1230	800/ 1250[a]	1030	695		450
L6 (min.)	400	300		300/500 [a]	300	300		100
D2 (max.)	350	270		165	180	115	165	115
D3±2	720	450		335	335	225	335	225
D4±1 (PCD)	660	400		290	290	185	290	185
D5xN	24x12	20x12		15x12	15 x12	15x6	15x12	15x6
D6 (max.)	350	270		180		115		115
L11	-	-	45	-	45	-	55	-
L12	-	-	40	-	40	-	40	-
L13	40	40	-	40	-	40	-	40
D7	Φ14	Φ14		Φ14	Φ14	Φ14	Φ14	Φ14
D8	-	-	Φ 14	-	-	-	-	-
Length & Diameter of Air End Terminal	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60	125 & Φ60

[a] for 765 kV class shunt reactor

Notes:

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

Annexure–N

CONNECTION ARRANGEMENT FOR BRINGING SPARE UNIT INTO SERVICE FOR REPLACEMENT OF ONE OF THE SINGLE PHASE TRANSFORMER/REACTOR UNITS OF A THREE PHASE BANK

Wherever single phase transformers/reactors are used, spare single phase transformer/reactor unit is to be provided as per Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations so that any of the faulty single phase units of a transformer/reactor bank can be replaced by spare unit to restore power supply at the earliest. This replacement can be done with or without physical shifting of unit from its location depending upon the availability of space by adopting one of two following arrangements:

1. **Connection of units through isolator switching arrangement without physical shifting of spare unit**

   (a) The connection of single phase units shall be made by isolator switching arrangement in such a way that spare unit can replace any of the other units, without physical shifting of the spare unit from its location. For this purpose, HV & IV connections (in case of transformer) and Line end connection (in case of reactor) of spare unit shall be extended up to the other unit(s) by forming auxiliary buses using flexible/rigid conductor and isolators of suitable rating (as shown below in the single line diagram). The Tertiary delta formation and connection with neutral bus shall be done by direct connection without the use of any isolator to make the connection simple. The tertiary bus for delta formation (for transformer) and neutral bus (for transformer/reactor) shall be supported on structure with bus post insulators at suitable intervals using flexible/rigid conductor and suitable clamps & connectors. Tertiary bus and connections shall be insulated with heat shrinkable insulating sleeve of adequate thickness suitable for at least 52kV. All associated materials like Bus post insulators, Aluminium tube, conductors, clamps & connectors, insulator strings, hardware, cables, support structures shall be provided for the above-mentioned arrangement. However, the detail configuration and hardware shall be finalised during detailed engineering and shall be subject to purchaser's approval.

   (b) The spare unit shall be completely erected, oil filled and commissioned similar to the other units and kept on the foundation after completing all necessary activities for long-term storage. The contractor shall carry out all pre-commissioning tests on the spare unit similar to the unit kept in service. Any special maintenance

procedure required for long period of storage shall be clearly brought out in the OEM's instruction manual.

(c) All the control, protection, indication signals of spare unit shall also be brought in Common Marshalling Box (CMB) of all the banks. Necessary arrangement in schematic of CMB is required to facilitate changeover of all the signals of faulty units to spare unit, to ensure flow of control, protection and indication signals between Purchaser's Control panels and individual units under operation (i.e. any designated unit for bank or spare unit, if it replace any designated unit). All the control, protection and indication signals of R, Y, B phase and Spare units from CMB shall be transferred to Purchaser's Control panels/SCADA. Change-over of spare unit signals with faulty unit shall be done through Purchaser's C & R panels/SCADA. The necessary switching arrangement through male-female plug-in Terminal Block (TB) assembly shall be provided for replacing spare unit with any one of the faulty phase unit for monitoring & control from CMB.

(d) A typical indicative arrangement for bringing spare transformer into service to replace one of the transformer units of the bank has been provided at the end of this Annexure for the benefit of the utilities.

2. **Connection of units with physical shifting of spare unit**

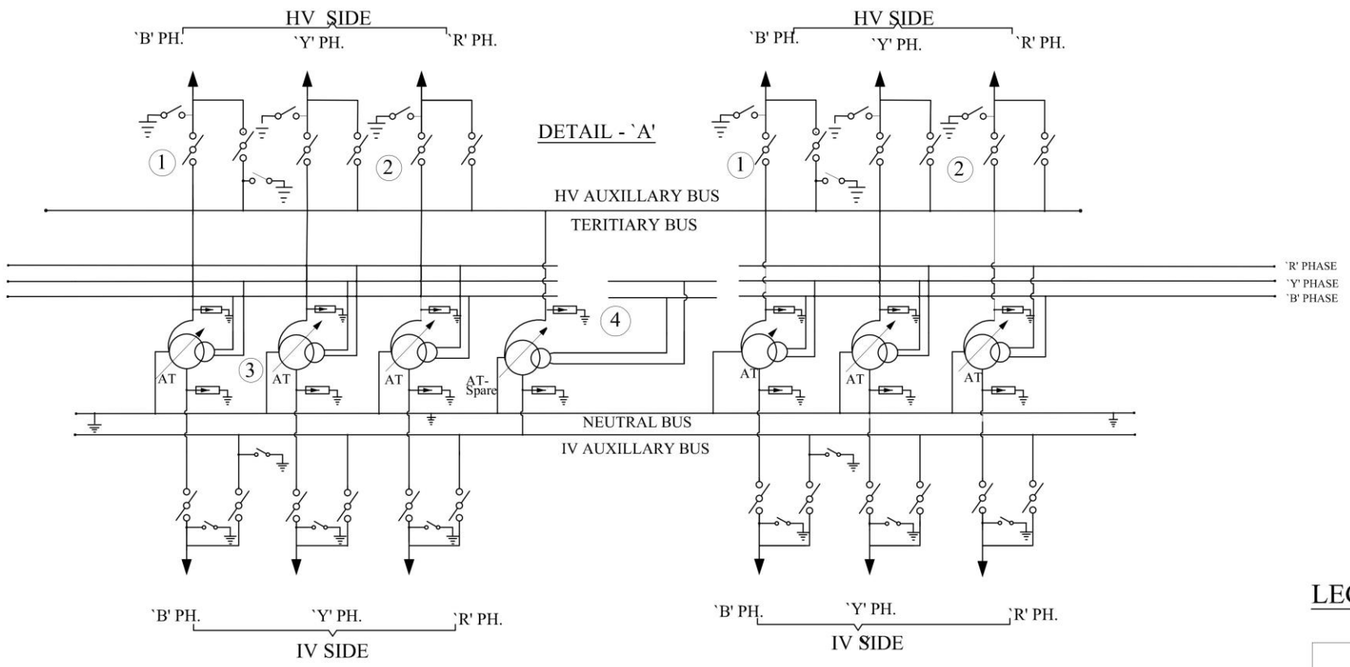
(a) For Generator transformers where isolator switching arrangement is not feasible because of use of high current bus duct on low voltage side or oil to SF6 bushings and for substations where sufficient space is not available for erecting auxiliary buses, neutral bus & isolators, the spare transformer/reactor unit shall be physically shifted to replace faulty unit in case of failure of any of the running units.

(b) The spare unit shall be placed on the elevated foundation block to facilitate quick movement. The spare unit may be required to be stored for long duration. The spare unit shall be completely erected and commissioned similar to the other units. However, erection of separate cooler bank is not envisaged. In case conservator is cooler bank mounted, suitable arrangement for mounting of conservator on tank top cover shall be provided. The contractor shall carry out all pre-commissioning tests on the spare unit similar to the other units kept in service. Any special maintenance procedure required for long term storage shall be clearly brought out in the OEM's instruction manual.

(c) All other accessories/fittings etc. shall be suitably packed in reusable boxes, which shall have long life and their drawings/ material would

be approved during detailed engineering. Instructions for dismantling, installation and safe storage shall be provided with every packing box. Arrangement shall be made to minimize moisture ingress inside the boxes. All pipes and radiators shall be provided with blanking plates during storage to prevent entry of foreign material/water.

INDICATIVE CONNECTION OF SINGLE PHASE UNITS AND SPARE TRANSFORMER UNIT WITH ISOLATING ARRANGEMENT



AT - AUTO TRANSFORMER

Notes:-

1. Neutral terminal of spare transformer shall be connected to the neutral bus only in the case spare transformer is used.
2. Tertiary bus of spare transformer shall be connected manually to the appropriale phase of tertiary bus of the transformer bank based on phase of the failed transformer.
3. If single spare transformer is used for connecting more than two transformer banks, location of spare transformer may be selected judiciously and tertiary bus of spare transformer may be connected accordingly.

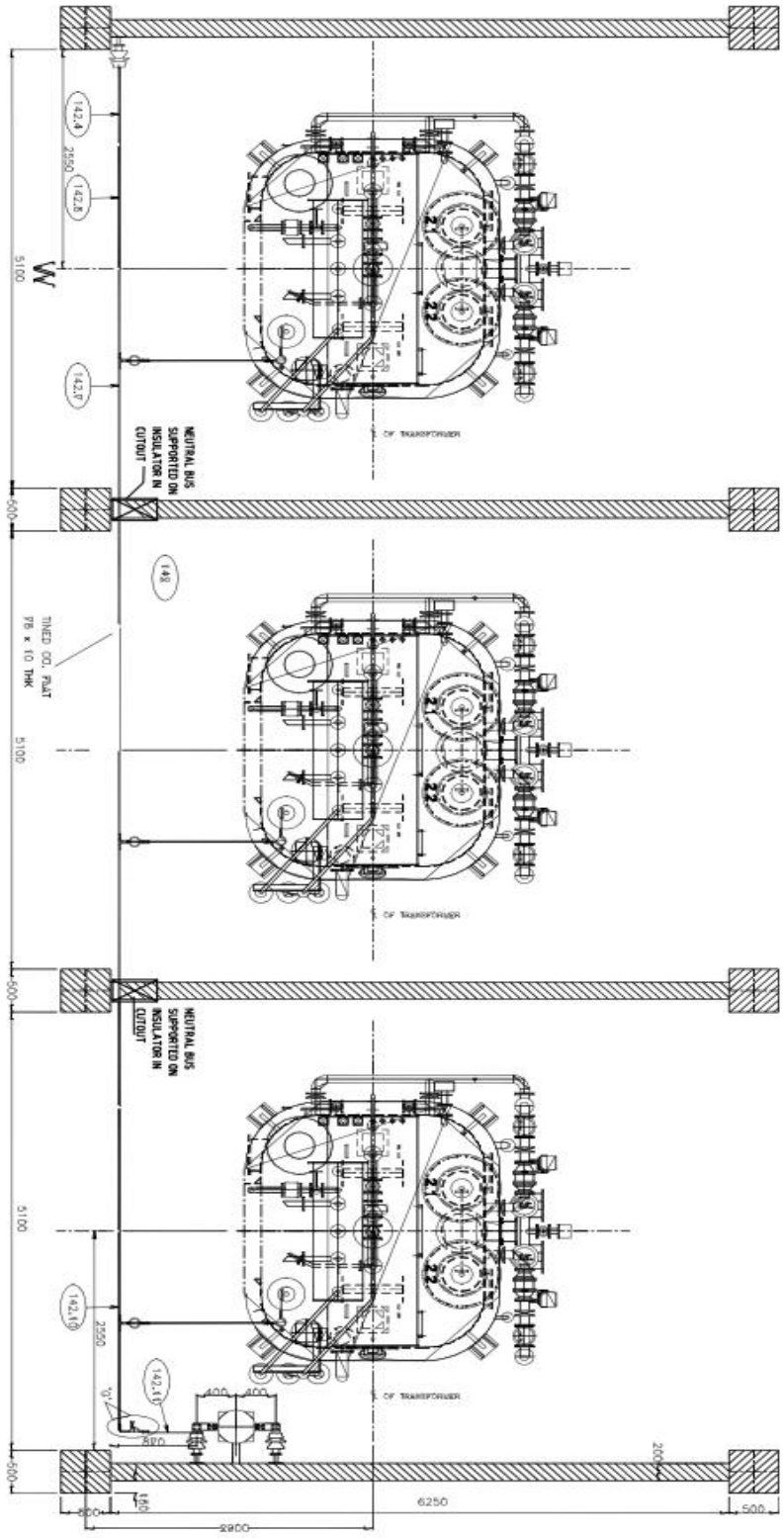
LEGEND

	SYMBOL	DESCRIPTION/RATING
1		Isolator (Single pole) with E/S
2		Isolator (Single Pole) without E/S
3		1 Phase Auto Transformer
4		Surge Arrestor

NOT TO SCALE

Annexure-O

TYPICAL ARRANGEMENT FOR NEUTRAL FORMATION FOR SINGLE PHASE UNITS



(Note: Dimensions are given for illustration purpose only and will depend upon transformer/reactor size)

Annexure-P

PHYSICAL INTERCHANGEABILITY OF TRANSFORMERS/ REACTORS OF DIFFERENT MAKES

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

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

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

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

b) Transformer can be placed on foundation either directly or on roller assembly (with suitable locking arrangement) and the reactor shall be placed directly on concrete plinth foundation along with suitable anti Earthquake Clamping Device as specified in Chapter-2.

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

d) The pedestal support should be provided for supporting the cooler bank, firefighting system etc. The RCC Rail-cum-road system integrated with the transformer/reactor foundation may be provided to enable installation and the replacement of any failed unit. The transfer track system should be suitable to permit the movement of any failed unit fully assembled (including OLTC, bushings) with oil.

This system should enable the removal of any failed unit from its foundation to the nearest road. If trench/drain crossings are required, then suitable R.C.C. culverts should be provided in accordance with I.R.C. standard/relevant IS.

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

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

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

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

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

j) The minimum height of the retaining walls of pit should be 150 mm to 200 mm above the finished ground level to avoid outside water pouring inside the pit. The bottom of the pit is generally made of PCC

M15 grade and should have a uniform slope towards the sump pit. While designing the oil collection pit, the movement of the transformer/reactor must be taken into account.

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

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

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

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

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

existing foundation resulting in reduction in the outage time of replacement of old transformer or reactor.

5.0 The rail track gauge shall be 1676 mm. Single Phase auto transformers of 765kV class and 3-Phase auto transformers of 400kV class shall have four (4) rails and other voltage class transformers shall have two (2) rails. However, Generator transformers of 765kV & 400kV class (single phase units) may have two (2)/ three (3) rails.

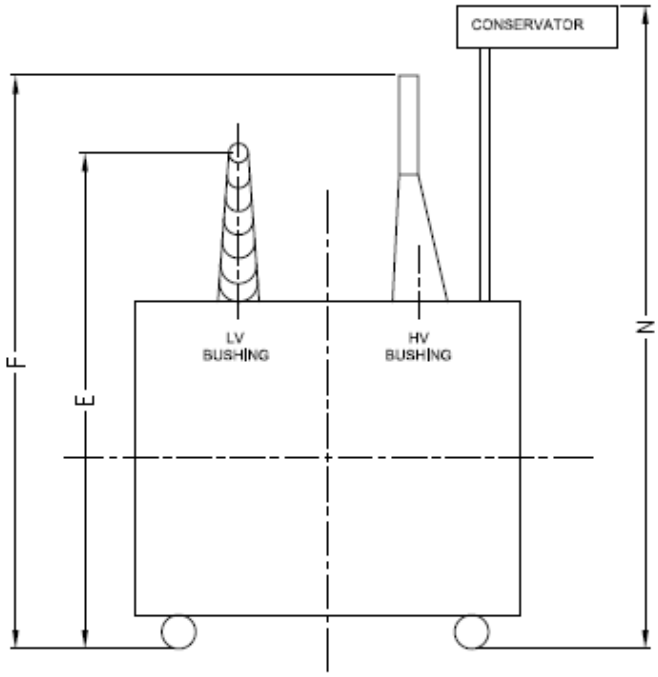
6.0 The manufacturers have different arrangement of jacking and different spacing between jacking pads. Hence, it is difficult to standardize the civil foundation drawing based on jacking pad locations arrangement. Design of block foundation based on weight of transformer/reactor for a particular MVA/MVAR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

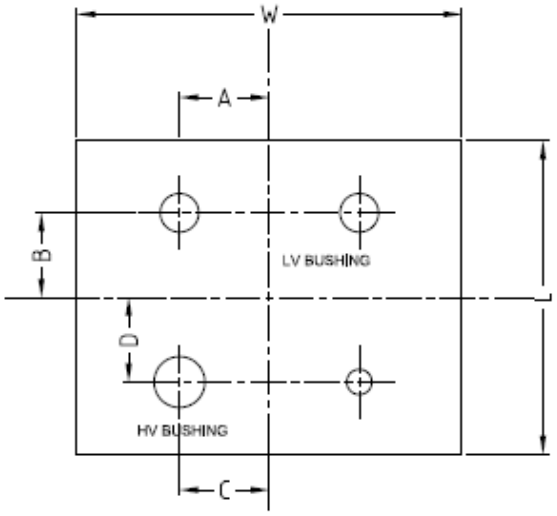
Rating of Transformer (MVA, Voltage ratio, no. of Phases)	**Weight of transformer/ reactor (in metric Tons)**	**Minimum size of removable metal plates for Jacking of transformer**
500MVA, (765/√3)/(400/√3)/33kV, 1-Phase Auto Transformer	375	400 mm x 400 mm x 32 mm thick
500MVA, 400/220/33kV **(or)** 400/230/33kV, 3-Phase Auto Transformer	450	400 mm x 400 mm x 32 mm thick
315MVA, 400/220/33kV **(or)** 400/230/33kV, 3-Phase Auto Transformer	375	400 mm x 400 mm x 32 mm thick

167MVA, (400/√3)/(220/√3)/33kV **or** (400/√3)/(230/√3)/33kV, 1-Phase Auto Transformer	200	400 mm x 400 mm x 32 mm thick
105MVA, (400/√3)/(220/√3)/33kV **or** (400/√3)/(230/√3)/33kV, 1-Phase Auto Transformer	150	400 mm x 400 mm x 32 mm thick
315MVA, 400/132/33kV 3-Phase Auto Transformer	375	400 mm x 400 mm x 32 mm thick
200MVA, 400/132/33kV **or** 400/132/33kV, 3-Phase Auto Transformer	300	400 mm x 400 mm x 32 mm thick
200MVA/160MVA, 220/132kV **or** 230/110kV or 220/110kV, 3-Phase Auto Transformer	250	400 mm x 400 mm x 32 mm thick
160MVA, 220/66kV **or** 230/66kV, 3-Phase Power Transformer	225	400 mm x 400 mm x 32 mm thick
100MVA, 220/33kV **or** 230/33kV, 3-Phase Power Transformer	200	400 mm x 400 mm x 32 mm thick
80MVA/50MVA, 132/33kV **or** 110/33kV, 3-Phase Power Transformer	150	400 mm x 400 mm x 32 mm thick
31.5MVA, 132/33kV **or** 110/33kV, 3-Phase Power Transformer	100	300 mm x 300 mm x 30 mm thick
31.5MVA/20MVA/12.5MVA, 66/11kV, 3-Phase	75	300 mm x 300 mm x 30 mm thick
265MVA/315MVA, Generation Voltage/(800/√3) kV Single Phase Generator Transformer	400	400 mm x 400 mm x 32 mm thick
200MVA/265MVA/315MVA, Generation Voltage/(420/√3) kV Single Phase Generator Transformer	375	400 mm x 400 mm x 32 mm thick

110MVAR/80MVAR, (765/√3)kV, 1-Phase Shunt Reactor	175	400 mm x 400 mm x 32 mm thick
50MVAR/63MVAR/80MVAR/125MVAR, 420kV, 3-Phase Shunt Reactor	225	400 mm x 400 mm x 32 mm thick
50MVAR/63MVAR/80MVAR/125MVAR, 420kV, 3-Phase Shunt Reactor	175	400 mm x 400 mm x 32 mm thick
50MVAR, 245kV, 3-Phase Shunt Reactor	75	300 mm x 300 mm x 30 mm thick
25MVAR, 245kV, 3-Phase Shunt Reactor	50	300 mm x 300 mm x 30 mm thick

STANDARD GA DRAWINGS AND LIMITS OF SUPPLY BETWEEN SUPPLIERS OF TRANSFORMER AND DRY-TYPE CABLE/GIS TERMINATION FOR HYDRO PLANTS

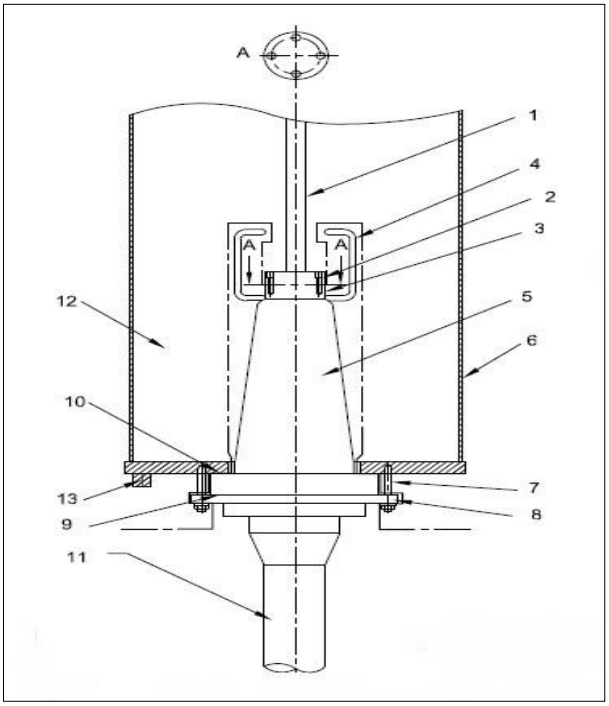




TYPICAL BUSHING ARRANGEMENT FOR GSU TRANSFORMER IN HYDRO PROJECT

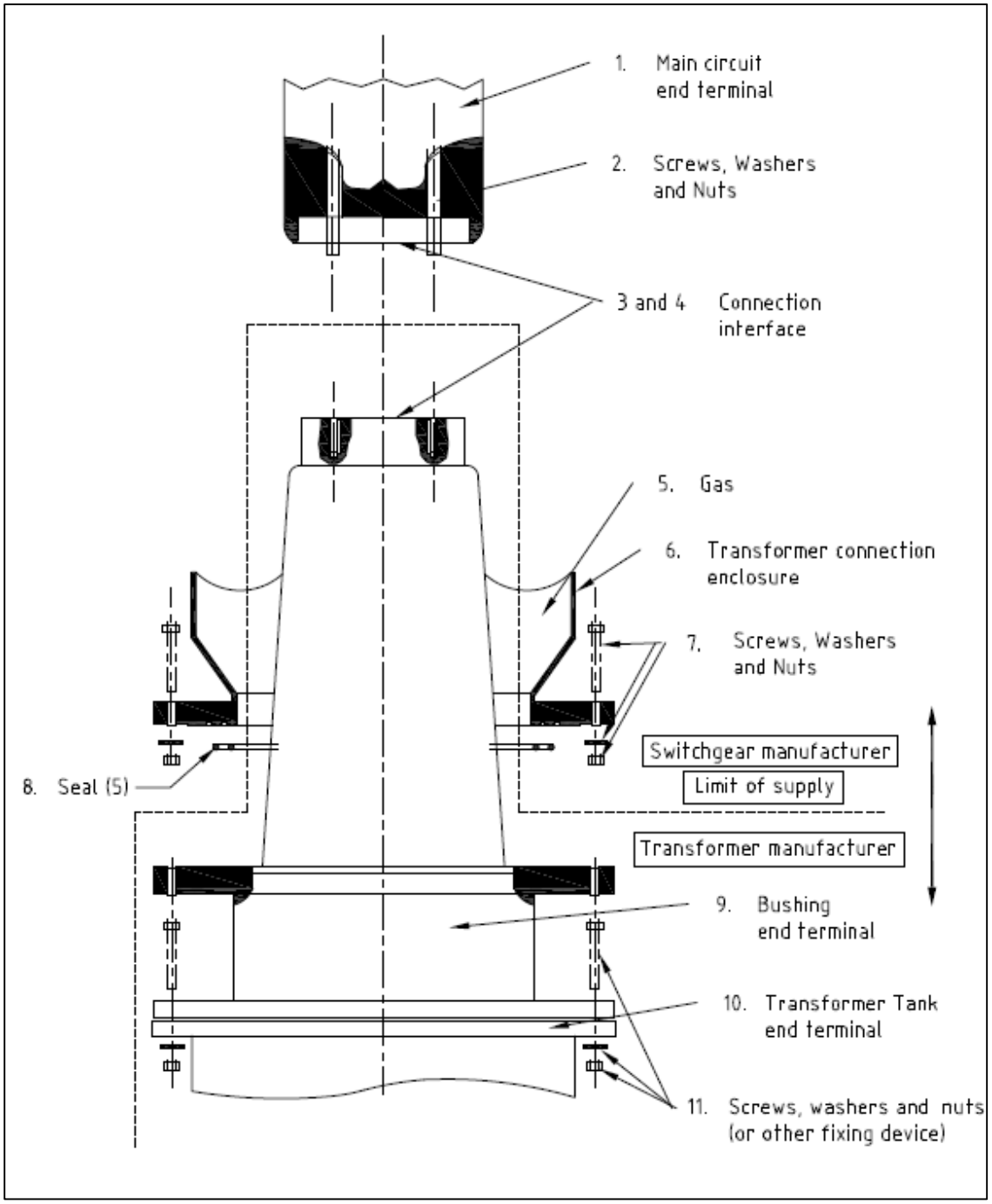
Typical Transformer Dimensions for single phase transformers in hydro projects			
Parameters	For 400 KV, MVA rating greater than 100 MVA	For 400 KV, MVA rating less than 100 MVA	For 220 KV Transformers
A	650	650	550
B	1100	950	725
C	1000	900	650
D	1550	1150	950
E	5500	5000	4500
F	6000	5500	5000
N (Max)	6300	6000	5700
Max. Overall Dimension (LXW)	5500x6500	5000x6000	4500x5000
HV Bushing Position	side left when viewed from HV side	side left when viewed from HV side	side left when viewed from HV side

Limits of supply between suppliers of transformer and dry-type cable termination



Description	Item	Supplier	
		Transformer	Dry type cable termination
Conductor current terminal with removable link	1	X	
Connection interface including fixing elements	2	X	
Connection interface	3		X
Shielding electrode*	4		X
Socket	5		X
Cable connection box	6	X	
Bolts, washers, nuts	7	X	
Clamping flange#	8		X
Intermediate gasket#	9		X
O-ring seal	10	X	
Cable gland	11		X
Insulating liquid	12	X	
Earthing terminal	13	X	
*divided or removable because of mounting #If needed			

Typical direct connection between transformer and gas insulated metal enclosed switchgear



Limits of Supply
(Refer typical connection between Power Transformer and Gas Insulated Switchgear)

Description	**Item**	**Manufacturer**	
		Switchgear	**Transformer**
Main circuit end terminal	1	X	
Screws, washers and nuts	2	X	
Connection Interface	3	X	
Connection Interface	4		X
Gas	5	X	
Transformer Connection Enclosure	6	X	
Screw, washer, nuts	7	X	
Seal	8	X	
Bushing	9		X
Transformer tank	10		X
Screw, washer and nuts	11		X

Annexure - R

1100 V GRADE POWER & CONTROL CABLES

1.1 Separate cables shall be used for AC & DC.

1.2 Separate cables shall be used for DC1 & DC2.

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

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

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

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

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

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

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

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

1.11 Repaired cables shall not be accepted.

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

1.13 **PVC Power Cables**

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

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

1.14 **PVC Control Cables**

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

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

Annexure-S

SPECFICATION FOR OIL STORAGE TANK

1. Oil storage tank shall be of adequate capacity as specified by the utility along with complete accessories. The oil storage tank shall be designed and fabricated as per relevant Indian Standards e.g. IS: 803 or other internationally acceptable standards. Transformer oil storage tanks shall be towable on pneumatic tyres and rested on manual screw jacks of adequate quantity & size. The tank shall be cylindrical in shape and mounted horizontally and made of mild steel plate of adequate thickness. Diameter of the tank shall be 2.0 meter approximately. The tank shall be designed for storage of oil at a temperature of 100°C.

2. The maximum height of any part of the complete assembly of the storage tank shall not exceed 4.0 metres above road top.

3. The tank shall have adequate number of jacking pad so that it can be kept on jack while completely filled with oil. The tank shall be provided with suitable saddles so that tank can be rested on ground after removing the pneumatic tyres.

4. The tank shall also be fitted with manhole, outside & inside access ladder, silica gel breather assembly, inlet & outlet valve, oil sampling valve with suitable adopter, oil drainage valve, air vent etc. Pulling hook on both ends of the tank shall be provided so that the tank can be pulled from either end while completely filled with oil. The engine capacity in horse power to pull one tank completely fitted with oil shall be indicated.

5. Oil level indicator shall be provided with calibration in terms of litre so that at any time operator can have an idea of oil in the tank.

6. Solenoid valve (Electro-mechanically operated) with Centrifugal pump shall be provided at bottom inlet so that pump shall be utilised both ways during oil fill up and draining. Suitable arrangement shall also be provided to prevent overflow and drain from the tank.

7. The following accessories shall also form part of supply along with each Oil storage tank.

   (a) Four numbers of 50 NB rubber hoses suitable for Transformer oil application up to temperature of 100°C, full vacuum and pressure up to 2.5 Kg/cm^2 with couplers and unions each not less than 10 metre long shall be provided.

(b) Two numbers of 100 NB rubber hose suitable for full vacuum without collapsing & kinking vacuum hoses with couplers & unions, each not less than 10 metre long, shall also be provided.

(c) One number of digital vacuum gauge with sensor capable of reading up to 0.001 torr, operating on 240V 50Hz AC supply shall be supplied. Couplers and unions for sensor should block oil flow in the sensor. Sensor shall be provided with at-least 8 meter cable so as to suitably place the Vacuum gauge at ground level.

(d) The painting of oil storage tank and its control panel shall be as per Annexure-K.

(e) The tank shall contain a self-mounted centrifugal oil pump with inlet and outlet valves, with couplers -suitable for flexible rubber hoses and necessary switchgear for its control. There shall be no rigid connection to the pump. The pump shall be electric motor driven, and shall have a discharge of not less than 6.0 kl/hr. with a discharge head of 8.0m. The pump motor and the control cabinet shall be enclosed in a cubicle with IP-55 enclosure.

Annexure-T

TECHNICAL SPECIFICATION OF OIL BDV TEST SET (if applicable)

Particulars	**Specification**
Functional Requirement	1. The instrument should be suitable for Automatic Measurement of Electrical Breakdown Strength of Transformer oil as per relevant standards. 2. The test results should have repeatability, consistency in laboratory condition.
Test Output	0-100 kV (Rate of rise: 0.5 to 5kV/Sec)
Accuracy	± 1 kV
Resolution	0.1 kV
Switch off Time	≤ 1ms
Display/Control	LCD/Keypads
Printer	In-built/External
Measurement Programmes	Fully Automatic Pre-programmed/User programmed Test Sequences as per latest IEC & other National/International standards.
Test Lead/ Accessories	One complete set of electrodes, gauge etc. compatible with the instruments should be provided for successfully carrying out the test in the purchaser's substation. Additionally, all the required accessories, tools, drawing, documents should be provided for the smooth functioning of kit. Further a robust/ rugged carrying case shall be provided for ensuring proper safety of the kit during transportation.
Design/Engg.	The complete equipment along with complete accessories must be designed/ engineered by Original Equipment Manufacturer.
Power Supply	It shall work on input supply variations, V: 230 V ±10 %, f: 50 Hz ±5 % on standard sockets.
Operating Temperature	0 to +50 ^{o}C

Relative humidity	Max. 90% non-condensing
Protection/ Control	Adequate protection shall be provided against short circuit, over load, transient surges etc. Also the instrument should have facility of stopping automatically on power failure. Also the kit should have facility of HV chamber interlocking as well as zero start interlocking.
Environment	The test kit shall be compatible for EMI/EMC/Safety environment requirement as per IEC.
Warranty	Warranty Period: Minimum of five (5) years from the date of successful & complete commissioning of the test kit at the purchaser's sub-station. All the materials, including accessories, cables, laptops etc. are to be covered under warranty period. If the kit is to be shifted to supplier's works for repairs within warranty/guaranty period, suppliers will have to bear the cost of spares, software, and transportation of kit.
Calibration Certificate	Unit shall be duly calibrated before supply and the date of calibration shall not be older than two month from the date of supply of Kit.
Training	Supplier shall have to ensure that the instrument is user friendly. Apart from the detailed demonstration at site, the supplier shall also have to arrange necessary training to the purchaser's engineers.
Commissioning, handing over the Instrument	Successful bidder will have to commission the instrument to the satisfaction of the purchaser. The instrument failed during the demonstration shall be rejected and no repairs are allowed.
After sales service	Bidder will have to submit the documentary evidence of having established mechanism in India for prompt after sales services.

Technical Specification of Portable Dissolved Gas Analysis (DGA) kit (if applicable)

Particulars	**Specification**
Functional Requirement	The Portable DGA equipment to extract, detect, analyze and display the dissolved gases in insulating oil as specified in IEEE C57.104 and IEC 60599.
Detection of Gases	All the fault gases i.e. H_2, CH_4, C_2H_2, C_2H_4, C_2H_6, CO & CO_2 concentrations shall be individually measured and displayed. The minimum detection limits of the instrument for the above gases shall strictly meet the requirement of IEC-60567.
Power Supply	It shall be operated with AC single phase, 50 Hz ±5%, 230 V ±10% supply. All power cable and necessary adaptors shall be provided by supplier.
Instrument control and Data handling, Internal Memory	a) Instrument shall be having in-built control for all the functions (data acquisitions and data storage). It shall have facility for communication with computer for downloading the data from instrument via USB port. b) Laptop shall be provided for communication with the instrument and it shall be of latest configuration with licensed preloaded Operating System and software for interpreting DGA results accordance with IEEE C57.104 and IEC 60599. Laptop carrying case shall also be provided. c) Internal Memory shall be capable to store at least 15000 records
General Conditions	a) Performance Parameters like - Minimum Detection Limits, Working Range, Accuracy, repeatability etc. shall be finalized during detailed engineering. b) During commissioning of the portable DGA equipment, the supplier shall demonstrate repeatability of test results and the results are within the specified accuracy. Purchaser will provide only the insulating oil/ GAS-IN-OIL standard for testing.

	c) All required items/instruments/spares/consumable/ connecting cables/communication cables/instruments/ manuals/Certificates/training materials/original software/original licensed data/station operating software/education CD/DVDs etc. that are essential for operation of the instrument shall be supplied at no extra cost.
Operating Temperature, Relative humidity & Dimensions	a) Temperature: 0-50 Deg. C b) Relative Humidity: 85% non-condensing c) Portable
Warranty	The entire test set up shall be covered on warranty for a period of 5 year from the last date of complete commissioning and taking over the test set up. If the kit is to be shifted to supplier's works for repairs during warranty period, supplier will have to bear the cost of spares, software, transportation etc. of the kit.
Service Support	The supplier shall furnish the requisite documents ensuring that the equipment manufacturer is having adequate service team and facility in India to take care of any issues during operation of the instrument.
Training	The supplier shall provide adequate training (minimum for a period of two working days) pertaining to the operation and troubleshooting to site personnel.

Annexure-U

SPECIFICATION FOR ON-LINE INSULATING OIL DRYING SYSTEM (CARTRIDGE TYPE) (For 400 kV & above transformer/reactor)

In addition to provision of air cell in conservators for sealing of the oil system against the atmosphere, each transformer/reactor of 400 kV and above voltage class shall be provided with an on line insulating oil drying system of adequate rating with proven field performance. This system shall be separately ground mounted and shall be housed in metallic (stainless steel) enclosure. The bidder shall submit the mounting arrangement. This on line insulating oil drying system shall be:

1. Designed for very slow removal of moisture that may enter the oil system or generated during cellulose decomposition. Oil flow to the equipment shall be controlled through pump of suitable capacity (at least 5 litres/minute).

2. The equipment shall display the moisture content in oil (PPM) of the inlet and outlet oil from the drying system.

3. In case, drying system is transported without oil, the same shall be suitable for withstanding vacuum to ensure that no air/ contamination is trapped during commissioning.

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

5. Minimum capacity of moisture extraction shall be 10 Litres before replacement of cartridge. Calculation to prove the adequacy of sizing of the on line insulating oil-drying system along with make and model shall be submitted for approval of purchaser during detail engineering.

6. The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.

7. The equipment shall be capable of transferring data to substation automation system confirming to IEC 61850 through FO port. Necessary interface arrangement shall be provided by the contractor for integration with the automation system.

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

Annexure-V

SPECFICATION FOR OIL SAMPLING BOTTLES

1. Oil sampling bottles shall be supplied as specified by the utility and shall be suitable for collecting oil samples from transformers and shunt reactors, for Dissolved Gas Analysis (DGA). Bottles shall be robust enough, so that no damage occurs during frequent transportation of samples from site to laboratory.

2. Oil sampling bottles shall be made of stainless steel having a capacity of one litre. Oil Sampling bottles shall be capable of being sealed gas-tight and shall be fitted with cocks on both ends.

3. The design of bottle & seal shall be such that loss of hydrogen shall not exceed 5% per week.

4. An impermeable oil-proof, transparent plastic or rubber tube of about 5 mm diameter, and of sufficient length shall also be provided with each bottle along with suitable connectors to fit the tube on to the oil sampling valve of the equipment and the oil collecting bottles respectively.

SPECFICATION FOR OIL SYRINGE

1. If specified by the utility, the glass syringe of capacity 50 ml (approx.) and three way stop cock valve shall be supplied. The syringe shall be made from Heat resistant borosilicate Glass, shall have metal luer lock tip and shall comply with BS EN ISO 595-2 and ISO 80369-7. The material and construction should be resistant to breakage from shock and sudden temperature changes, reinforced at luer lock tip Centre and barrel base.

2. The cylinder-plunger fitting shall be leak proof and shall meet the requirement of IEC-60567. Plunger shall be grounded and fitted to barrel for smooth movement with no back flow. Barrel rim should be flat on both sides to prevent rolling and should be wide enough for convenient finger tip grip. The syringe shall be custom fit and uniquely numbered for matching. The syringe shall be clearly marked with graduations of 2.0 ml and 10.0 ml and shall be permanently fused for life time legibility.

ANNEXURE – W

LIST OF CODES/STANDARDS/REGULATIONS/PUBLICATIONS

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

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

IEC 60076 All parts	-	Power Transformers
IS 3024 : 2015	-	Grain Oriented Electrical Steel Sheet and Strip (Third Revision)
IS 8468 : Part 1 : 2018 IEC 60214-1 : 2014	-	Tap-Changers Part 1 Performance Requirements and Test Methods (First Revision)
IEC / IEEE 60214-2:2019		Tap-changers- Part 2: Application guidelines
IS 8478 : 1977 (Reaffirmed Year : 2016)	-	Application guide for on-load tap changers
IS 649 : 1997 (Reaffirmed Year : 2018)	-	Methods for testing steel sheets for magnetic circuits of power electrical apparatus
IS-10028 (Part 1, 2 & 3)	-	Code of practice for selection, installation & maintenance of transformer
IS 3639 : 1966 (Reaffirmed Year : 2016)	-	Fittings and Accessories for Power Transformers
IS 3637 : 1966 (Reaffirmed Year : 2016)	-	Gas Operated Relays
IS 335 : 2018	-	New Insulating Oils — Specification (Fifth Revision)
IEC 60296-2020	-	Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment
IEC 60422 : 2013	-	Mineral insulating oils in electrical equipment - Supervision and maintenance guidance
IS 6792 : 2017	-	Insulating Liquids - Determination of the Breakdown Voltage at Power Frequency - Test Method (Second Revision)
IS/IEC 60137 : 2017	-	Bushings for alternating voltages above 1000 Volts
IS 12676 : 1989 (Reaffirmed Year : 2016)	-	Oil Impregnated Paper Insulated Condenser Bushings - Dimensions and Requirements

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

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

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

IEEE Standard C57.156-2016		Guide for tank rupture mitigation of oil immersed transformers
IEEE Standard C57.150-2012		Guide for Transformer Transportation
IEEE Standard C57.149-2012		Guide for the application and interpretation of Frequency Response Analysis of oil immersed transformers
IEEE Standard C57.104-2019		Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers
IEC 60599-2015		Mineral oil-filled electrical equipment in service - Guidance on the interpretation of dissolved and free gases analysis
IEEE Std. C57.12.10 - 2017		Standard requirements for liquid immersed power transformers
IEEE Std. 57.104-2019		Guide for the Interpretation of Gases Generated in Mineral Oil-Immersed Transformers
IEC 60599		Mineral oil-filled electrical equipment in service – Guidance on the interpretation of dissolved and free gases analysis
IEEE Std. 62-1995		Guide for Diagnostic Field Testing of Electric Power Apparatus - Part 1: Oil Filled Power Transformers, Regulators, and Reactors
CIGRE Technical Brochure No. 529 -2013		Guide lines for conducting design reviews for Power Transformers
CIGRE Technical Brochure No. 673-2016		Guide on Transformer Transportation
CIGRE Technical Brochure No. 530-2013		Guide for conducting factory capability assessment for Power Transformers
CIGRE Technical Brochure No. 761 (WG A2.49)		Condition assessment of power transformers
CIGRE TB 209		Short Circuit Performance of Power Transformers

CIGRE TB 436		Experiences in service with new insulating liquids
Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations		
Central Electricity Authority (Technical Standard for Construction of Electrical Plants and Electric Lines) Regulations		
Central Electricity Authority (Installation and Operation of Meters) Regulations		
CBIP Manual on Transformers (Publication No. 317)		
ISO 9001: Quality System – Model for Quality Assurance in Design/Development.		
ISO-14001 (Environmental Management System)		
OHSAS 18001 (Occupational Health and Safety Management System)		

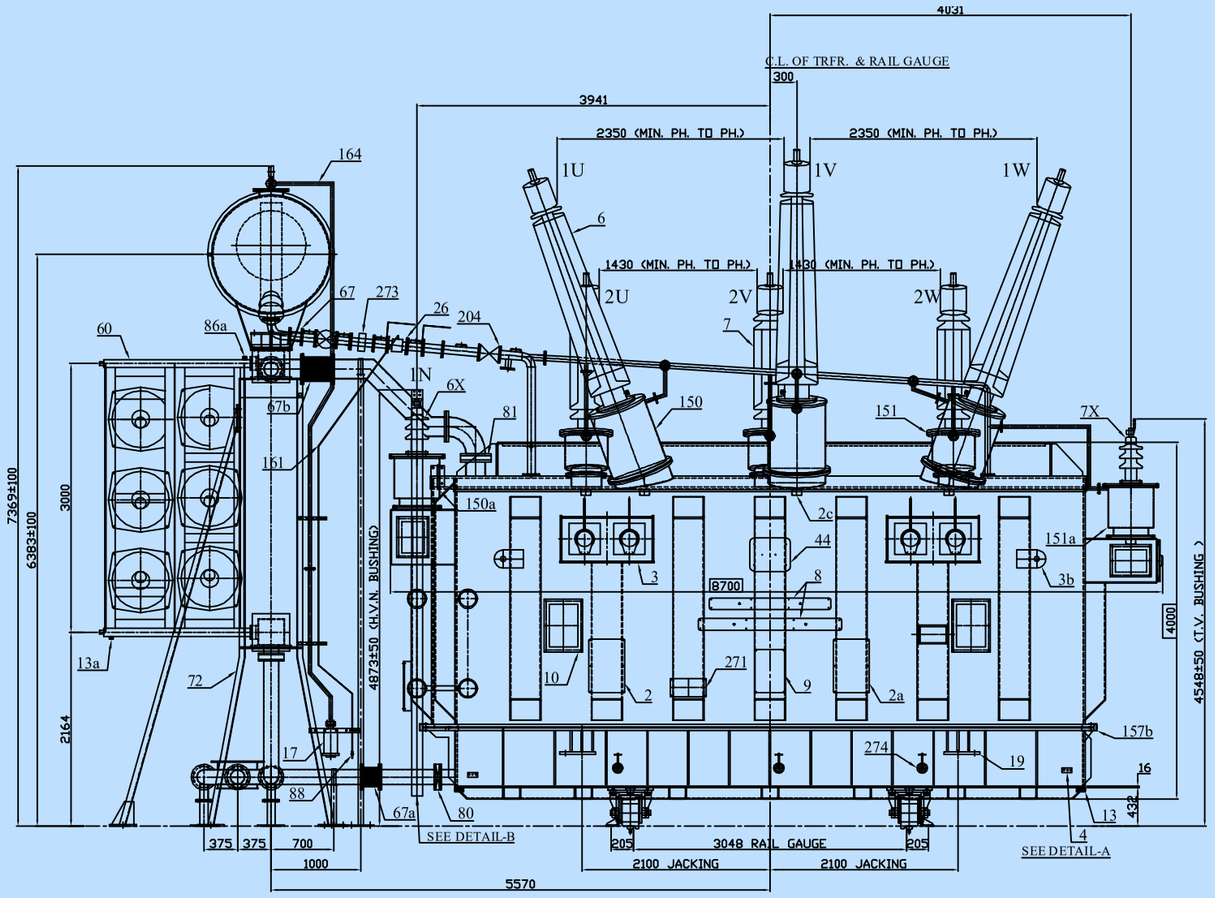
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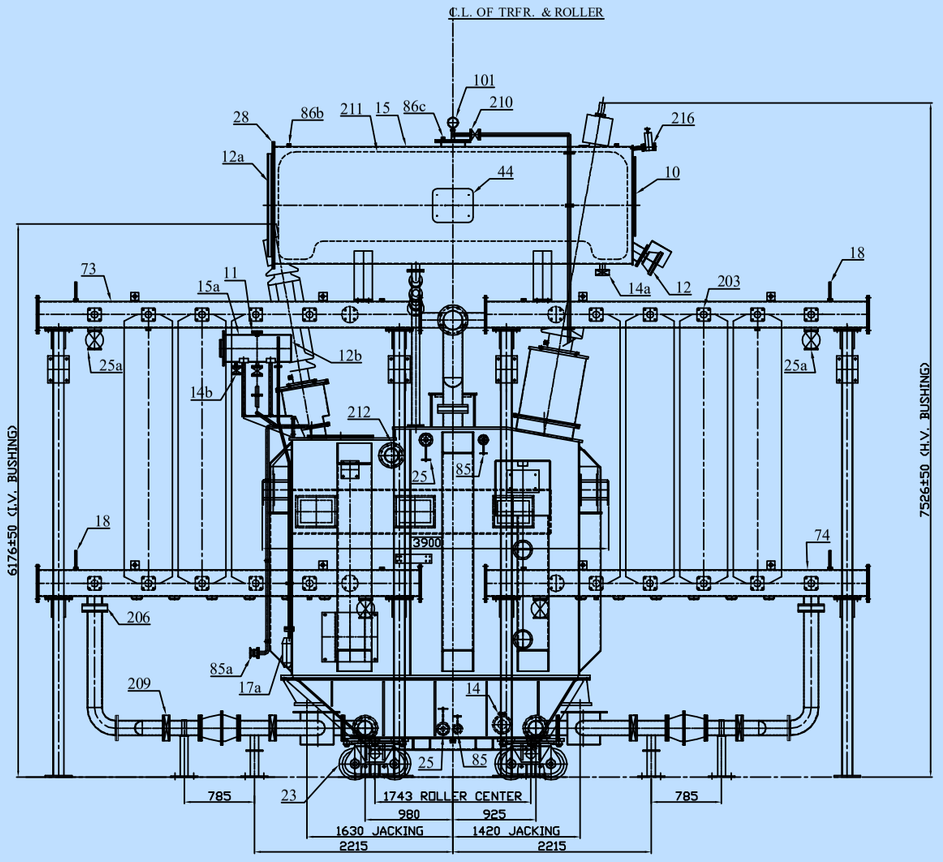
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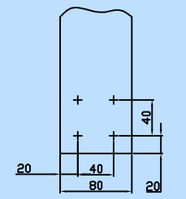
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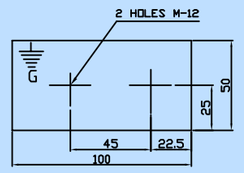
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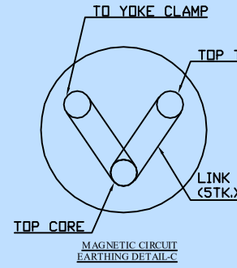




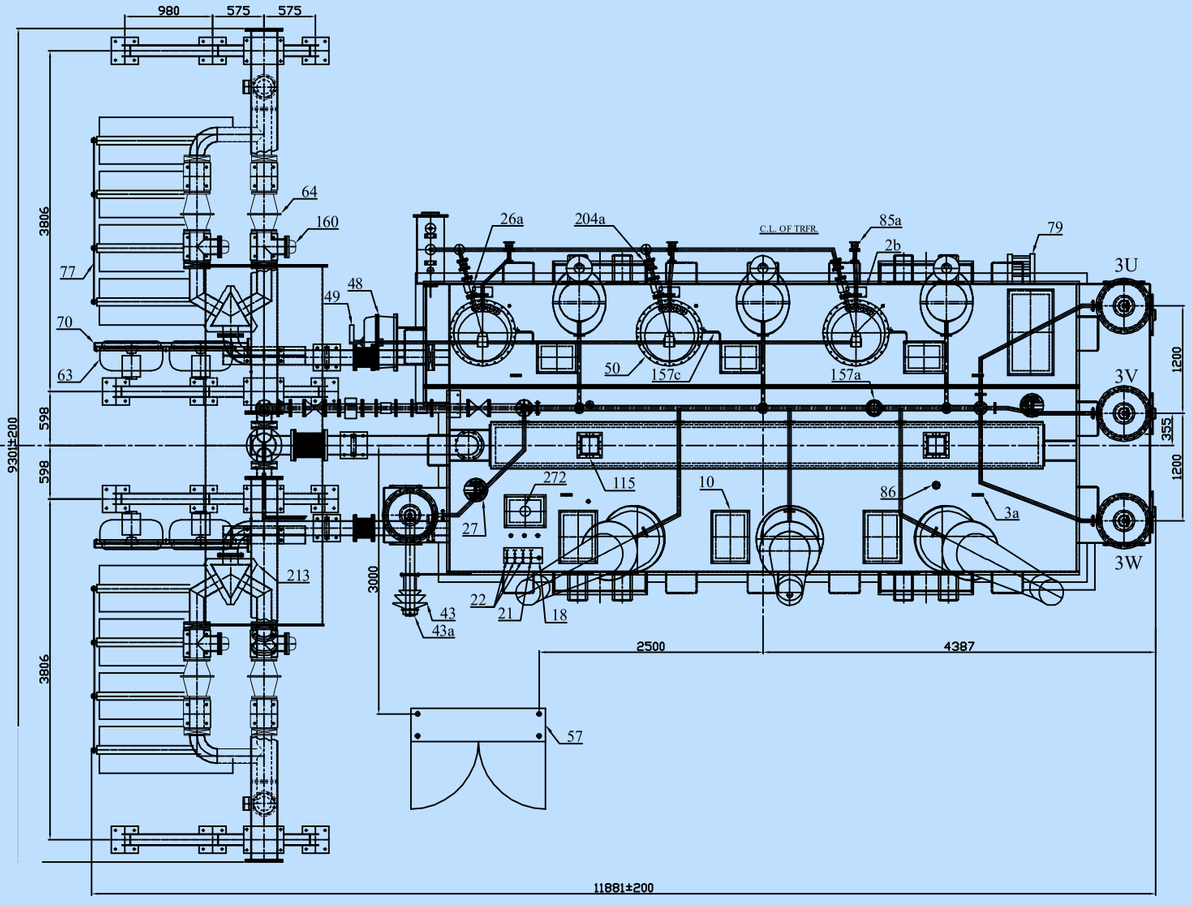
DETAIL-B

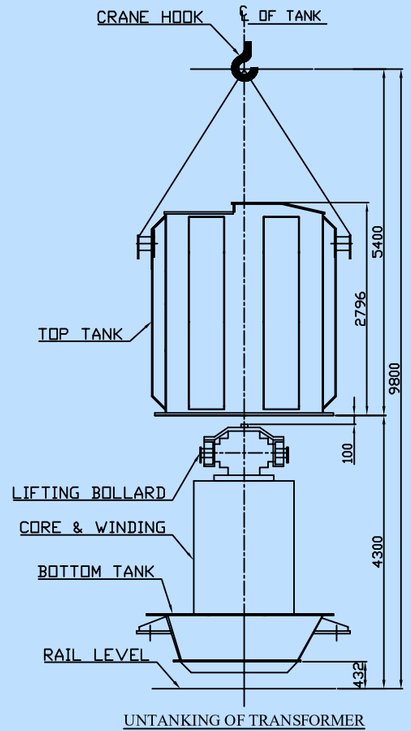


DETAIL-A

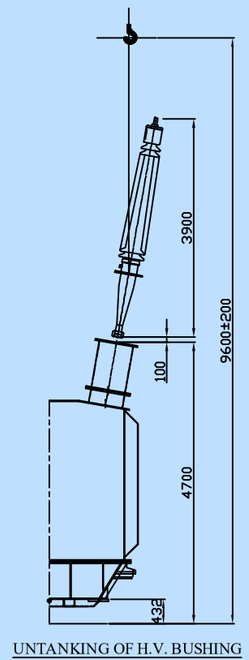


MAGNETIC CIRCUIT
EARTHING DETAIL-C





UNTANKING OF TRANSFORMER



UNTANKING OF H.V. BUSHING

TABLE OF FITTINGS

ITEM NO.	DESCRIPTION	QTY.
2	COMBINED RATING & DIAGRAM PLATE (HINDI & ENGLISH)	01NO.
2a	VALVE SCHEDULE PLATE	01NO.
2b	CAUTION PLATE FOR OLTC	01NOS.
2c	TERMINAL MARKING PLATE	16NOS.
3	LIFTINGS LUGS	04NOS.
3a	LIFTINGS LUGS ON TANK COVER	04NOS.
3b	LASHING LUGS ON TOP TANK	04NOS.
4	EARTHING TERMINAL	02NOS.
6	H.V. LINE TERMINALS 245 KV, 1250 AMP.	03NOS.
6x	H.V.NEUTRAL TERMINAL 36 KV, 2150 AMP.	01NO.
7	I.V. LINE TERMINAL 145 KV, 1250 AMPS.	03NOS.
7x	T.V. LINE TERMINAL 36 KV, 3150 AMP.	03NOS.
8	NAME PLATE (HINDI & ENGLISH)	01NO.
9	OIL FILLING INSTRUCTION PLATE	01NOS.
10	INSPECTION COVERS	16NOS.
11	OIL FILLING HOLES ON OLT.C. CONSERVATOR	01NO.
12	MAGNETIC OIL GAUGE (WITH LOW OIL LEVEL ALARM) FOR MAIN CONS.	01NO.
12a	PRISMATIC OIL GAUGE FOR MAIN CONS.	02NOS.
12b	PRISMATIC OIL GAUGE FOR OLTC CONS.	01NO.
13	DRAIN PLUG ON BOTTOM TANK	02NOS.
13a	DRAIN PLUG ON RADIATOR, HEADER & OIL REVERSE FLOW	14NOS.
14	DRAIN VALVE ON TANK (100 NB)	01NO.
14a	DRAIN VALVE ON MAIN CONSERVATOR (50 NB)	01NO.
14b	DRAIN VALVE ON OLTC CONSERVATOR (25 NB)	01NO.
15	OIL CONSERVATOR AIR CELL TYPE	01NO.
15a	OLTC CONSERVATOR	01NO.
17	ON LINE TYPE MAINTENANCE FREE BREATHER FOR MAIN CONSERVATOR	01NO.
17a	ON LINE TYPE MAINTENANCE FREE BREATHER FOR OLTC CONSERVATOR	01NO.
18	THERMOMETER POCKETS (WITH ALCOHAL THERMOMETER) ON TANK COVER & HEADER	07NOS.
19	JACKING LUGS	04NOS.
21	OIL TEMPERATURE INDICATOR	01NO.
22	WINDING TEMPERATURE INDICATOR WITH REPEATOR	03NOS.
23	FLANGE BI-DIRECTIONAL # 320 TWIN ROLLER WITH STOPPER ARRGT.	04NOS.
25	FILTER VALVE ON TOP TANK & BOTTOM TANK (50 NB)	02NOS.
25a	FILTER VALVE ON HEADER (50 NB)	04NOS.
26	BUCHHOLZ RELAY (80 NB)	01NO.
26a	OIL SURGE RELAY OLTC	02NOS.
27	PRESSURE RELIEF VALVE	02NOS.
28	END COVER FOR MAIN CONSERVATOR	01NO.
43	33 KV, POST INSULATOR	02NOS.
43a	HV NEUTRAL GROUNDING STRIPS	01NOS.
44	BILINGUAL COMPANY'S NONEPLATE (ON TANK & MAIN CONSERVATOR)	02NOS.
48	MOTOR DRIVING GEAR	01NO.
49	HAND OPERATING HANDLE	01NO.
50	ON LOAD TAP CHANGER	01NOS.
57	MARSHALLING KIOSK (GROUNDING MOUNTED)	01NO.
60	RADIATORS	08NOS.
63	24" FAN & MOTOR (01 NO. STANDBY + 05 NOS. RUNNING PER BANK)	10NOS.
64	OIL PUMP & MOTOR (1500LPM) (01 NO. STANDBY + 01 NO. RUNNING PER BANK)	04NOS.
67	FLEXIBLE JOINT (80 NB)	01NO.
67a	FLEXIBLE JOINT (150 NB)	02NOS.
67b	FLEXIBLE JOINT (200 NB)	01NO.
70	FAN SUPPORT	02NOS.
72	'A' FRAME (RADIATOR HEADERS SUPPORTS)	04NOS.
73	TOP HEADERS	02NOS.
74	BOTTOM HEADERS	02NOS.
77	RADIATOR TIE BAR	12NOS.
79	LADDER WITH SAFETY FLAP	01NO.
80	OIL INLET VALVE (150NB BUTTERFLY) ON TANK	02NOS.
81	OIL OUTLET VALVE (200 NB BUTTERFLY) ON COVER	01NO.
85	SAMPLING VALVE (25 NB) ON TOP TANK & BOTTOM TANK	02NOS.
85a	SAMPLING VALVE (25NB) FOR OLTC DIVERTER SVITCH	02NOS.
86	AIR RELEASE VALVE (15 NB) ON COVER	02NOS.
86a	AIR RELEASE PLUG ON RADIATORS & HEADERS,	12NOS.
86b	AIR RELEASE PLUGS (3/4" BSP) ON MAIN CONSERVATOR	02NOS.
86c	AIR RELEASE PLUG (1/4" BSP) ON MAIN CONSERVATOR	01NO.
88	BUCHHOLZ RELEASE COCK (6 NB)	01NOS.
101	PRESSURE GAUGE ON MAIN CONSERVATOR	01NO.
115	LOCKING ARRANGEMENT	02NOS.
150	H.V. TURRET (DETACHABLE)	03NOS.
150a	H.V. NEUTRAL TURRET	01NO.
151	I.V. TURRET (DETACHABLE)	03NOS.
151a	T.V. TURRET (DETACHABLE)	03NOS.
157a	EARTHING CONNECTION BETWEEN CORE TO END FRAME & END FRAME TO TANK	01NO.
157b	EARTHING CONNECTION BETWEEN TOP TANK TO BOTTOM TANK	02NOS.
157c	EARTHING CONNECTION BETWEEN TAP CHANGER TO TANK COVER	03NOS.
160	OIL FLOW INDICATOR 150 MM DIAL SIZE	04NOS.
161	BUCHHOLZ GAS RELEASE PIPE 6 NB	02NOS.
164	BREATHER PIPE	01NOS.
203	RADIATOR VALVE (80 NB BUTTERFLY)	16NOS.
204	CONSERVATOR VALVE (80 NB) FOR MAIN CONS.	02NOS.
204a	CONSERVATOR VALVE (25 NB) FOR OLTC CONS.	04NOS.
206	VALVE FOR DISCONNECTING RADIATOR BANK (150 NB)	04NOS.
209	VALVE FOR DISCONNECTING PUMP & MOTOR (150 NB)	08NOS.
210	VALVE (25 NB) FOR BREATHER CONNECTION ON MAIN CONSERVATOR	01NO.
211	FLEXIBLE SEPERATOR (AIR CELL)	01NO.
212	NIFPS DRAIN VALVE (150 NB)	01NO.
213	OIL REVERSE FLOW STOPPING DEVICE	02NOS.
215		
216	AIR CELL RUPTURE INDICATING DEVICE	01NO.
271	FIBER OPTIC TEMP. MONITORING SYSTEM	01NO.
272	FEED THROUGH PLATE FOR FIBER OPTIC SENSORS	01NO.
273	PRE STRESSED NON RETURN VALVE FOR NIFPS IN CONSERVATOR PIPE WORK	01NO.
274	NITROGEN INJECTION VALVE (25 NB)	06NOS.

KV	MIN. AIR CLEARANCES	
	PHASE TO PHASE	PHASE TO EARTH
H.V. 220	2350	2150
I.V. 132	1430	1270
T.V. 11	350	320

Typical GA Drawing of Transformer for reference and education purpose