सत्यमेव जयते
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
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दिनांक: 23.08.2019

विषय: Invitation of Comments on Draft of Standard Specifications of Transformers and Reactors (66 kV & above voltage class) - reg.

A Standardization Committee under the Chairmanship of Member (PS), CEA, was constituted vide Office order no. 10/24/2016-PG dtd. 20.10.2016, to adopt country-wide standard designs of Power Transformers and Reactors for each class, ratings and performance parameters wise. In this regard, various meetings were held periodically along with numerous communications with different Utilities/ Manufactures/ Stakeholders. After prolonged discussions and much deliberations on various aspects of the Transformer and Reactor design, the final draft of the 'Standard Specifications of Transformers and Reactors (66 kV & above voltage class)' has been prepared.

All the Utilities/ Manufactures/ Stakeholders are requested to send their comments on the draft by post or through e-mail [karan.sareen@gov.in] latest by 21st September, 2019.

(योगेन्द्र कुमार स्वर्णकार)
निदेशक

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

भारत सरकार
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Ministry of Power
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CONTENTS

CHAPTER -1

INTRODUCTION

Rapid growth of demand in electricity in India has necessitated commensurate growth in transmission network in India. Expansion of transmission network demands installation of transmission lines, new substations or augmentation of capacity of the existing substations. One of the key elements in commissioning of a new substation or augmentation of the existing capacity of any substation is Power Transformers. Varying load conditions on long lines has necessitated installation of shunt reactors to maintain voltage profile within limits. Just like transformer, shunt reactor is also very costly equipment and very similar in construction, which makes shunt reactor also one of the key elements. However, the time involved in design, engineering, manufacturing and commissioning process of transformers and reactors is very high. This is because the specification of each Transformer is unique and the manufacturers take time in meeting such specifications by doing specific design and subsequently manufacturing it.

To overcome this issue, process of standardization of technical specification of Power Transformers & Shunt Reactors was initiated with a view to have standard products and processes from Procurement to Commissioning and Life cycle management. This standardization process shall have following advantages:

- The procurement time shall be reduced
- Due to standard design, frequent design reviews shall be avoided
- Standard ratings shall be interchangeable across the utilities
- Standard fittings and accessories
- Standard layout and architectural features
- Lesser requirement of inventories

A committee vide Ministry of Power's office order no. 10/24/2016-PG dated 20.08.16, was constituted under the Chairmanship of Member (Power System), CEA, with the following composition:

1. Member (Power System), CEA
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.

In this process, CEA held several round of meetings with various utilities and transformer & accessories manufacturers for standardization of Technical Specification of Transformer and Reactor so that all utilities across the country should be benefitted and have standard process from procurement to commissioning of Transformers and Reactors.

The objective of such a Manual is to get a quality Transformer/ Reactor in less time by optimizing the design thus benefiting the manufacturers on the overall cost of production and the utilities on the reliability of the Transformers/Reactors.

This manual shall be applicable for transformers/reactors of 66 kV and above voltage class. Although some ratings of generator transformers could not be decided due to certain technical limitations, the utility may follow this manual for such GTs also as far as possible.

Our first attempt was to try to limit the number of ratings of Power Transformers and Reactors so that utilities and manufacturers shall have fewer numbers of ratings to choose from for installation and replacement. Manufacturer also shall have to design and manufacturer fewer ratings making it easier to have less inventory of components and improved manufacturing time.

Primary voltage rating for Generator Transformers (GTs) can not be standardized as this rating is dependent on generator parameters. However, MVA ratings of GTs for thermal plants have been fixed. MVA rating for GTs for Hydro plant may be decided by the respective utility.

Following ratings for power/auto transformers, generator transformers and reactors of 66 kV and above have been standardized based on general practice and most used ratings in India. Utilities should, as far as practically possible, procure transformers and reactors of these ratings only. Transformers/reactors of other ratings should be procured only under special circumstances such as transportation/ space constraints or to match with the existing transformer unit for parallel operation.

Power/ Auto Transformer:

Sr.No	MVA	Line Voltage Rating	Phase	Type
1.	500 MVA	765/400/33kV	Single Phase	Auto
2.	500 MVA	400/220/33kV	Three Phase	Auto
3.	315 MVA	400/220/33kV	Three Phase	Auto
4.	315 MVA	400/132/33kV	Three Phase	Auto
5.	200 MVA	400/132/33kV	Three Phase	Auto
6.	167 MVA	400/220/33kV	Single Phase	Auto
7.	105 MVA	400/220/33kV	Single Phase	Auto
8.	200 MVA	220/132/33kV	Three Phase	Auto
9.	160 MVA	220/132/33kV	Three Phase	Auto
10.	100 MVA	220/132kV	Three Phase	Auto
11.	160 MVA	220/66kV	Three Phase	Power
12.	80MVA	220/33kV	Three Phase	Power
13.	100 MVA	132/66kV	Three Phase	Auto
14.	50 MVA	132/33kV	Three Phase	Power
15.	31.5 MVA	132/33kV	Three Phase	Power
16.	31.5MVA	66/11kV	Three Phase	Power
17.	20MVA	66/11kV	Three Phase	Power

Generator Transformer:

Sr.	MVA Rating	Line Voltage Rating	Phase	Type
1.	315 MVA	Generation Voltage/420 kV	Single	GT
2.	265 MVA	Generation Voltage/420 kV	Single	GT
3.	265 MVA	Generation Voltage/420 kV	Single	GT
4.	200 MVA	Generation Voltage/420 kV	Single	GT
5.	315 MVA	Generation Voltage/245 kV	Three	GT
6.	105MVA	Generation Voltage/420 kV	Single	GT

Shunt Reactor:

Sr.	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.	25 MVAR	245kV	Three Phase

In order to ensure uniformity in design of transformers/ reactors, technical specification have been standardized and covered under **Chaper-2: Technical Specifications for Transformers and Reactors** and the major technical parameters of single phase & three phase transformer & reactor units and current transformers are defined at **Annexure – A & B**. The utilities are expected to follow the specifications fixed as far as possible so as to bring uniformity to the Transformers/ Reactors deployed in India. However, the specifications provided in the Manual are intended only for new Transformers/ reactors. For parallel operations, specifications of existing Transformer may be used.

Along with standardizing the design, we have also endeavored to fix the maximum permissible loss values (No-load loss, Load loss, I^2R loss and auxiliary loss) for the Transformers in consultation with numerous utilities and lead manufacturers such that these losses are easily measured and verified at works and at site and utility is provided with high efficiency product. It is planned to keep these losses fixed at least for the next 5 years and may be revised afterwards based on experience attained by the utilities and the manufacturers. This will reduce the number of variants of Transformers and reactors to be manufactured for the field. This will bring financial benefit as well as save time. Need for Dynamic short circuit testing may also be reduced due to freezing of design and loss values.

Keeping in view the large number of failures owing to improper maintenance and sudden use of OLTC after a long period of disuse, we have tried to have tap-less transformers at 400 kV and 765 kV levels. The change in voltage offered by OLTC in such cases is very minimal and doing away with OLTCs would not only lead to a simpler design but would also reduce the number of failures due to OLTC.

It has been observed by CEA while investigating failures of transformers and reactors that most of these equipment fail during first 5 years of service. A warranty/defect liability period of 5 years for transformer/ reactor have been proposed so that manufacturer pay full attention to the quality aspect of the equipment and failure rate is reduced. However, this warranty period should not make utilities complacent to carry out regular Operation & Maintenance activities.

Design review is the most important task to be carried out before initiation of the manufacturing of transformer/reactor to ensure its quality. **Chapter-3 : Design Review** details all the necessary steps required for the design review and also includes list of documents required to be submitted by the manufacturer to the purchaser. The design review may be carried out by the purchaser or a consultant appointed by the purchaser. Design review, if done by one utility, may also be used by another utility with the permission of the manufacturer.

Annexure-C (Guaranteed and other technical particulars) lists out all the parameters which are required to be specified by the manufacturer to the purchaser for design review and other necessary action.

Attempt is also made with the aid of various prominent stakeholders to have a standardized QAP so as to ensure that all necessary tests required to ensure the quality of the offered Transformer/ Reactor are carried out as per standard uniform manufacturing quality plan by the purchaser. The outcome of this activity has been prepared in the form of the **chapter-4: Quality Assurance Program**. A typical test plan for Transformers/ Reactors have also been listed in **Annexures D**.

General Arrangement drawing and foundation drawings are also standardized to improve the interchangeability of different units, thus reducing the delay in commissioning, as well as optimizing the requirement of spares and have been provided at **Annexure-P**. Similarly, GA drawing specifically for Hydro Plants has been provided at **Annexure-Q**. Standardizing the layout of foundation of Transformers and cooler banks as well as general layout will bring uniformity, which, in turn, would facilitate replacement and retrofitting as per requirement.

With a view to standardize the handling, loading-unloading, transportation, storage etc., we have included a chapter on **'Transportation, Erection, Testing and Commissioning'** as well. It shall act as a model document for the utilities' reference. However, the utilities may frame the contractual obligations including the scope of transportation, erection, commissioning etc. and modify the document in that regard accordingly as per their requirement.

The manufacturers are expected to develop their manufacturing facility at par with the global practices to improve quality and manufacturing processes for transformer and reactor. The list of facilities required by manufacturers has been provided in **Annexure-G.** In case the manufacturers do not have the required facilities as given, it may be ensured by the manufacturers that the same may be developed within a specified time-frame.

To promote the best practices among the utilities and to bring O&M practices throughout all the utilities in the country to a common highest level, a chapter, '**Condition Monitoring & Life Cycle Management'**, on the subject has been included. Provisions shall be made by the utilities for condition monitoring and health assessment of their Transformers/ reactors. Although no such recommendation has been given by us, utilities may procure and employ diagnostic equipment like DGA, wingding resistance meter, SFRA, capacitance and tan delta measuring units etc. as per requirement of CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations and their discretion either for a substation or cluster of substations. All necessary steps shall be taken to ensure proper monitoring and maintenance of Transformer/ Reactor for their longevity without any interruptions. Suggestive limits for parameters measured with the help of various diagnostic equipment are also given in the chapter. Values of these parameters shall be recorded over time, since the time of commissioning, to carry out a trend analysis. Health indexing of Transformer/ Reactor based on various indicators derived through condition based analysis shall be carried out for residual life assessment and for taking Run/Refurbish/ Replacement decision.

Specification for Breakdown Voltage (BDV) test set, portable DGA kit for transformer oil and online insulating oil drying system has been included in **Annexure-T & U** for the reference of the utility.

Since the Manual only covers Transformers and Reactors, no specification for fire- fighting provisions have been given. But, the utilities shall ensure that their substation have capable and efficient fire-fighting provisions adhering to CEA (Measures Relating to Safety and Electric Supply) Regulations.

As per CEA Regulations, one no. single phase spare transformer/reactor is required to be provided for the substations/switchyards where bank of single phase units has been installed. For reference purposes, connection arrangement for bringing spare unit into the circuit in case of failure of one of the other units is given in **Annexure N.**

Failure of GT/ Power Transformers leads to huge loss in terms of revenue, time, reliability of the system and the requirement of additional transformer leads to additional capital, material for manufacturing/ commissioning and time requirement for replacement. Also, due to long repair time of Transformers, utilities have to maintain capital spare which is costly and in the absence of required care and maintenance, may fail without ever being utilized, incurring further loss. Standardization will be a big step in reducing these difficulties.

There have been some concerns that freezing the design as well as loss figures would leave no jiggling room for the designers. There is a wide array of available raw materials and technology. Lack of fixed parameters leaves lots of possibilities to cut down on the price by compromising on quality. As utilities, more often than not, are only equipped to check a few parameters to ascertain the quality of the product they purchase, cost inadvertently governs the process during the design stage. Similarly, designers may find it difficult to justify any additional cost on account of modification in technology or material. Freezing of these parameters helps to ensure that at the least a certain level of quality is available to the utilities while at the same time allowing the designers to implement and execute their innovative ideas and help in design improvement. Aside from tangible benefits, this will help in strengthening the relation between the manufacturers and the utilities by removing any apprehension of being underpaid or overcharged as well as any distrust on the quality of the unit/ product received.

In course of various tasks of CEA, it has been brought to our attention that a significant number of transformers fail due to poor workmanship during installation. At the same time, poor operation and maintenance is also a culprit. After extensive deliberation and discussions with various stakeholders, we have tried to determine the best practices for transportation, testing, commissioning and life cycle management of the Transformers as a guideline for both manufacturers and utilities. Once on-site, the standardized transformer design will reduce the dependency on the skill and experience of man-power during installation and commissioning. This is not to say that such skill will not be required but that due to standardized design, installation process will also become defined thereby limiting the chances of error by removing any ambiguities for the workforce on site. At the same time, the standardization of O&M practices will equip the operating personnel to better handle and manage their Transformers and Reactors.

In the end, the purpose of this document is to bring uniformity in the design as well as O&M practices throughout the country to promote faster and efficient production and inter-changeability of transformers as well as reactors in general. It is expected that all utilities should follow this manual and will endeavor to achieve the goal **"One Nation One Specification"**.

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 Sixty (60) months warranty shall be provided for transformers and reactors from the date of commissioning or 12 months from the date of receipt at site whichever is earlier. For the purpose of this clause, the Measurable Defects as per the Technical Specifications shall also be considered for Transformer and Reactor.

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

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

1.5 Components having identical rating shall be interchangeable.

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

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 only these ratings of Transformers & Reactors are procured by utilities to have standard ratings across the country.

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 output from generator voltage to specified voltage for power evacuation. Generator Transformer should be suitable for back charging from HV side and should be used to step down 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 shall come into operation by pre-set contacts of winding temperature indicator and the transformer shall operate as a forced cooling unit initially as ONAF up to specified load and then as OFAF (or ODAF or ODWF, as specified). Cooling shall be so designed that during total failure of power supply to cooling fans and oil pumps, the transformer shall be able to operate at full load for at least ten (10) minutes without the calculated winding hot spot temperature exceeding 140 deg C. If the Transformer is fitted with two coolers, each capable of dissipating 50 per cent of the loss at continuous maximum rating, it shall be capable of operating for 20 minutes in the event of failure of the oil circulating pump or blowers associated with one cooler without the calculated winding hot spot temperature exceeding 140 deg C at continuous max rating. 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 (including spare) are in operation.

5.1.4 The transformers shall be capable of being continuously operated 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 95 deg. 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 without damage, the thermal and mechanical effects of any external short circuit to earth and of short circuits at the terminals of any winding. The transformer (power/auto) shall be designed to withstand the thermal stress for short circuit duration of 2 seconds and the same shall be verified during design review. However, generator transformer shall be designed to withstand the thermal stress for short circuit duration of 3 seconds.

5.1.9 The short circuit level of the HV & IV System to which the transformers will be connected is as follows:

5.1.10

765kV system	- 63kA for 1 sec (sym, rms, 3 phase fault)
400kV system	- 63kA 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)
33kV & 11kV system	- 25 kA for 3 sec (sym, rms, 3 phase fault)

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

5.1.11 Transformer shall be capable of withstanding thermal and mechanical stresses caused by symmetrical or asymmetrical faults on any terminals. Mechanical strength of the transformer shall be such that it can withstand 3-phase and 1- phase through fault for transformer 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. The maximum short circuit output current at the tertiary terminals shall be limited to a safe value to make the transformer short circuit proof.

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

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

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

5.1.13 The air core reactance of HV winding of transformer shall not be less than 20% for 400kV and above voltage class Transformer.

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.

5.3 Shunt Reactor

5.3.1 Shunt reactors will be connected to the transmission system for reactive compensation and shall be capable of controlling the dynamic over voltage occurring in the system due to load rejection.

5.3.2 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 dynamic conditions which may cause additional current flow as a result of changed saturation characteristics/slope beyond 1.5 p.u. voltage.

5.3.3 Shunt reactors of 420kV & 800kV Class shall be capable of operating continuously at a voltage 5% higher than their rated voltage without exceeding winding hot spot temperature 140 Deg C. Shunt Reactors of 245kV Class and below shall be capable of operating continuously at a voltage 10% higher than their rated voltage without exceeding winding hot spot temperature 140 Deg C. Maximum ambient temperature shall be considered as 50 Deg C.

5.3.4 The reactor shall be designed to withstand the following over-voltages repeatedly without risk of failure (w.r.t. Hotspot temperature & core saturation):

1.05 Ur for continuous (for 420kV & above Class Reactor)
1.10 Ur for continuous (for below 420kV Class Reactor)
1.25 Ur for 1 minute
1.50 Ur for 5 seconds
(Ur is rated voltage of reactor)

5.3.5 The winding hot spots shall be calculated using the maximum localized losses, insulation thickness at the maximum loss positions, 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.

5.3.6 The hot spot temperatures and surface temperatures in the magnetic circuit (core) shall be calculated with maximum allowed 125 deg C and 120 deg C respectively under over voltage conditions specified above.

5.3.7 Tank hotspot temperature under over voltage condition specified above shall not exceed 95 Deg C considering maximum ambient temperature as 50 Deg C.

5.3.8 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.

5.3.9 The magnetic circuit shall be designed such that the 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 so as to minimise interference with communication circuit.

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 values of losses at principal tap rating at full load at 75 deg C have been specified in Annexure-A for the ratings covered under this specification. The losses shall be firm and no positive tolerance shall be allowed. No weightage shall be given for supply of transformer/reactor, with losses (measured during routine tests) less than the losses specified in Annexure –A.

7.0 Dynamic Short Circuit Test requirement and Validity

The transformer of design similar to the offered transformer (meeting requirement as per Annexure-J) should have been successfully tested within last 10 years (from the originally scheduled date of bid opening) for short circuit withstand capability as per IEC 60076-5/ IS 2026 Part-5 and shall enclose the relevant Test Report/certificate along with bid. In case, manufacturer has not conducted short circuit test earlier, the same shall be carried out on offered transformer. Further, design review of offered transformer shall be carried out based on the design of short circuit tested reference transformer in line with IEC 60076-5/ IS 2026 Part-5.

8.0 Type tests requirement and validity

The offered transformer/reactor should have been successfully type tested unless the type tests on transformer/reactor of same rating & design have been carried out within last 5 years from the originally scheduled date of bid opening. The earlier conducted type test reports are acceptable provided offered transformer/reactor is of the same design as that of type tested transformer and active materials like – CRGO, copper conductor and insulation material are of same or better grade with respect to type tested unit, failing which type tests on offered transformer/reactor shall be carried out by the manufacturer at his own cost. However, manufacturer may use same or different approved make of Bushings, On Load Tap changer (OLTC)/Off Circuit Tap Changer (OCTC) and other accessories used in type tested or short circuit tested unit in their equipment. Further, type test report of transformer/reactor from the same manufacturing plant shall only be acceptable.

The validity of type test of major fittings shall be 10 year from the date of testing.

The type tests conducted earlier should have either been conducted in accredited laboratory by the national accreditation body of the country where the laboratory is located, or witnessed by the representative of any utility or of an accredited test laboratory.

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 "Guidelines for conducting design reviews for power transformers working group A2.36 Task Force 2" (Replaces TB 204). However, salient points on process for 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 for mechanical strength and durability due to inrush current. The latest recommendations of IEC and CIGRE SC 12 shall be applied for short circuit withstand evaluation.

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 Measurable Defects

The following shall constitute as Measureable Defects for the purpose of Defect Liabilities. The violation of any of the following within warrantee period, manufacturer shall be liable to extend warrantee period of further 2 years in addition to the original warrantee period of 5 years.

a) Repair, inside the Transformer/Reactor and OLTC (including oil migration) either at site or at factory is carried out after commissioning.

b) The concentration of any fault gas is more than values of condition-1 indicated in clause no 6.5 of IEEE-C57.104-2008, which are as detailed below.

H_2	CH_4	C_2H_2	C_2H_4	C_2H_6	CO	CO_2	TDCG
100	120	1	50	65	350	2500	720

c) The winding tan delta goes beyond 0.005 or increases more than 0.001 w.r.t. pre-commissioning values within warranty period. No temperature correction factor shall be applicable for tan delta.

d) The moisture content goes above 12 ppm at any temperature during operation including full load.

11.0 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)	Yearly weighted average cooling air ambient temperature	
iii)	Monthly average cooling air temperature of hottest month	
iv)	Minimum cooling air temperature	
v)	Wave shape of supply voltage	
vi)	Total Harmonic current	
vii)	Seismic ground acceleration	
viii)	Combined voltage and frequency variation	
ix)	winding pressure	
x)	Maximum humidity	
xi)	Minimum humidity	
x)	Creepage of insulation in air	

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

12.0 Construction Details

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

12.1 Tank

12.1.1 The tank shall be of proven design of conventional (preferably)/ Bell type with welded / bolted top cover. Bell type tank, if provided, shall have joint at about 500 mm above the bottom of the tank.

12.1.2 Tank shall be capable of withstanding without damage severe strains that may be induced under normal operating conditions or during lifting, jacking and pulling forces encountered during shipping and handling at site or factory. Tank and associated structure should be adequately designed for forces arising out of normal oil pressure, test pressures and seismic conditions, short circuit forces specified.

12.1.3 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 BS-4360 / IS 2062.

12.1.4 All seams and joints which are not required to be opened at site, shall be factory welded, and wherever possible they shall be double welded. Welding shall conform to BS-5135/IS 9595. The requirement of post weld heat treatment of tank/stress relieving shall be based on recommendation of BS-5500 table 4.4.3.1/IS 10801.

12.1.5 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.

12.1.6 Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water. Sharp edges on stiffeners should be avoided for better paint adhesion.

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

12.1.8 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.

12.1.9 The base of each tank shall be designed such that the complete transformer may be moved by skidding in any direction without damage when using plates or rails.

12.1.10 Tank should be provided with adequately sized manhole(s) to enter inside for active part inspection preferably at diagonally opposite sites either in circular shape or in rectangular shape.

12.1.11 Tank shall be provided with:

a. Lifting lugs: Minimum four 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.

b. A minimum of four jacking pads in accessible position to enable the transformer complete with oil to be raised or lowered using hydraulic jacks. Each jacking pad shall be designed to support with an adequate factor of safety at least half of the total mass of the transformer filled with oil allowing in addition to maximum possible misalignment of the jacking force to the centre of the working surface.

c. Suitable haulage holes shall be provided.

d. 04 nos. of Gate valves of 50 NB (min.) shall be provided for UHF sensors for PD Measurements (applicable for 400kV and above voltage class Transformer only) at suitable locations. Location of valves shall be finalized during design review. Further, manufacturer shall demonstrate PD measurement with use of 04 nos. of UHF sensors using the same gate valves during Type test under each contract. However, scope of supply of UHF based PD measurement system shall be applicable if specified by the utility.

e. Suitable provisions of pockets for OTI, WTI & RTDs including two spare pockets.

12.2 Tank Cover

12.2.1 Tank cover shall be capable of withstanding without damage severe strains that may be induced under normal operating conditions or during shipping and handling at site or factory. Cover should be capable of withstanding without damage or permanent deformation the collapsing forces produced by completely evacuating the tanks for vacuum filling. Cover shall be either plain or curved or slanted, to prevent retention of rain water & it shall be designed for efficient movement of fault gas to Buchholz relay.

12.2.2 For anti-fall protections, cover shall be provided with permanent mounting brackets provision as the points of attachment for a temporary detachable safety pole of minimum 1 m height. Safety poles to be supplied along with each transformer, for hooking safety harness by operator, if specified by purchaser. These poles shall be removed by the operators, during transformer/reactor working conditions. Cover should have anti-skidding arrangement.

12.2.3 At least two adequately sized inspection openings, one at each end of the tank shall be provided for easy access to bushings and earth connections & tap changers. Tank cover should be provided with hand holes either in circular or rectangular shape. The inspection cover shall not weigh more than 25kgs. Handles shall be provided on the inspection cover to facilitate its lifting.

12.2.4 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 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.

12.2.5 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.

12.2.6 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.

12.2.7 To allow for the effect of possible induced and capacitive surge current flow, 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.

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

12.2.9 **Gas venting**

The transformer/reactor cover and generally the internal spaces of the transformer and all pipe connections shall be designed so as to provide efficient venting of any gas in any part of the transformer/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.

12.3 Gasket for tank & cover

All gasketed joints shall be designed, manufactured and assembled to ensure long-term leak and maintenance free operation. All gasketed joints shall preferably of O-ring and groove type. All tank gaskets/O-rings used shall be of NBR (Acrylonitrile butadiene Rubber) conforming to IS 4253. Material selected shall suit temperature conditions expected to be encountered at the site.

All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. If gasket/O-rings is compressible, metallic stops/other suitable means shall be provided to prevent over-compression. The properties of all the above gaskets / O-Rings shall comply with the requirements of IS-11149. Gaskets and O-rings shall be replaced every time whenever the joints are opened.

12.4 Foundation, Roller Assembly and Anti Earthquake Clamping Device

Transformer/reactor shall be rested on foundation on roller assembly. The rollers 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/reactor. The rail track gauge shall be 1676 mm. To prevent movement during earthquake, suitable clamping devices shall be provided for fixing the transformer/reactor to the foundation. In case rail is not required for smaller rating transformers/reactor, arrangement of unidirectional roller mounted on channel shall be provided and channel shall be locked with the plinth suitably.

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

For support of cooler pipes, Buchholz pipe (if required) 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.

All control cubicles shall be mounted at least 1 (One) meter above FGL to take care of water logging during flooding. Suitable arrangement (ladder and platform) shall be provided for safe access to control cubicles.

12.5 Conservator

12.5.1 Main tank conservator 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.

12.5.2 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 110 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.

12.5.3 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.

12.5.4 Conservator shall be positioned so as not to obstruct any electrical connection to transformer.

12.5.5 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".

12.5.6 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 110 Deg C during operation. As such air cell used shall be suitable for operating continuously at this temperature.

12.5.7 The transformer/reactor manual shall give full and 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.

12.5.8 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.

12.5.9 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.

12.5.10 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.

12.6 Piping works for conservator

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

12.6.2 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 5 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.

12.6.3 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.

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

12.7 Dehydrating Silicagel Filter Breather

Conservator of Main Tank and OLTC shall be fitted with a dehydrating silicagel filter breather. 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 silicagel.

b) Silicagel 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 transformer/reactor and two breathers (of identical size) for below 220kV transformer/reactor shall be connected in series for main tank conservator. Manufacturer shall provide flexible connection pipes to be used during replacement of any silicagel breather.
f) To minimise the ingress of moisture, two in series of identical size shall be connected to OLTC Conservator. Manufacturer shall provide flexible connection pipes to be used during replacement of any silicagel breather.

12.8 Pressure Relief Device (PRD)

One PRD of 150 mm Diameter is required for every 30000 Litres of oil. However, at least two numbers PRD shall be provided. Its mounting should be either in vertical or horizontal orientation, preferably close to bushing turret or cover or side. 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 bottom 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 and 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

12.9 Sudden Pressure Relay (for 220kV and above transformer/reactor)

One number of Sudden Pressure relay with alarm/trip contacts (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.

12.10 Buchholz Relay

Double float, reed type Buchholz relay shall be provided in series of the connecting 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.

12.11 Oil Temperature Indicator (OTI)

The transformer/reactor shall be provided with a 150 mm dial type thermometer for top oil temperature indication with angular sweep of 270°. Range of temperature should be 0-150°C with accuracy of ±1°C. The instruments should be capable of withstanding line to body 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, 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 240A AC. 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 ingress protection class 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 OTI instrument by means of flexible stainless steel armour to protect capillary tubing with additional Stainless steel armour to reinforce at the entry to the case. 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.

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 IEC 60751-2 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 IEC 61850 compliant communications.

12.12 Winding Temperature Indicator (WTI)

The transformer/reactor shall be provided with a 150mm dial type hot spot indicator 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°C. The instruments should be capable of withstanding line to body 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's, 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 240A AC. 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 ingress protection class 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 with additional Stainless steel armour to reinforce at the entry to the case. 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.

In addition to the above, the following accessories shall be provided for remote indication of oil 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 IEC 60751-2 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 IEC 61850 compliant communications.

The temperature indicators (OTI & 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.

12.13 Optical sensors & temperature measuring unit (for 400kV and above rating Transformer/Reactor)

Optical temperature sensors shall be fitted on each transformer/reactor unit. Minimum number of probes shall be as per following:

Rated power MVA	Cooling system	Number and phases of installation								
		Total	On central phase			On each lateral phase			Core (Top)	Top Oil
			HV winding	IV winding	LV winding	HV winding	IV winding	LV winding		
3-Ph rating	All system	14	2	2	2	1	1	1	1	1
1-Ph rating	All system	8	2	2	2	-	-	-	1	1

However, the number of sensors (more than the above) in all windings (HV, IV, LV) and other locations to be mounted is left to agreement between manufacturer and purchaser.

The optical sensors measuring system shall be of direct measurement non-calibrating type. All the sensors shall be brought out to separate optical sensor box or in Individual Marshalling Box mounted on transformer/reactor tank.

In order to facilitate measurement of temperature from the optical sensors, temperature-measuring unit/system having at least 16 channels shall be mounted inside the separate optical sensor box or Marshaling Box for each Transformer/reactor unit**.** The measuring unit shall be capable to retain temperature data for at least 30 days with facility to download these data.

Temperature measuring unit/system shall be suitable for satisfactory operation with ambient conditions and IEC 61850 compliant to interface with Purchaser's SCADA system through FO port.

Location of optical temperature sensors inside the transformer/reactor shall be decided during design review.

The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.

12.14 Earthing Terminals

12.14.1 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.

12.14.2 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. double earthing shall be provided through the tank for which provision shall be made through tank and connected through two flexible insulated copper link.

12.14.3 Equipotential flexible copper link of suitable size at least 4 Nos. for Tank mounted turret with tank and tank with cover and or Bell shall be provided. For other components like - pipes, conservator support etc. connected to tank shall also be provided with equipotential flexible copper link.

12.14.4 Each transformer/reactor unit should have provision for earthing and connected to grounding mat when not in service. For this purpose, neutral shall have provision for connection to ground by a brass/tinned copper grounding bar supported from the tank by using porcelain insulator. The end of the tinned/brass copper bar shall be brought to the bottom of the tank at a convenient point for making bolted connection to 75 X 12 mm GS flat connected to station grounding mat. The other end of the tinned/brass copper bar shall be connected to the neutral bushing through flexible conductor/jumper. HV & IV terminals shall also be earthed through neutral by flexible copper connection. Contractor shall provide suitable arrangement for the above.

12.15 Core

12.15.1 The core shall be constructed from non-ageing, cold rolled high permeability grade or better grain (as per IS 3024) oriented silicon steel laminations. Indian transformer manufacturers shall use core material as per above specification with BIS certification.

12.15.2 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 noise, no-load current and no-load loss performance.

12.15.3 The temperature of any part of the core or its support structure in contact with oil shall not exceed 120 deg C under normal operating condition and 130 deg C under 10% over voltage and maximum ambient air temperature conditions of 50 deg C. Adequate temperature margin shall be provided to maintain the long life expectancy for this material.

12.15.4 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.

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

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

12.15.7 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.

12.15.8 Adequate lifting lugs shall be provided to enable lifting of entire active part.

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

12.15.10 Single point core earthing should be ensured to avoid circulating current. Core earth should be brought separately 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 ≥ 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.

12.15.11 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.

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

12.15.12 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.

12.15.13 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.

12.15.14 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.

12.15.15 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.

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

12.15.17 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.

12.15.18 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.

12.15.19 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.

12.15.20 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.

12.16 Windings

12.16.1 The manufacturer shall ensure that windings of all transformers are made in dust proof (Cleanroom class ISO 9 or better as per ISO 14644-1) and air conditioned atmosphere.

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

12.16.3 The conductor insulation shall be thermally upgraded type 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.

12.16.4 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.

12.16.5 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.

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

12.16.7 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.

12.16.8 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.

12.16.9 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 >0.75g/cc.

12.16.10 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.

12.16.11 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. When multiple blocks are used, the blocks shall be separated with glued washers. If the axial key spacer height space is more than 50mm, it shall be separated by full circumference washers to maintain mechanical stability of the winding. 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.

12.16.12 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.

12.16.13 Winding paper moisture shall be less than 0.5%.

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

12.16.15 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 due to line to line and line to ground Short circuits. Manufacturer shall have system which allows only qualified personnel to make brazing or crimping joints.

12.17 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.

12.18 Winding terminations into bushings

12.18.1 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.

12.18.2 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.

12.18.3 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.

12.18.4 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.

12.18.5 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.

13.0 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.

14.0 Insulating Oil

The insulating oil shall be virgin high grade inhibited, conforming to IEC 60296 & 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 inhibited 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.

Sufficient quantity of oil necessary for maintaining required oil level in case of leakage in tank, radiators, conservator etc. till the completion of warranty period shall be supplied.

Inhibited 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.

Utilities may use uninhibited insulating oil or Ester (synthetic / natural) fluid for Transformer/Reactor as per their requirement. New generation insulating oils incorporating different process like- Gas to liquid, oil with increased molecular weight resulting in benefits like – higher flash point, increased purity etc. may also be considered based on utilities / transformer manufacturer's experience.

14.1 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.

15.0 Spare Transformer/Reactor Units Connection Arrangement

Detail procedure for storage of spare transformer/reactor unit with and without isolator switching arrangement is enclosed at **Annexure-N.**

16.0 Bushings

16.1 245 kV and 420kV bushings shall be Resin Impregnated Polymer (RIP)/ Resin Impregnated Synthetic (RIS) bushing with composite polymer insulator. Bushing for 420kV & 800kV side of 800kV Class Transformer shall be of porcelain or polymer housing and hermetically sealed oil filled condenser type. 36 kV and below voltage class bushing shall be solid porcelain or oil communicating type, however for GTs, for high current requirement, 36 kV and below voltage class bushings can be oil filled condenser type. Other rating bushings may be of RIP/RIS/OIP type.

16.2 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 IEC: 60137. All details of the bushing shall be submitted for approval and design review.

16.3 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)

16.4 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.

16.5 RIP type 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.

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

16.7 Bushings of identical rating shall be interchangeable to optimise the requirement of spares. Mounting dimensions of bushing shall be as per drawing mentioned at **Annexure –R**.

16.8 Polymer/composite 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.

16.9 The weather sheds of the insulators shall be of alternate shed profile as per 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 IEC-60587. The strength of the weather shed to sheath interface shall be greater than the tearing strength of the polymer. The composite insulator shall be capable of high pressure washing.

16.10 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.

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

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

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

16.14 No arcing horns shall be provided on the bushings.

16.15 RIP 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. Bushing oil end portion 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. Alternatively, oil filled metal housing with suitable arrangement for taking care oil expansion due to temperature variations shall also 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.

16.16 The terminal marking and their physical position shall be as per IEC: 60076.

16.17 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) 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.

16.18 Tan δ value of RIP condenser bushing shall be 0.005 (max.) in the temperature range of 20°C to 90°C. The measured Tan δ value at site should not exceed by 0.001 w.r.t. factory results (measured at approx. similar temperature conditions) and in no case shall exceed 0.005 during warrantee period. No temperature correction factor is applicable.

16.19 Tan δ value of OIP condenser bushing shall be 0.004 (max.) at ambient temperature. The measured Tan δ value at site should not exceed by 0.001 w.r.t. factory results and in no case shall exceed 0.004 during warrantee period. No temperature correction factor is applicable.

17.0 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 on HV side of transformers 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 bushing 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).

17.1 Cable Box (if applicable):

Cable box shall be designed to fit transformer and 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 and 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 of supply of cable manufacturer and the transformer manufacturer shall also be as per the scope mentioned in the EN-50299. The electrical clearances as per prevalent International Standards shall be maintained inside the cable box. Transformer manufacturer shall coordinate with the cable manufacturer to resolve the interfacing issues. To avoid any interfacing problem at site, the fitting of dummy cable termination and cable box preferably needs to be checked at transformer manufacturer's premise. The detailed scope of supply of transformer manufacturer and cable manufacturer as per EN-50299 has been shown at **Annexure-Q.**

17.2 Transformer – Connection to GIS:

Transformer connection enclosure shall be part of gas insulated metal enclosed switchgear which shall house one end of a completely immersed bushing fitted on a power transformer and main circuit end terminal of GIS. The transformer connection enclosure shall be designed as per the recommendations of IEC 62271-211 and the limit of supply of switchgear manufacturer and the transformer manufacturer shall also be as per the scope mentioned in the 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 switchgear manufacturer shall make necessary arrangement to limit the very fast front transient ground potential rises which may occur during switching operation. The detailed scope of transformer manufacturer and GIS manufacturer as per IEC 62271-211 has been shown at **Annexure-Q**.

18.0 Neutral Formation and Earthing Arrangement

18.1 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 the bottom of the tank, at a convenient point, for making bolted connection to two (2) numbers 75 x 12 mm galvanised steel flats connected to grounding mat. Aluminium clamps & connectors suitable for conductor between neutral of the shunt reactor, surge arrester and the neutral grounding reactor (NGR) as applicable shall be provided.

18.2 For 1-Phase Unit

The neutral of the transformer/reactor shall be brought out through bushing. The neutrals of 1-phase transformers/reactors shall be connected by overhead connection using an overhead common brass/tinned copper/Aluminum pipe /ACSR conductor grounding bus, supported from the tank and fire walls by using porcelain insulators and wherever flexible jumper needs to be provided, same shall be through twin conductor. The neutral formation shall be such that neutral winding of single-phase spare transformer can be disconnected or connected to either of the three phase banks.

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

19.0 Delta Formation (applicable for 1-Phase Transformer):

The tertiary/LV winding terminals of the transformer shall be brought out through bushing. The contractor shall connect Tertiary/LV of 1-phase transformers in DELTA configuration by overhead connection to operate in 3-Phase Bank. The Delta shall be formed by approximate size of 3" IPS Al tube, which shall be insulated with heat shrinkage insulating sleeve or cable of suitable voltage class and adequate thickness and shall be supported by structure mounted bus post insulators at suitable intervals. Jumpers (twin) wherever provided shall also be insulated at site using suitable insulation tape or sleeve of at least 52kV class for 33kV bus and at least 36kV class for below 33kV voltage class bus. The minimum phase to phase horizontal spacing for delta formation shall be 1.5 meter.

Delta Formation in Case of single phase GTs of Hydropower Plant:

The LV winding of Generator Transformers shall be brought out through bushing and LV of single phase transformers shall be connected in delta configuration by Bus Duct to operate in three phase bank. Delta formation shall be done as per the vector group Ynd11 of the transformer. Phase to phase horizontal spacing for delta formation shall be co-ordinated by Transformer and Bus duct manufacturer.

20.0 Cooling Equipment and its Control

20.1 Radiator based cooling for Power/Auto transformer & Reactor

20.1.1 The transformer/reactor shall be designed with cooler system as specified in **Annexure-A** and relevant following provisions, as applicable, shall be followed. As an alternative to radiator base cooling system, unit cooler system as specified in clause 20.2 may also be provided for power/auto transformers.

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

20.1.3 In case of separately mounted radiator bank arrangement, 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.

20.1.4 The radiator shall be of sheet steel in accordance with IS 513 and minimum thickness 1 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
(c) Drain Valve and sampling valve
(d) Top and bottom oil filling valves
(e) Air release plug
(f) Two grounding terminals for termination of two (2) Nos. 75x12 mm galvanised steel flats.
(g) Thermometer pockets with captive screw caps at cooler inlet and outlet.
(h) Lifting lugs

20.1.5 Each radiator bank shall be detachable and shall be provided with flanged inlet and outlet branches. Expansion joint shall be provided on top and bottom cooler pipe connection.

20.1.6 If radiators are directly mounted on tank, sufficient number of thermometer pockets fitted with captive screw cap on the inlet and outlet of tank side pipe of radiators shall be provided to record temperature during temperature rise test.

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

20.1.8 Cooling fans shall not be directly mounted on radiator. It may cause undue vibration. These 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.

20.1.9 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.

20.1.10 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.

20.1.11 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.

20.1.12 Cooling fans and oil pump motors shall be suitable for operation from 415 volts, three phase 50 Hz power supply and shall conform to IS: 325 / IEC 60034. 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: 4691/ IEC 60034-5.

20.1.13 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.

20.1.14 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.

20.1.15 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 cooling option. The setting shall be such that hunting i.e. frequent start-up operations for small temperature differential do not occur.

20.1.16 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.

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

20.1.18 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) Cooling fan failure for each bank
f) Cooling pump failure for each pump
g) Common thermal overload trip

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.

20.1.19 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.

20.1.20 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).

20.1.21 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.

20.2 Unit cooler arrangement for Generator Transformer in Thermal plants

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

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

20.2.3 For generator transformer in thermal plants cooling shall be affected by use of tank mounted minimum six (6) nos. of 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.

20.2.4 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.

20.2.5 An 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.

20.2.6 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.

20.2.7 Cooling fans and oil pump motors shall be suitable for operation from 415 volts, three phase 50 Hz power supply and shall conform to IS: 325/IEC34. 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:4691/IEC:34-5. The temperature rise of the motor shall be limited to 70 deg. C above ambient of 50 deg. & shall comply with IS:325.

20.2.8 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.

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

20.2.10 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.

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

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

20.2.13 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.

20.2.14 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.

20.2.15 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

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

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

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

- Cooler Supply failure (main)
- Cooler supply changeover
- Cooler Supply failure (standby)
- Control Supply failure
- Cooler unit failure for each unit cooler
- No oil flow/reverse oil flow for pumps
- 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.

20.3 Transformer Cooling System for Generator Transformers in Hydro Plants:

20.3.1 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 of 100% each 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.

20.3.2 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.

20.3.3 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.

20.3.4 An electro-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

20.3.5 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.

20.3.6 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

20.3.7 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.

20.3.8 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.

21.0 Auxiliary Power Supply for OLTC, Cooler Control and Power Circuit

21.1 For Single Phase unit

21.1.1 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.

21.1.2 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.

21.1.3 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. Further any special cable (if required) from CMB to Owner's Control Panels/Digital RTCC panels is also in the scope of the manufacturer.

21.2 For Three Phase Transformer

21.2.1 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.

21.2.2 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 by contractor in cooler control cabinet/ Marshalling Box.

21.2.3 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. Further any special cable (if required) from MB to Owner's Control Panels/Digital RTCC panels is also in the scope of the manufacturer.

21.2.4 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
415V	$\pm$ 10%	50 $\pm$ 5%	3/4 Wire	Solidly Earthed.
240V	$\pm$ 10%	50 $\pm$ 5%	1/2 Wire	Solidly Earthed.
220V	190V to 240V	DC	Isolated 2 wire System	-
110V	95V to 120V	DC	Isolated 2 wire System	-
48V	--	DC	2 wire system (+) earthed	-

Combined variation of voltage and frequency shall be limited to $\pm$ 10%.

21.2.5 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.

21.2.6 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.

22.0 Valves

22.1 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.

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

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

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

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

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

22.7 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.

22.8 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.

22.9 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.

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

22.11 **Flow sensitive conservator Isolation valve**

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.

b) A valve which 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. 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.

c) 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.

22.12 The typical valve schedule for GTs of hydropower stations has been provided at **Annexure–O**.

23.0 Cabling

23.1 All interconnecting control and power cables between 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-M**.

23.2 Cabling of spare unit with isolator switching arrangement shall be in such a way that spare unit of transformer/reactor can be connected in place of faulty unit without physically shifting and all the control, protection, indication signals of spare unit shall be brought in common marshalling box 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.

24.0 Tap Changing Equipment

Each transformer shall be provided with Off Load Tap / On Load Tap changing equipment as specified elsewhere.

24.1 Off Load Tap Changing (OCTC) Equipment

24.1.1 The tap changer shall be single-phase hand operated for switching taps on single phase by operating an external hand wheel.

24.1.2 The tap changing shall be possible without disturbing the transformer in any way except de-energizing.

24.1.3 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.

24.1.4 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:

(i) A mechanical operation indicator.

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

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

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

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

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

24.1.6 Following signals to be provided:

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

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

24.2 On Load Tap Changing (OLTC) Equipment (Vacuum or Oil type)

24.2.1 Main OLTC Gear Mechanism

24.2.1.1 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.

24.2.1.2 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. The contacts shall be accessible for inspection without lowering oil level in the main tank and the contacts shall be replaceable.

24.2.1.3 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.

24.2.1.4 The OLTC oil chamber shall have oil filling and drain valve, oil sampling valve, relief vent and level glass. Oil sampling valve of minimum size, 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.

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

24.2.2 Local OLTC Control Cabinet (Drive Mechanism Box)

24.2.2.1 OLTC shall be suitable for manually handle operated and electrically motor operated. For local manual operation from Local OLTC Control cabinet (Drive Mechanism Box), an external handle shall be provided.

24.2.2.2 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. The mechanism shall be complete with the following:

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

(ii) 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.

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

(iv) 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.

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

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

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

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

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

(ii) Emergency Push Button to stop OLTC operation

(iii) Cubicle light with door switch

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

(v) Padlocking arrangement for hinged door of cabinet

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

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

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

24.2.2.6 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.

24.2.2.7 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.

24.2.2.8 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 CMB (for single phase unit) and input to Digital RTCC/SCADA system.

24.2.2.9 '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 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 DM Box. In remote mode electrical commands from CMB/ Digital RTCC/SCADA etc. shall be executed. The remote-local selector switch shall be having at-least two spare contacts per position.

24.2.2.10 Following minimum contacts shall be available in DM Box, which shall be wired to CMB for single phase unit. Further these contacts shall be wired to Digital RTCC panel:

i) INCOMPLETE STEP which shall not operate for momentary loss of auxiliary power.
ii) OLTC motor overload protection
iii) Supply to DM Motor fail
iv) OLTC IN PROGRESS
v) Local / Remote Selector switch position

vi) OLTC upper/lower limits reached

24.2.2.11 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.

24.2.2.12 A permanently legible lubrication chart if required shall be fitted within the OLTC local control cabinet.

24.2.3 OLTC Control from Common Marshalling Box (CMB)

24.2.4.2 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. 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.

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

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

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

24.2.4.6 In **'remote'** position control of OLTC shall be possible from Digital RTCC/SCADA etc.

24.2.4.7 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 will be prevented.

24.2.4.8 Following minimum **LED indications** shall be provided in CMB:

a. INCOMPLETE STEP
b. OLTC motor overload protection
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

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

Following **contacts** shall be wired to TBs in CMB for further wiring to digital RTCC Panel:

a. INCOMPLETE STEP
b. OLTC motor overload protection
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

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 to display tap positions for all three 1-ph units separately.

24.2.4 Digital RTCC Panel

24.2.4.1 The transformers with on line tap changer shall be provided with digital RTCC panel which shall have Automatic Tap Changer control and monitoring relay with Automatic Voltage Regulating features (referred as **Digital RTCC relay**) to remotely control and monitor OLTC.

24.2.4.2 For new substation, Digital RTCC panel shall consist of 4 Nos. Digital RTCC relays. Further, one spare Digital RTCC relay shall also be provided in the same panel. 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),

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 to finalise matching digital RTCC relays requirements need to be specified. 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.

24.2.4.3 Digital RTCC relay shall be microprocessor based adopting the latest state of the art design & technology with in-built large 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 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.

All Digital RTCC Relays shall be of same make for smooth integration of these relays for parallel operations of all transformers in the substation.

24.2.4.4 The RTCC Panel shall be provided with digital RTCC relay having Raise/Lower push buttons, Manual/ Automatic mode selection features, Master / Follower/ Independent/ Off mode selection features for control of OLTC. Touch screen option in the relay, instead of electrical push button/switch is also acceptable.

24.2.4.5 **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.

24.2.4.6 **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.

24.2.4.7 **Master / Follower/ Independent/ Off mode**

Master / Follower parallel operation is required with Group simultaneous feature in Digital RTCC relay. 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

24.2.4.8 **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.

24.2.4.9 Digital RTCC relays shall communicate with SCADA using 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. The digital RTCC Relay shall have multiple selectable set point voltages and it shall be possible to select these set points from SCADA, with a facility to have the possibility of additional set points command from SCADA.

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.

24.2.4.10 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.

24.2.4.11 The relays shall ensure positive 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.

24.2.4.12 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
i. (In case of single phase transformer)
j. 415V, AC Mail Supply Fail.
k. 415V, AC Standby Supply Fail

24.2.4.13 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.

25.0 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 (if any), shall be 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 IEC 61850. This Ethernet switch shall be provided in IMB or CMB. 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) or CMB (for 1-Ph unit), all the cables from RTCC to DM and any special cable between IMB (for 3-Ph unit) or 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) or CMB (for 1-Ph unit) to switchyard panel room/control room and power supply (AC & DC) to MB and integration of above said IEC-61850 compliant equipment with Substation Automation System may be a part of sub-station contract.

26.0 Constructional features of Cooler Control Cabinet/ Individual Marshalling Box/ Common Marshalling Box/ Outdoor cubicle and Digital RTCC Panel

26.1 Each transformer unit shall be provided with local OLTC Drive Mechanism Box, 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).

26.2 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 and Cooler Control Box shall be tank mounted or ground mounted. All the 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.

26.3 The Cooler Control Cabinet/ Individual Marshalling Box, Common Marshalling Box, 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**.

26.4 The degree of protection shall be IP: 55 for outdoor and IP: 43 for indoor in accordance with IS: 13947/IEC: 60947.

26.5 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 better approved quality, whereas for all indoor control cabinets / Digital RTCC panel, the sealing gaskets shall be of neoprene rubber or any better approved quality. The gaskets shall be tested in accordance with approved quality plan, IS: 1149 and IS: 3400.

26.6 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.

26.7 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.

27.0 Bushing Current Transformer and Neutral Current Transformer

27.1 Current transformers shall comply with IEC-61869-1 and 61869-2.

27.2 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.

27.3 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.

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

27.5 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.

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

28.0 Hand Tools

One set of hand tools of reputed make packed in a carry bag/box broadly comprising of double ended spanners (open jaws, cranked ring, tubular with Tommy bar each of sizes 9mm to 24mm, one set each), adjustable wrenches (8 &12 inch one set), gasket punches (of different sizes used - one set), pliers (flat nose, round nose & side cutting one of each type), hammer with handle (one), files with handle (two), knife with handle (one), adjustable hacksaw (one), and cold chisel (one), bushing handling and lifting tools with nylon rope/belt, chain block (2 Nos.) and D-Shackle shall be supplied for one substation to cater to number of transformers/reactors.

29.0 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 silicagel filter breather with flexible connection pipes to be used during replacement of any silicagel breather

(b) Conservator for OLTC with drain valve, oil surge relay, filling hole with cap, prismatic oil level gauge and dehydrating breather (for transformer only)

(c) Pressure relief devices

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

(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 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

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

(l) Protected type mercury or alcohol in glass thermometer or magnetic or micro-switch type dial type temperature indicator as applicable

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

(n) Roller Assembly

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

(p) Cooling equipment

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

(r) Oil flow indicators (if applicable)

(s) Terminal marking plates

(t) Valves schedule plate

(u) Bottom oil sampling valve, Drain valves, Filter valves at top and bottom with threaded male adaptors, Shut off valves on the pipe connection between radiator bank and 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, Valve for on line DGA (if applicable), valves for Drying out system (if applicable), Flow sensitive conservator Isolation valve, Valve for UHF sensors, valves for NIFPS system (if applicable) etc.

(v) Ladder to climb up to the transformer/reactor tank cover with suitable locking arrangement to prevent climbing during charged condition

(w) 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.

(x) Haulage lugs

(y) Suitable terminal connectors on bushings

(z) 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

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

(bb) Fibre optic sensor based temperature measuring system (for 400kV and above Transformer/Reactors only)

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

For 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) Conservator air cell rupture relay

(e) Air release plug

(f) Inspection openings and covers

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

(h) Oil temperature indicators

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

(j) Rating and diagram plates

(k) Roller Assembly

(l) Marshalling Box (Tank mounted)

(m) Cooling equipment as applicable

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

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

(p) Terminal marking plates

(q) Valves schedule plate

(r) 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.

(s) Suitable terminal connectors on bushings

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

(u) Haulage lugs

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

30.0 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 provided in **Chapter-4: Quality Assurance Programme.**

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, standards and Guaranteed Technical Particulars (GTP) furnished by vendor. It is a scrutiny of design, materials, and accessories plus manufacturing processes so as to ensure that offered guaranteed technical particulars, are thoroughly met, ensuring quality and reliability.

- Manufacturer understands the purchaser technical specifications and the prepared design meets those requirements.
- Design meets the tender GTP- grade /quantity of active materials sufficient to limit losses as offered.
- 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.
- To exchange experiences that can be used to improve the current design and future specifications.
- To understand technical capabilities and experience of manufacturer; to appreciate the manufacturing and 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.).
- Transportability to site. Any stringent limitation to be highlighted, if any.
- Service conditions. If any abnormal service condition exists customer has to point out.

2.0 Stages of Design Review

Design Review 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 to specific 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 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 and chaired 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.
- At the completion of DR, a summary report indicating list of items with actions 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.

4.0 Calculation of Losses

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

Calculation of no-load losses:

- No-Load losses = 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 x no. of phases

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

  R_W = W x D x π / (k x S)
  R_L = L / (k x 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.

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) Power Transformer Standardization Manual – No.25-2014 – Section 7 –Pages261-268- by IEEMA Transformer Division

(e) CIGRE Technical Brochure No.530-2013 Guide for conducting factory capability assessment for Power Transformers

(f) IEEE Standard C57.150-2012 Guide for Transformer Transportation

(g) CIGRE TB No406-2010 HVDC Converter Transformers –Design Review, Test Procedures, Ageing Evaluation and Reliability in service JWG SC A2/B4.28

(h) IEC 60076-5 ed3.0-2006 Power Transformers-Part 5 Ability to withstand short circuit

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 route and the persons responsible for quality implementation should religiously follow the defined quality route.

Quality of a transformer/reactor can be improved by taking effective steps in the origin stage itself which are '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).

To ensure that the equipment and services are in accordance with the specifications, the transformer/reactor manufacturer shall adopt suitable quality assurance programme 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/authorised representative, after discussions before the award of the contract. The Quality Assurance programme shall be generally in line with ISO-9001/IS-14001. A quality assurance programme of the manufacturer shall generally cover the following:

a) His 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 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) Control of non-conforming items and system for corrective actions

l) Inspection and test procedure both for manufacture and field activities

m) Control of calibration and testing of measuring equipment

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

The manufacturer shall use state-of-the-art technology and dirt, dust and humidity free 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-B*. In case the manufacturers do not have the required facilities as given in *Annexure-B*, 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 the stages, as per a comprehensive Quality Assurance Programme, the detailed Quality Plans for manufacturing and field activities shall be drawn up by the manufacturer 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.**

2.3 List of testing equipment available with the manufacturer for stage/final testing of transformer specified 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 shall also furnish copies of the reference documents/plant standards/acceptance norms/tests and inspection procedure etc., as referred in Quality Plans along with 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 beyond which 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 The manufacturer shall submit to the Purchaser Field Welding Schedule for field welding activities, if applicable. The field welding schedule shall be submitted to the Purchaser along with all supporting documents, like welding procedures, heat treatment procedures, NDT procedures etc. before schedule start of erection work at site.

2.6 Transformer/reactor manufacturer will 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 commissioning site.

2.7 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.

2.8 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.

2.9 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.

2.10 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.

2.11 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.

2.12 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.

2.13 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.

2.14 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.

2.15 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, etc.

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

2.17 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.

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

3.0 QUALITY ASSURANCE DOCUMENTS

3.1 The manufacturer shall be required to submit the QA Documentation in hard copies and CD ROMs, 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) 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 shall be required to submit hard copies and CD ROM, containing QA Documentation pertaining to field activities as per Approved Field Quality Plans and other agreed manuals/ procedures, prior to commissioning.

3.5 Before despatch / commissioning 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 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 fifteen (15) 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 fifteen (15) days of the date on which the equipment is noticed as being ready for test/inspection.

4.4 The Inspector shall within fifteen (15) 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.

4.5 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 fifteen (15) days after completion of tests but if the tests are not witnessed by the Inspector, the certificate shall be issued within fifteen (15) days of the receipt of the Manufacturer's test certificate by the Inspector.

4.6 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.

4.7 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.

4.8 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. Wherever asked specifically, the manufacturer shall re-calibrate the measuring/test equipment in the presence of the Inspector.

4.9 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, 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.

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 approved source of 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 as per "**Annexure-D** and **Annexure-E".** All tests shall be done in line with IS: 2026/IEC: 60076**.** 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 complete winding of all phases shall be replaced by new one.

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

Horizontal Length of flat plate (in mm)	Permanent deflection (in mm)
Up to and including 750	5.0
751 to 1250	6.5
1251 to 1750	8.0
1751 to 2000	9.5
2001 to 2250	11.0
2251 to 2500	12.5
2501 to 3000	16.0
Above 3000	19.0

(C) Pressure Test

All transformer tanks, its radiator, conservator and other fittings together or separately shall be subjected to a pressure corresponding to twice the normal head of oil or normal oil head pressure plus 35 KN/ sq.m whichever is lower, measured at the base of the tank and maintained for one hour. 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, Coil & Tank during the manufacturing stages of the transformer. The manufacturer will have to call for the stage inspection and shall arrange the inspection at manufacturer's premises or manufacturer's sub-supplier's premises, as applicable, free of cost.

5.2.2 Stage inspection will be carried out on 1 (one) number Transformer against an offer of minimum 50% of the ordered quantity as mentioned in delivery schedule. On the basis of satisfactory stage inspection, manufacturer will proceed further.

5.2.3 The manufacturer will offer the core for stage inspection and get approval from purchaser during manufacturing stage. The 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, 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 during stage inspection and estimation of core quantity during stage inspection in 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.

1) Bushing (including Seismic test for 400 kV voltage class bushing as per IEC:60137)
2) OLTC (Test as per IEC:60214 and IP-55 test on driving mechanism box)
3) Buchholz relay
4) OTI and WTI
5) Pressure Relief Device (including IP 55 test in terminal box)
6) Sudden Pressure Relay (including IP 55 test in terminal box)
7) Magnetic Oil Level gauge & Terminal Box for IP-55 degree of protection.
8) 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

9) Marshalling & common marshalling box and other outdoor cubicle (IP-55 test)
10) RTCC (IP-43 test)

5.4 Pre-Shipment Checks at Manufacturer's Works

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

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

5.4.3 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.

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

5.4.5 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.

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

5.5 Transportation, erection, testing and commissioning at site

The details of transportation, erection, testing and commissioning at site has been covered under **Chapter-5.**

The manufacturer shall carry out a detailed inspection and testing programme for field activities covering areas right from the receipt of material stage up to commissioning stage. An indicative programme of inspection as envisaged by the Purchaser is given below. However, it is manufacturer's responsibility to draw up and carry out such a programme duly approved by the Purchaser. Testing of oil sample at site shall be carried out as per specification.

CHAPTER-5

TRANSPORTATION, ERECTION, TESTING AND COMMISSIONING

1. 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 trailers 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.

1.4. All metal blanking plates and covers which are specifically required for transportation and storage of the transformer/reactor shall be considered part of the transformer/reactor and 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 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, after which the transformer/reactor shall be processed as per the recommendation of manufacturer if not filled with oil. The dry air cylinder(s) 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. Transformer/reactor shall also be fitted with Electronic impact recorders (on returnable basis) at least 2 numbers for 400kV class transformer/reactor and 1 number for below 400kV class transformer/reactor 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 supplier 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. Points to be checked after receipt of Transformer/ Reactor at site in presence of manufacturer’s representative:

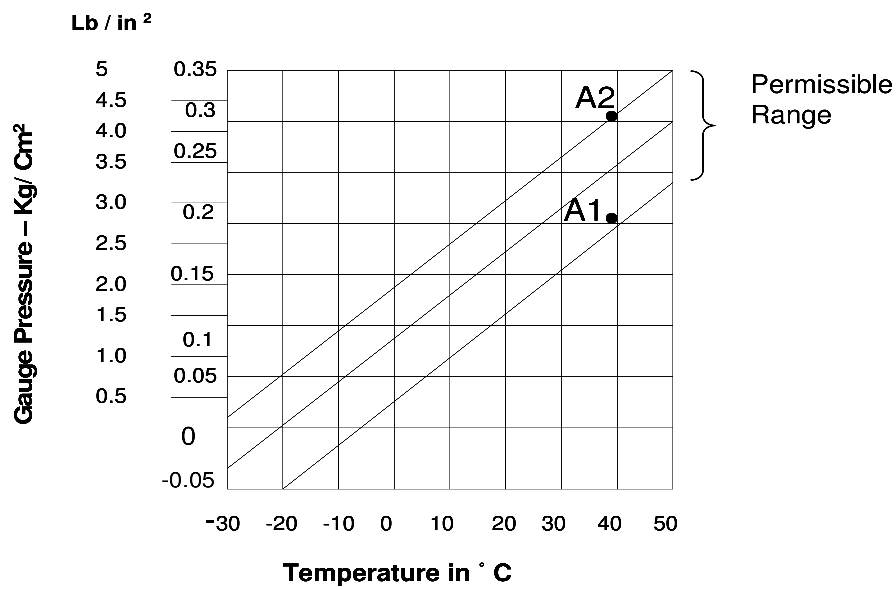
2.1. Pressure and Dew point of dry air shall be checked after receipt of transformer/reactor at site. It should be within permissible band (as per the graph provided by manufacturer which is also given below in Fig-1)

2.2. Core Insulation Test shall be carried out to check insulation between core to tank, core to yoke clamp (frame) and yoke clamp (frame) to tank. (Not applicable for Air Core Reactors)

2.3. 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.

2.4. 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. 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 insuring agency so that the same can be investigated or shortage made up as per the terms/ conditions of the contract.

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/ Cm^2 at point A1
- maximum pressure of gas can be 0.32 Kg/ Cm^2 at point A2

Fig-1

2.5. **Storage of the main unit and the accessories at site:**

2.5.1. 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.

2.5.2. 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.

2.5.3. 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 plan has to be taken from the manufacturer regarding proper storage of the Main Unit.

2.5.4. If the Transformer/ Reactor is to be stored up to three (3) months 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.

2.5.5. 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 and ppm ≤ 5ppm and BDV ≥ 70kV. In case of storage of transformer/reactor in oil-filled condition, the oil filled in the units hall 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.

2.6. Insulating Oil

2.6.1. When oil is dispatched to site separately, it is usually in sealed steel drums. 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.

2.7. **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 preferably be collected in clean glass bottles. The bottles shall be rinsed with the same oil and shall be without any air bubble.

2.8. **Internal Inspection**

2.8.1. Before starting erection, thorough internal inspection of Transformer/ Reactor shall be carried out by engineer along with manufacturer's representative.
Internal inspection shall preferably be carried out in dry and sunny weather along with circulation of dry air 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.

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.

2.8.2. **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 DETC and in-tank 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.

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.

3. Precautions during erection

3.1 During all erection activities, a well qualified and experienced representative of manufacturer shall be present at the site for supervision and other necessary activities.

3.2 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.

3.3 Further, either dry air generator should be running all the time or dry air cylinders may be used to minimize ingress of moisture. The transformer/reactor should be sealed off after working hours. **Transformer/ reactor shall never be allowed to be opened without application of dry air.**

3.4 It is practical to apply a slight overpressure overnight with dry air inside – less than 300 mbar (30 kPa or 0.3 atmospheres). Next day the pressure shall be checked and suspected leaks may be detected with leak detection instruments/ with soap water or with plastic bags tightened around valves (being inflated by leaking air)

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 erections
- 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 .

"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.

For transformer/reactor s with a gas pressure of 2.5- 3 PSI, the acceptable limits of dew point shall be as under:

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

TABLE 1- Variation of Dew Point of N2 Gas Filled in Transformer/reactor Tank w.r.t Temperature

3.5 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. When vacuum is applied to a transformer/reactor without oil, a leakage test must be carried out to ensure that there are no leaks on the tank which would result in wet air being drawn into the transformer/reactor . The following procedure is to be adopted:

- Connect the vacuum gauge to a suitable 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 - 1 kPa (1 - 10 mm mercury) to be used.
- Connect the vacuum pump to another opening.
- 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 express 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 reading (at least 2 to 3) at successive 30 min intervals to confirm the result.
- If the leak test is successful, the pumping will be continued, until the pressure has come down to 0.13 kPa (1 Torr) or less. The vacuum shall then be held for the time given in Table-2 before the oil filling starts.
- If the specified vacuum cannot be reached, or if it does not hold, the leak 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 diverter switch compartment may also be evacuated simultaneously so that 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 maintain during the subsequent oil filling operations by continuous running of the vacuum pumps.

3.6 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 liquid residue from earlier use shall be carefully removed, and the container flushed with a small quantity of new oil, which is then discarded.

After filtration, oil sample is tested for meeting specification for new oil.

Prior to filling in main tank at site, it shall be tested for:

1. Break Down voltage (BDV)	: 70 kV (min.)
2. Moisture content	: 5 ppm (max.)
3. Tan-delta at 90 °C	: Less than 0.01
4. Interfacial tension	: More than 0.035 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.

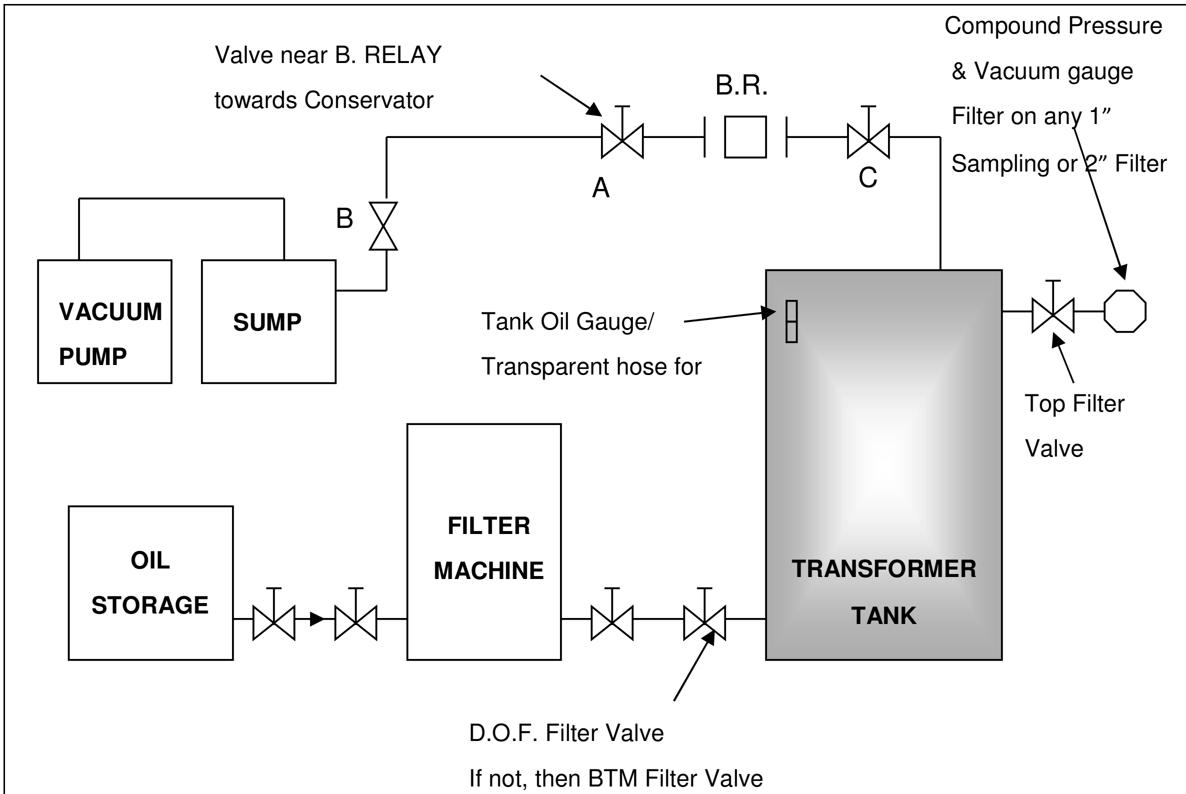


Figure-2 : Arrangement for Evacuation and Oil filling upto tank Oil gauge & Conservator

When the vacuum filling of the transformer/reactor 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, with the cooler vented at the top and the top cooler filter valve unblanked and open to atmosphere. As the oil level reaches the top vent, then top valve 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. 0.035kg/cm2 max. by applying pressure (N_2/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 over and 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.

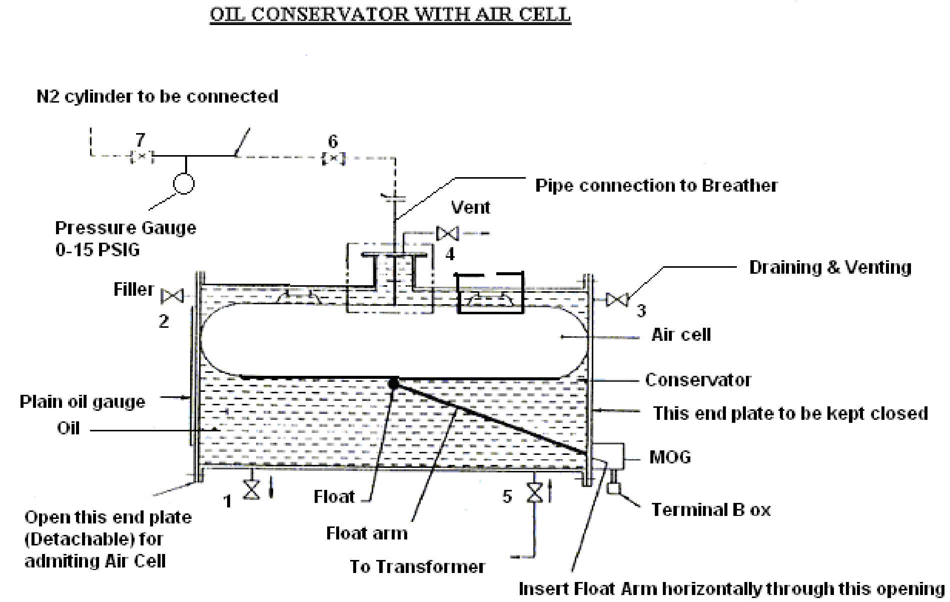


Figure-3 : General Arrangement For Oil Conservator

After Oil filling, Hot Oil Circulation has to be applied to all 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.

3.7 Hot oil circulation using high vacuum oil filter machine

3.7.1 To ensure proper dryness and absorption of possible trapped gas bubbles, the oil in the tank is circulated through the vacuum filter and with circulation direction 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 filter to the transformer/reactor at the top and from the transformer/reactor to the filter at the bottom. (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 has passed through the loop corresponding to 2 times the total oil volume in the tank. (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).

3.7.2 The oil sample from the transformer/reactor tank, after filling in tank before commissioning should meet the parameters specified in the specifications elsewhere.

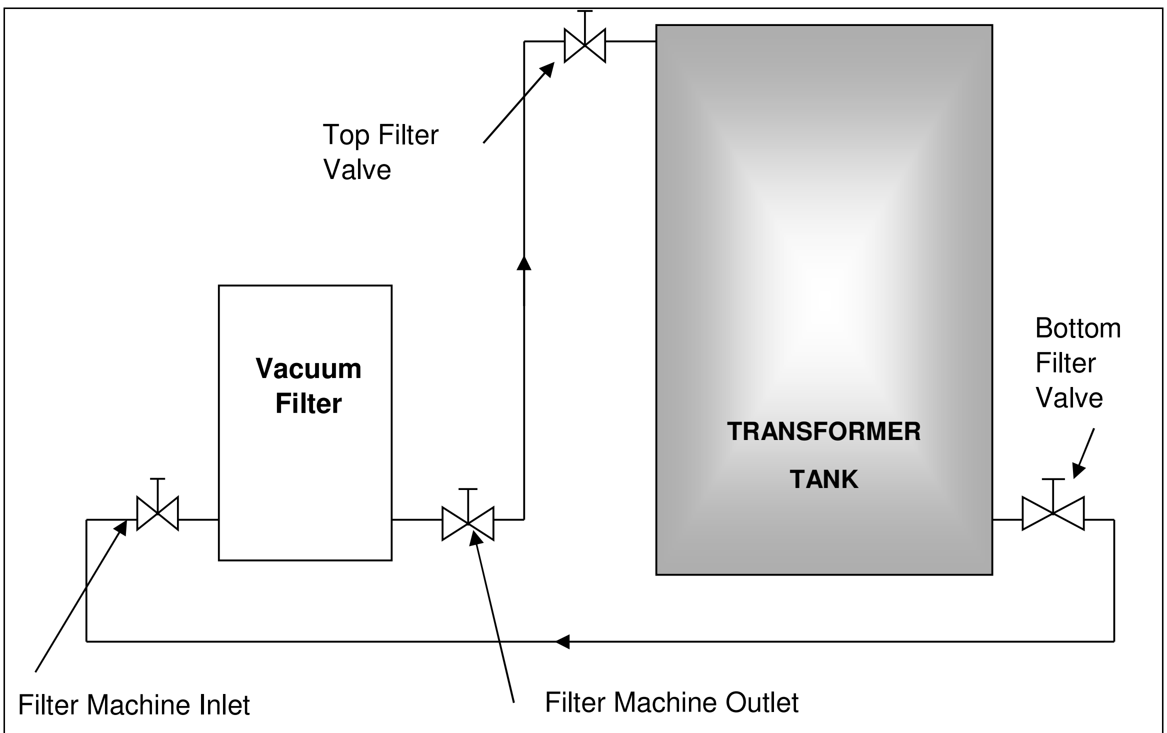


Figure-4: Arrangement for Hot Oil Circulation and Filtration

3.8 Drying of wet winding of transformer/ reactor by application of vacuum, N2 filling and heating

The drying of a new Transformer/ Reactor is required when the moisture gets absorbed by the solid insulation used in Transformers/ Reactors 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 fire fighting 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.

3.8.1 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.

3.8.2 Procedure

(a) Fill the main transformer/ reactor tank with Nitrogen (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. It is kept for about 48 hrs. At the end of 48 hrs, dew point of N_2 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 N_2 circulation is in progress, the heaters are to be installed around the transformer/reactor tank as shown in the Annexure. The heaters are to be kept ON until we achieve a temperature of about 75^o C – 80^o C of the core & winding of transformer/reactor as measured by top oil temperature in the transformer/reactor .

(c) After ascertaining that there is no leakage, pull out vacuum and keep the transformer/reactor under near absolute vacuum (1-5 torr) and keep under vacuum for about 96 hours running the vacuum pump continuously. The duration of vacuum can vary between 48 to 96 hrs depending upon the dew point being achieved. Keep Vacuum machine ON and collect condensate 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. The dew point of nitrogen at the inlet is to be measured and should be of the order of - 50 °C or better. When the nitrogen comes to the positive pressure of 0.15 kg/cm2, it is stopped and kept for 24 hours. Heating from outside is to be continued while N2 circulation is in progress. Then the nitrogen pressure is released and the outlet nitrogen dew point is measured. If the dew point is within acceptable limits as per Table-I, then the dryness of transformer/reactor is achieved. If not, again the transformer/reactor is taken for vacuum treatment and then nitrogen is admitted as mentioned above and tested. The cycle is to be continued till desired dew point as per Table-1 is achieved.

(e) Periodicity of vacuum cycle may vary between 48-96 hrs. Initially two N2 cycles may be kept for 24 hrs. After that it may be kept for 48 hrs depending upon dew point being achieved.

3.8.3 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

Transformer HV Rated Voltage (in kV)	**Application of Vacuum & holding for (before oil filling)*** (in hours)	**STANDING TIME After Oil circulation and before energizing** (in Hours)
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 expiry of this time, air release operation is to be carried out in Buchholz relays, turrets and other release points given by the manufacturers before charging.

4. Pre-Commissioning checks/tests for Transformers and Reactors

4.1 Once oil filling is completed, following pre-commissioning checks/ tests are performed to ensure the healthiness of the Transformer/ Reactor prior to its energization.

(a) Inspection and performance testing of accessories like tap changers, cooling fans, oil pumps etc.

(b) Check the direction of rotation of fans and pumps and check the bearing lubrication.

(c) Check whole assembly for tightness, general appearance etc.

(d) Oil leakage test

(e) Capacitance and tan delta measurement of bushing before fixing/connecting to the winding, contractor shall furnish these values for site reference.

(f) Leakage check on bushing before erection.

(g) Measure and record the dew point of gas in the main tank before assembly.

(h) Check the colour of silica gel in breather.

(i) Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.

(j) Check the bushing for conformity of connection to the lines etc.

(k) Check for correct operation of all protection devices and alarms/trip :

i) Buchholz relay
ii) Excessive winding temperature
iii) Excessive oil temperature
iv) Low oil flow
v) Low oil level indication

vi) Fan and pump failure protection

(l) Check for the adequate protection on the electric circuit supplying the accessories.

(m) Check resistance of all windings on all steps of the tap changer. Insulation resistance measurement for the following:

i) Control wiring
ii) Cooling system motor and control
iii) Main windings
iv) Tap changer motor and control

(n) Check for cleanliness of the transformer and the surroundings

(o) 2 kV for 1 minute test between bushing CT terminal and earth

(p) Polarity and vector group test

(q) Ratio test on all taps

(r) Magnetising current test

(s) Capacitance and Tan delta measurement of winding and bushing

(t) Frequency response analysis (FRA). FRA equipment shall be arranged by purchaser.

(u) DGA of oil just before commissioning and after 24 hours energisation at site.

4.2 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 and noise level etc.

4.3 Continuously observe the transformer operation at no load for at least 24 hours.

4.4 Contractor shall prepare a comprehensive commissioning report including all commissioning test results as per Pre-Commissioning Procedures forward to Purchaser for future record.

4.5 Significance of various tests to be performed on transformer/reactor is given below:

Sr. No.	Name of Test/ Check point	Purpose of test/ check
1.	Core insulation tests	Allows for investigating accidental grounds which results in circulating currents if there is more than one connection between the core and ground.
2.	Earth pit resistance measurement	To check the resistance of earth pit provided for Transformer/reactor. In case, the resistance is more, proper treatment is to be given.
3.	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)
4.	Capacitance and Tan δ measurement of bushings	Measurement of Capacitance and Tanδ in UST mode. Changes in the normal capacitance of an insulator indicate abnormal conditions such as the presence of moisture layer, short -circuits or open circuits in the capacitance network.
5.	Capacitance and Tan δ measurement of windings	Dissipation factor/Loss factor and capacitance measurement of winding is carried out to ascertain the general condition of the ground and inter-winding insulation
6.	Turns ratio (Voltage ratio) measurement	To determine the turns ratio of transformers to identify any abnormality in tap changers/ shorted or open turns etc.
7.	Vector Group & Polarity	To determine the phase relationship and polarity of transformers
8.	Magnetic Balance test	This test is conducted only in three phase transformers to check the imbalance in the magnetic circuit
9.	Floating Neutral point measurement	This test is conducted to ascertain possibility of short circuit in a winding.
10.	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.

11.	Exciting/Magnetizing current measurement	To locate defect in 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
12.	Operational checks on OLTCs	To ensure smooth & trouble free operation of OLTC during operation.
13.	Tests/ Checks on Bushing Current Transformers (BCTs)	To ascertain the healthiness of bushing current transformer/reactor at the time of erection
14.	Operational Checks on protection System	Operational Checks on cooler bank (pumps & Fans), Breathers (Silica gel or Drycol), MOG, temperature gauges (WTI/OTI), gas actuated relays (Buchholz, PRD, SPR etc.) and simulation test of protection system
15.	Stability of Differential, REF 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.
16.	Frequency Response Analysis (FRA) measurement	To assess the mechanical integrity of the transformer. 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 active part has not suffered any severe impact/ jerk during transportation.
17.	Winding resistance measurement	To check for any abnormalities due to loose connections, broken strands and high contact resistance in tap changers.
18.	Dissolved Gas Analysis (DGA) of oil sample	Oil sample for DGA to be drawn from transformer main tank before commissioning for having a base data and after 24 hrs. of charging subsequently to ensure no fault gas developed after first charging. DGA analysis helps the user to identify the reason for gas formation & materials involved and indicate urgency of corrective action to be taken.

19.	Tan delta of bushing at variable frequency (Dielectric frequency response)	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) at site and the result shall be compared with factory results to verify the healthiness of the bushing.

Chapter 6

CONDITION MONITORING AND LIFE CYCLE MANAGEMENT

In the factory the transformer/reactor can be tested using a plethora of means & 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.

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.

As per *Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations*, diagnostic equipment shall be provided 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.

The condition monitoring activities of any Power Transformer/Reactor can be classified as the following based on testing methodology:

i. Off Line Monitoring Activities
ii. On Line Monitoring Activities

However these activities can be further sub-divided based on relevancy for Transformer or Reactor.

I. Off Line Monitoring Activities for Transformer/ Reactor

A. Low Voltage Conventional Tests

The low voltage conventional tests are described as the tests which are carried out at site and the test results are compared to the factory test results/ pre-commissioning results.

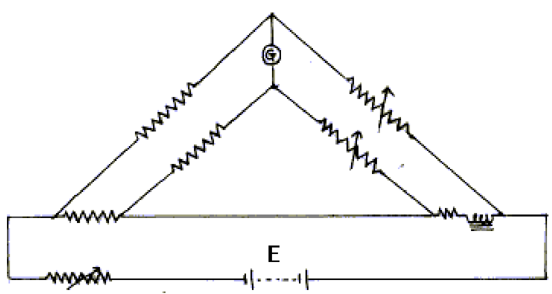
1. Winding Resistance (Applicable to both Transformer & Reactor)

   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 and compare the measured values with factory test values.

As the transformer/reactor resistance is Low resistance, 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 shall be preferably 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 should preferable be carried out last after completion of all other LV tests, as after this test core gets saturated and tests like magnetizing current, magnetic balance etc. carried out after winding 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 the tested value. If **neutral bushing is not available on Star connected windings**, take measurement between each phase and ground (if the neutral is grounded), or take readings between pairs of bushings as if it were a Delta connected winding. *Repeat 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 auto-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*

Take the winding temperature reading while doing the resistance measurement and Calculate the resistance at 75°C as per the following formula

$R_{75} = R_t (235+75) / (235+t)$,

Where R_t = Resistance measured at winding temperature t

Results are to be compared to other phases in Star-connected transformers or between pairs of terminals on a Delta–connected winding to determine if a resistance 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 (like Tr. Ohm meter) is affected by the presence of stray fields of relatively low capacitances. Comparison of readings with identical transformer has much more significance. As a check, Key gases increasing in DGA will be ethane and /or ethylene and possible methane of close connections or broken strands or OLTC contact problems.

2. Voltage Ratio Test (For Transformers Only)

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 according to transformer type on HV terminals. Measure the voltages applied on each phase (Phase-Phase) on HV and IV terminals simultaneously. Repeat this for each of the tap position separately and after interchanging the voltmeters of HV and IV windings and then average the readings for final calculation of ratio.

The above tests can also be performed by Transformer turns ratio (TTR) meter available in convenient portable form. They operate at low voltages, such as 8-10 V and 50-60 Hz, so that the test may 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, with exciting current 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 effected. 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 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.

3. Excitation/ Magnetization Current (For both Transformers & Reactors)

Exciting/ Magnetizing current is the current required to force a given flux through the core. This test should be done before DC measurements of winding resistance to reduce the effect of residual magnetism. Therefore, transformer 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, usually the high-voltage side, 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. Keep the tap position alternatively in the Lowest position, Normal position & Highest position and IV and LV terminals open. Measure the voltages applied on each phase (Phase wise) on HV terminals and current in each phase of HV terminal. Afterwards keep the tap position in normal position and keep HV and LV terminals open. Apply 1phase 10kV supply on IV terminals 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 max. 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.

4. <u>Insulation Resistance (For both Transformers & Reactors)</u>
   Insulation resistance (IR) of windings is the simplest and most widely used test to check the soundness of transformer 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 (like failure to remove the temporary transportation bracket on the live portion of tap-changer part). Insulation resistance is measured by means of Meggers which are available in 500 V, 1000 V, 2500 V and 5000 V ratings. For transformer windings with voltage rating 11 kV and above, 2.5 kV megger shall be used. IR value

measurements of EHV transformers 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	

Record 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.

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	300 MΩ
33kV	400 MΩ
66kV & above	500 MΩ

Even if the insulation is dry, IR values will be low if the resistivity of oil is poor. With the 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 with class A insulation, in reasonably dried condition the absorption coefficient at 30°C will be more than **1.3.**

Polarization Index Test is 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 temp 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** is the ratio of the 10 min to the 1 min megohm readings.

$PI = R_{10} / R_1$ *(dimensionless)*

Where PI is Polarisation Index and R is resistance

The following are guidelines for evaluating transformer 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 PI of more than 1.25 and DAI of more than 1.3 are generally considered satisfactory for a transformer when the results of other low voltage tests are found in order. PI less than 1 calls for immediate corrective action.

5. <u>Capacitance and Tan delta of Windings (Both Transformer & Reactors)</u>
Dissipation factor/Loss factor (Tan δ) and capacitance measurement of winding is carried out to ascertain the general condition of the ground and inter-winding insulation of transformer and reactors.

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.

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 of an insulator indicate abnormal conditions such as the presence of moisture, layer short circuits or open circuits in the capacitance network.

Dissipation factor measurements can indicate the following conditions:

- 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. paper insulation, oil impregnated 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 be within +10%, -5% in capacitance value. Comparison of test results to those for similar piece of equipment especially those tested under the same conditions shall be done.

6. <u>Capacitance and Tan delta of Bushings (Both Transformer & Reactors)</u>

Insulation power factor or dissipation factor (Tan δ) and Capacitance measurement of bushing provide an indication of the quality and soundness 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 test set or bridge frequency different 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 and Correction factor need not be applied. The following precautions/ steps 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 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.

The acceptance criterion to assess the probable condition of the insulation of the transformer is no substantial variation in the measured values of tan delta (dissipation factor) at periodic interval when compared with previous references. For bushings, the tan delta value shall not exceed **0.5% (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 be less than 5%. The capacitance between bushing test tap and ground is largely influence by the stray capacitances to ground parts in the transformer and hence large deviation in the measured value shall be accepted when compared with the factory test value.

7. Short Circuit Impedance (For Transformers Only)
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 further investigated.

8. 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 in either the high voltage winding or 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. Prior to opening the OLTC compartment, it should be inspected for external symptoms of potential problems. Such things as integrity of Paint, weld leaks, oil seal integrity, pressure relief device and liquid level gauge are all items which should be inspected prior to entering the OLTC.

Following de-energization, 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 for internal inspection. Upon opening the OLTC compartment, the door gasket should be inspected for signs 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 check points/guide lines for inspection and maintenance should be addressed and the manufacturer's service engineer should be consulted for details of maintenance/overhauling activity to ensure the absence of problems and ensure proper operation in the future:

- Function of control switches
- OLTC stopping on position
- Fastener tightness
- Signs of moisture such as rusting, oxidation or free standing water and leakages
- 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

B. Oil Parameters

1. Visual Inspection / Color
   Black color of the oil indicates presence of carbonization in the oil. Oil to be visually inspected for healthiness.

2. Dielectric Strength (BDV)

The Electric Strength (dielectric breakdown) is the minimum voltage at which an electric discharge/ flashover occurs between two electrodes set 2.5 mm apart when the voltage is increased at a standard rate under prescribed test conditions. It is a measure of the ability of oil to withstand electrical stress at power frequencies without failure. A low value for the dielectric breakdown voltage generally indicates the presence of contaminants such as water, dirt, or other conducting particles in the oil.

3. Moisture Content (PPM)

Transformer insulation is highly hygroscopic and presence of moisture (water) contributes hazard not only to the dielectric property of oil but also to the cellulosic insulation (i.e. kraft paper, pressboards etc.) that are immersed in the oil. Transformer leaves factory with moisture of less than 0.5% in cellulose which increases due to ageing (formed as byproduct) during operation. Moisture ingress can also take place during erection or operation due to leakage.

As the acidity of the oil increases during use as a result of oxidation or contamination, the tendency to form a water emulsion increases as a result of temperature cycling or agitation. Thus water content determination becomes a crucial factor in deciding the insulating capability of the oil in service and a periodic monitoring becomes essential.

4. Dielectric Loss/Power factor / Dissipation factor (Tan Delta)

The Dielectric Dissipation Factor (DDF) also known as tan of the oil is the tangent of the phase angle between a sinusoidal voltage applied to the oil and the resulting current. DDF is the ratio of power dissipated in the oil in watts to the product of the effective voltage and current in VA, when tested with a sinusoidal field under prescribed conditions. Tan indicates the dielectric loss of an oil; thus the dielectric heating. A high tan is an indication of the presence of contamination or deterioration products such as moisture, carbon or other conducting matter, metal soaps and products of oxidation.

Specific resistance is the ratio of DC potential gradient in Volts per cm paralleling the current flow within the sample to the current density in amperes per sq. cm at given instant of time and under prescribed test conditions. Resistivity is the coefficient of DC electrical field strength and steady state current density within the material. This is a numerical equal to the resistance between opposite faces of a centimeter cube of a liquid and is expressed in -cm. The measurement of resistivity of insulating oil is a sensitive test for the detection of conducting impurities particularly to check purity of new & unused insulating liquids.

5. Inter facial Tension (IFT)

The Inter Facial Tension (IFT) of insulating oil is the force in dynes per cm or Newton per metre required to rupture the oil film existing at an oil-water interface. When certain contaminants such as soaps, paints, varnishes and oxidation products are present in the oil, the film strength of the oil is weakened, thus requiring less force to rupture. Determination of Inter Facial Tension between water and oil gives a measure of the polar compounds present in the oil, which in turn is a measure of level of oil oxidation. Thus this test provides a means of detecting soluble polar contaminants and products of deterioration/ oxidation in the oil.

A low IFT indicates accumulation of contaminants, oxidation products, or both. It is a precursor of objectionable oxidation products which may attack the insulation and interfere with the cooling of transformer windings.

6. Acidity (Neutralization No.)

This test is conducted to find out relative changes that occur in insulating oils during use under oxidizing conditions i.e. to determine the quantum of acidic constituents in insulating oils. Acid content is gauged by a Neutralization No. (NN) which is expressed in milligrams of KOH required to neutralize completely the acid present in one gram of oil. A low Neutralization Number of mineral insulating oil is necessary to minimize electrical conduction, metal corrosion and to maximize the life of the insulation system.

Service-aged oil having a high NN or acid number indicates the oil is either oxidized or contaminated with materials such as varnish, paint or other foreign matter. The presence of acids in the oil is detrimental for besides corroding the various parts of the equipment but it also lowers BDV and often polymerizes to form insoluble sludge which can clog the cooling system. There is no direct correlation between NN and corrosive tendency of oil towards metal in electrical power equipment

7. Oxidation Stability /Ageing test

Insulating Oil, in service is continuously exposed to thermal & electrical stresses. Due to presence of dissolved oxygen in the oil, with copper windings acting as catalyst, the insulating oil undergoes gradual oxidation during its service life. As a result of this oxidation, acids are formed, increasing the acidity of oil. These acids make the oil more hygroscopic and prone to oxidation. The last stage of oxidation, sludge formation takes place. Sludge is detrimental for transformer health as it impairs its cooling. It is therefore desirable to know that any particular oil, which is going to be used, is how much resistant to oxidation.

Oxidation Stability of new insulating oil containing oxidation inhibitor (2-6 DBPC or 2-6 DBP) is a rapid test to evaluate the length of time required for the oil sample to react with a given volume of oxygen when a sample of oil is heated and oxidized under test conditions.

Oxidation Stability of service aged oil determines the resistance of mineral insulating oil to oxidation under prescribed accelerated ageing conditions. Oxidation stability is measure by the propensity of oils to form sludge and acid products during oxidation. The resistance against ageing is the ability of the oil to maintain its properties for a long time as an insulating and cooling medium by maintaining oxidation stability.

8. Particle Count

   Particle count is done at site to ensure the healthiness of the oil and avoid possibility of any flashover.

C. DGA at laboratories

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 with in 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 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 undergoes electrical, 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). Most commonly method used to determine the content of these gases in oil is using a Vacuum Gas Extraction Apparatus and Gas Chromatograph.

Interpretation of DGA results

Individual Fault Gases

To ensure that a transformer (with no measured previous dissolved gas history) is behaving normal, the DGA results are compared with the gassing characteristics exhibited by the majority of similar transformers or normal population. As the transformer ages and gases are generated, the normal levels for 90% of a typical transformer population can be determined. From these values and based on experience, acceptable limits or threshold levels have been determined.

Transformer Sub Type	**FAULT GASES (in µ l/l)**						
	H_2	**CH_4**	**C_2H_6**	**C_2H_4**	**C_2H_2**	**CO**	**CO_2**
All Transformers	50-150	30-130	20-90	60-280		400-600	3800-14000
No OLTC					2-20		
Communicating OLTC					60-280		

Total Dissolved Combustible Gas (TDCG) limits

The severity of an incipient fault can be further evaluated by the total dissolved combustible gas (All hydrocarbons, CO & H_2 but not CO_2) present. Limits for TDCG are as given in table below. An increasing gas generation rate indicates a problem of increasing severity and therefore shorter sampling frequency for closer monitoring.

TDCG LIMITS, PPM	**ACTION**
< or = 720	Satisfactory operation, Unless individual gas acceptance values are exceeded
721-1920	Normal ageing/ slight decomposition, Trend to be established to see if any evolving incipient fault is present.
1921-4630	Significant decomposition, Immediate action to establish trend to see if fault is progressively

TDCG LIMITS, PPM	ACTION
	becoming worse.
>4630	Substantial decomposition, Gassing rate and cause of gassing should be identified and appropriate corrective action such as removal from service may be taken.

Relationship of evolved gases with temperature and Associated Faults

The relationship of the evolved gases can be correlated with the following table to indicate the approximate temperature.

Relationship with temperature
Methane (CH_4) > 120° C
Ethane (C_2H_6) > 120° C
Ethylene (C_2H_4) > 150° C
Acetylene (C_2H_2) > 700° C

The associated faults for the different evolved gases can be correlated with the following table:

Associated faults with different gases
Oil Overheating : C_2H_4, C_2H_6, CH_4
Traces of acetylene with smaller quantity of Hydrogen may be evolved
Overheated Cellulose : CO
Large quantity of Carbon-Di-Oxide (CO_2) and Carbon Monoxide (CO) are evolved from overheated cellulose. Hydrocarbon gases such as Methane and Ethylene will be formed if the fault involves an oil impregnated structure.
Partial discharge in Oil (Corona): H_2, CH_4
Ionization of high stressed area where gas / vapour filled voids are present or 'wet spot' produces Hydrogen and methane and small quantity of other hydrocarbons like ethane and ethylene. Comparable amounts of carbon mono-oxide and di-oxide may result due to discharges in cellulose.
Arcing in Oil : C_2H_2, H_2
Large amount of Hydrogen and acetylene are produced with minor quantities of methane and ethylene in case of arcing between the leads, lead to coil and high stressed area. Small

amounts of carbon mono-oxide and di-oxide may also be formed, if fault involves cellulose.

IEC60599 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 PD (D_1-low energy or D_2-High energy), thermal faults of various temperatures (T_1<300°C, 300°C<T_2<700°C & T_3>700°C).

Case	Characteristic Fault	$\frac{C_2H_2}{C_2H_4}$	$\frac{CH_4}{H_2}$	$\frac{C_2H_4}{C_2H_6}$
PD	Partial discharges	NS	<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 < 300ºC	NS[1]	>1 but NS[1]	<1
T2	Thermal fault 300ºC < 1 < 700ºC	<0.1	>1	1-4
T3	Thermal fault	<0.2 [2]	>1	>4
NOTE 1 – In some countries, the ratio C2H2 / C2H6 is used, rather than the ratio CH4 /H2. 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 – CH4 / H2 <0.2 for partial discharges in instrument transformers. CH4/H2 <0.007 for partial discharges in bushings. NOTE 4 – Gas decomposition patters similar to partial discharges				

have been reported as a result of the decomposition of thin oil film between over-heated core laminates at temperatures of 140 ºC and above.
1. NS = Non- significant whatever the value 2. An increasing value of the amount of C_2H_2 may indicate that the hot spot temperature is higher than 1000ºC

Type	**Fault**	**Examples**
PD	Partial discharges	Discharges in gas-filled cavities resulting from incomplete impregnation, high-humidity in paper, Oil super saturation or cavitations, and leading to X-wax formation.
D1	Discharges of low energy	Sparking or arcing between bad 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 boiled connections (particularly between aluminium, busbar), 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.

Type	Fault	Examples
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.

IEC60599 method for Gas Analysis

Further the IEEE standard C57.104-1991also defines a four-level criterion to classify risks to transformers, when there is no previous dissolved gas history, for continued operation at various combustible gas levels. The criterion uses both concentrations for separate gases and the total concentration of all combustible gases.

The four IEEE conditions are defined below, and gas levels are in the table following the definitions.

Condition 1: Total dissolved combustible gas (TDCG) below this level indicates the transformer is operating satisfactorily. Any individual combustible gas exceeding specified levels in table 8 should have additional investigation.

Condition 2: TDCG within this range indicates greater than normal combustible gas level. Any individual combustible gas exceeding specified levels in table 8 should have additional investigation. A fault may be present. Take DGA samples at least often enough to calculate the amount of gas generation per day for each gas. (See table 8 for recommended sampling frequency and actions.)

Condition 3: TDCG within this range indicates a high level of decomposition of cellulose insulation and/or oil. Any individual combustible gas exceeding specified levels in table 8 should have additional investigation. A fault or faults are probably present. Take DGA samples at least often enough to calculate the amount of gas generation per day for each gas.

Condition 4: TDCG within this range indicates excessive decomposition of cellulose insulation and/or oil. Continued operation could result in failure of the transformer

Status	Hydrogen (H2)	Methane (CH4)	Acetylene (C2H2)	Ethylene (C2H4)	Ethane (C2H6)	Carbon Monoxide (CO)	Carbon Dioxide (CO2)1	TDCG
Condition 1	100	120	35	50	65	350	2,500	720
Condition 2	101-700	121-400	36-50	51-100	66-100	351-570	2,500-4,000	721-1,920

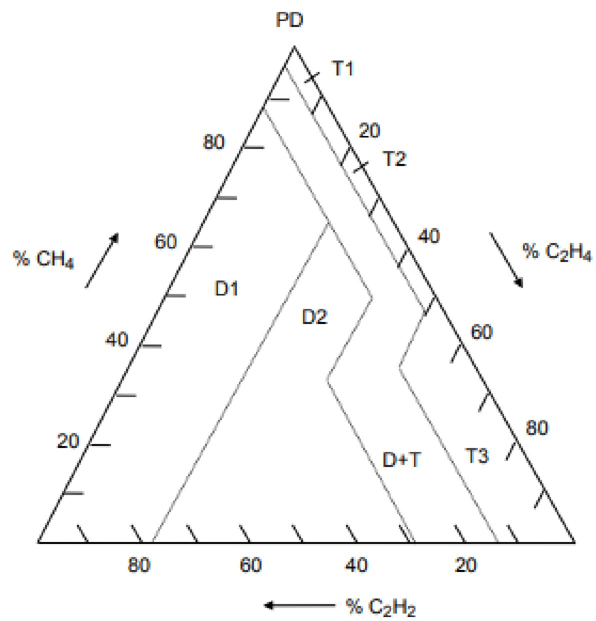
Condition 3	701-1,800	401-1,000	51-80	101-200	101-150	571-1,400	4,001-10,000	1,921-4,630
Condition 4	>1,800	>1,000	>80	>200	>150	>1,400	>10,000	>4,630

CO2 is not included in adding the numbers for TDCG because it is not a combustible gas.

Ratio of the Gases

Duval Triangle method has proven to be accurate and dependable over many years. In the above analysis, three gases are taken for the testing (CH4, C2H2, C2H4).The fault types considered are Partial discharge, thermal fault localized overheating, and overloading.

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.



The only disadvantage of the Duval triangle is that it can't be used to determine whether or not a transformer has a problem.

The **Doernenberg Ratio method** is used when prescribed normal levels of gassing are exceeded. It provides a simple scheme for distinguishing between pyrolysis (overheating) and PD (corona and arcing). In this method four ratios viz. CH_4/H_2, C_2H_2/C_2H_4, C_2H_2/CH_4 & C_2H_6/C_2H_2 are used.

Suggested Fault Diagnosis	Ratio 1 (R1)	Ratio 2 (R2)	Ratio 3 (R3)	Ratio 4 (R4)
	CH4/H2	C2H2/C2H4	C2H2/CH4	C2H6/C2H2
1- Thermal Decomposition	>1.0	<0.75	<0.3	>0.4
2-Corona (Low Intensity PD)	<0.1	Not Significant	<0.3	>0.4
3-Arcing (High Intensity PD)	>0.1	>0.75	>0.3	<0.4

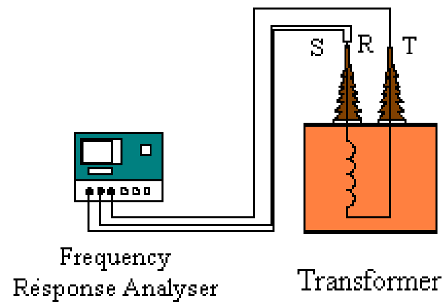
The **Rogers Ratio method** is a more comprehensive scheme using only three ratios viz. CH_4/H_2, C_2H_2/C_2H_4 & C_2H_4/C_2H_6, which details temperature ranges for overheating conditions based on Halstead's research and some distinction of the severity of incipient electrical fault conditions.

Case	***R2 (C2H2/C2H4)***	***R1 (CH4/H2)***	***R5 (C2H4/C2H6)***	***Suggested Fault Diagnosis***
0	<0.1	>0.1	<0.1	Unit normal
1	<0.1	<0.1	<0.1	Low-energy density arcing –PD (See Note)
2	0.1-3.0	0.1-1.0	>3.0	Arcing – High energy discharge
3	<0.1	>0.1 <1.0	1.0-3.0	Low temperature thermal
4	<0.1	>1.0	1.0-3.0	Thermal <700ºC
5	<0.1	>1.0	>3.0	Thermal >700ºC

D. Sweep Frequency Response Analysis

Frequency Response Analysis (FRA) is made to assess the mechanical integrity of the transformer. Transformers while experiencing severity of short circuit current loose 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 signature analysis, provides vital information of the internal condition of the equipment so that early corrective action could be initiated.

Sinusoidal signal output of approximately 2 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 tank. The voltage transfer function T1/R1 is measured for each winding for five standard frequency scans from 5 Hz to 10 MHz and amplitude & phase shift results are recorded. While the low frequency analysis reveals the winding movements, the high frequency analysis reveals the condition of joints.



It is ensured that winding which is not under test is terminated in open condition in order to avoid response difference among the three phases. The same procedure is followed on subsequent tests on the same or similar transformer, to ensure that measurements are entirely repeatable.

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 quantitative condition assessment of the transformer. 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 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 earlier signature.
- Variation in the responses of the three phases of the same transformer.
- Variation in the responses of transformers of the same design.

In all the above cases the appearance of new features 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 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. In general, changes of +/- 3 dB (or more) in following frequency range may indicate following faults:

Frequency Range	**Probable Fault**
5 Hz to 2 KHz	Shorted turns, open circuit, residual magnetism or core movement
50 Hz to 20 KHz	Bulk movement of windings relative to each other
500 Hz to 2 MHz	Deformation within a winding
25 Hz to 10 MHz	Problems with winding leads and/or test lead placement

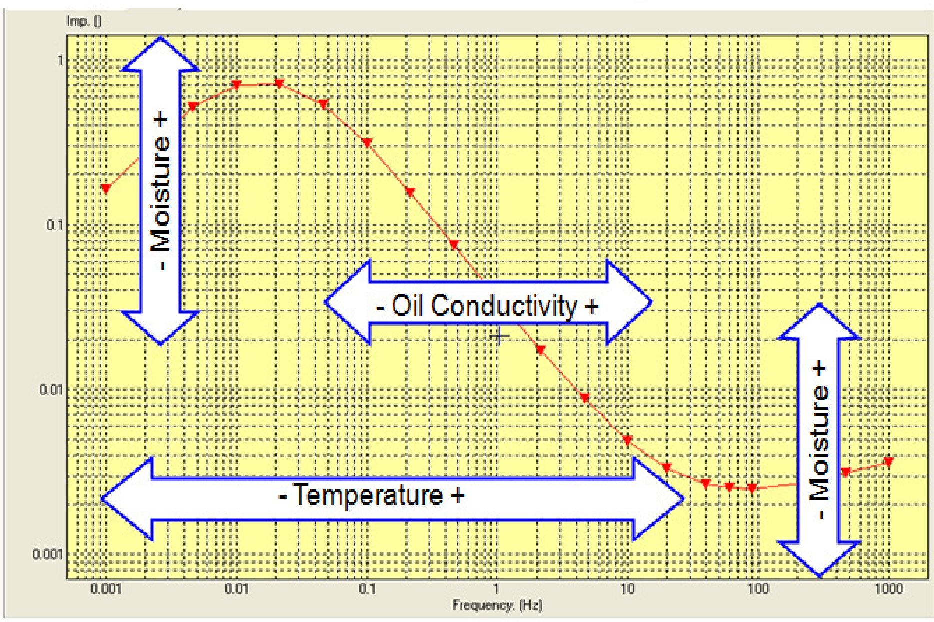
E. Frequency Domain Spectrometry of Bushings

Capacitance and dissipation factor (Tanδ) measurement at 50Hz 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 diagnostic quantities are sometime 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. Problems like partial discharge in bushings, development of bridging of grading layer are generally not reflected in substantial change in capacitance value at 50Hz. In all such cases, Capacitance and dissipation factor (Tanδ) measurement in variable frequency and DGA is proven to be supplement diagnostic tools for condition assessment of OIP bushings. It has been observed that Capacitance and Tan δ measurement in frequency domain (15Hz to 400 Hz and 1 mHz to 1kHz) have correlated very accurately to bushing DGA & Visual inspection upon dismantling.

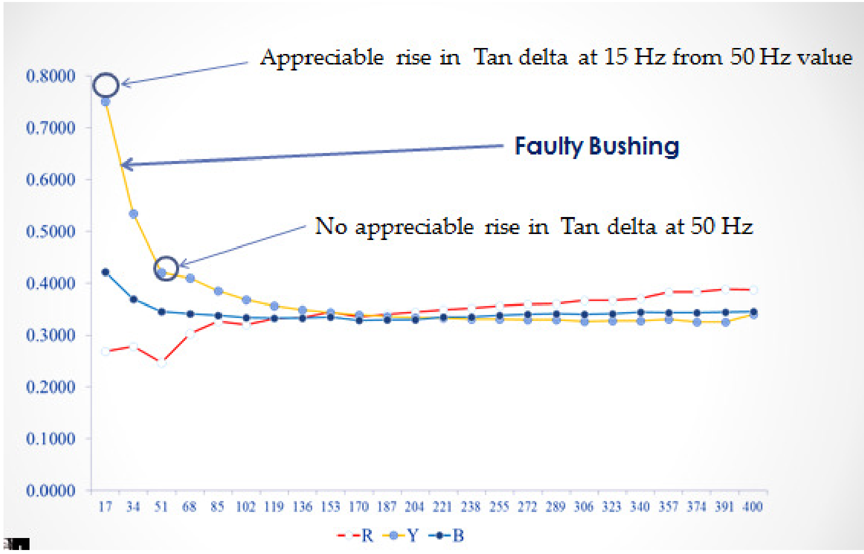
Dielectric losses measured in the frequency domain FDS (Frequency Domain Spectroscopy) reflect the same fundamental polarization and conduction phenomena in transformer insulation, the special feature of which is a combination of oil gaps and solid insulation and as a consequence are influenced strongly by both solid insulation moisture content and oil condition and less influenced by the geometry of the solid and liquid insulations.

The complex permittivity can be used to characterize the insulation. It is a dimensionless quantity consisting of a real part representing the energy stored in the electric field within the sample and an imaginary part representing the energy losses. FDS response of an oil paper composite insulation represents the frequency and temperature dependent permittivity and dissipation factor of composite insulation. In addition, faults 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 response of the bushing may be interpreted in the manner as suggested:



An Example of the result comparison of a faulty bushing is as shown:



II. On Line Monitoring Activities for Transformer/ Reactor

A. Online-DGA

Continuous On-Line Monitoring of DGA is very important monitoring technology for Transformers & Reactors. Several sensors technologies are available in the market using different detection techniques (fuel cell, chromatography, semiconductor, photo-acoustic spectroscopy, thermal conductivity). Depending on the technology and its implementation, the Online DGAs available in the market vary from two gases (Hydrogen & Moisture) to Ten Gas model (All Gases).

One of the major advantages of on-line monitors is that alarm can be raised in the event of exceeding fault gas from the threshold levels or rate of change (ROC) of fault gases. If asset manager responds to these alarms and prompt action are taken on time then major failures and damage to other associated equipment can often be prevented. By communicating the on line DGA data to remote center on continuous basis, suitable actions to each possible alarm should be formulated and should be made available with Asset Manager for responding to each incidence. Further, it can be helpful in health indexing as well as dynamic change of condition of the equipment on continuous basis.

The disadvantage of Single gas on line DGAs is that Hydrogen is considered as stray gas. Further, Hydrogen may also be generated by reaction of steel and galvanized steel with water as long as oxygen is available from the oil nearby. Large quantity of Hydrogen may also be generated due to presence of trapped air due to improper vacuum in the Transformer tank. Hence, based on only H2 concentration in the oil, it is difficult for taking decision for further course of action. However, if the multi gas on line DGA monitors are provided, then taking decision becomes easier based on the rising trend of all other fault gasses.

B. Partial Discharge Measurement

Partial discharges (PD) are localized dielectric discharges in a partial area of a solid or liquid electrical dielectric insulation system under high-voltage field stress. Partial discharges in a transformer deteriorate its insulation and can lead to failure of the transformer. 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.

The partial discharge (PD) results in localized, nearly instantaneous release of energy. The energy released in a PD produces a number of effects such as chemical and structural changes in the material, Electro-magnetic effects etc. The Acoustic Discharge Detection is based on detection of the mechanical signals emitted from the discharge. A fraction of the released energy from the PD source heats the adjacent material and can evaporate some of it, creating a small explosion. The discharge acts as a point source of acoustic waves that propagates throughout the insulation. The intensity of the emitted acoustic wave is proportional to the energy released in the discharge. Thus the amplitude of the wave is proportional to the square root of the energy in the discharge. As the energy is often proportional to the charge squared, a linear relationship between the amplitude of the acoustic wave and the discharge magnitude (in pico Coulombs) is common. In Acoustic measurement, the fault is localized based on the sensors which are placed on the wall and which are used to echo locate the fault within the transformer body.

Alternatively the electromagnetic emission of a PD can also be measured using an UHF antenna which is inserted into the transformer tank. Due to the Faraday shielding of the transformer 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 needs to have dedicated valves for providing the said sensors.

C. Bushing Tan delta measurement

Changes in bushing capacitance and power factor are indicative of insulation deterioration. Normally bushing tan delta is measured during shutdown period but in many cases where there was a very rapid deterioration of insulation sudden & catastrophic failures have resulted. To rule out these possibilities Online monitoring of Bushing Tan Delta can be undertaken.

Several On-Line bushing monitoring technologies are currently available in the market using different detection techniques (i.e *sum of leakage current method, Phase shift method etc.)* Depending on the technology and its implementation, the systems are able to provide to measure either relative change in capacitance & Tan δ or absolute capacitance and Tan δ.

The sensors can also be used to monitor the Partial Discharge in the bushings also. For partial discharge measurement, the signals from the sensors and Rogowski coils were used. The sensors provides primary diagnostic information for the system while the signals from the Rogowski coils are used to assist in identifying whether the partial discharge activity being measured was positive or negative and whether it was coming from inside the reactor or from outside sources.

PD generally occurs as the voltage stress increases and PD patterns are repeatable. Often the same pattern can be seen on the positive and negative half of the sine wave and over multiple data plots. These are fundamental characteristics of the activity to be classified as partial discharge.

D. Moisture Measurement & Control

Moisture in the transformer oil can be measured and also controlled using the Online Dryout system. The system is permanently installed which continuously keeps on removing the moisture while transformer is in charged stage. During the filtration process moisture PPM level is continuously monitored. This process does not only remove moisture from transformer oil but from the insulation as well.

The transformer oil is circulated through a series of cylinders filled with specially designed cartridges that absorbs moisture as well as removes solid contaminations from the oil. However this may not be suitable for Wet transformers/Reactors which may require Off Line Dryout.

E. Hot spot temperature

Transformers can be fitted with Fibre Optic Sensors which can be used to monitor the temperature at identified points in the transformer. The sensors' locations are based on the design of the transformer to monitor the temperatures at the various identified temperature hotspots.

F. Thermovision Scanning

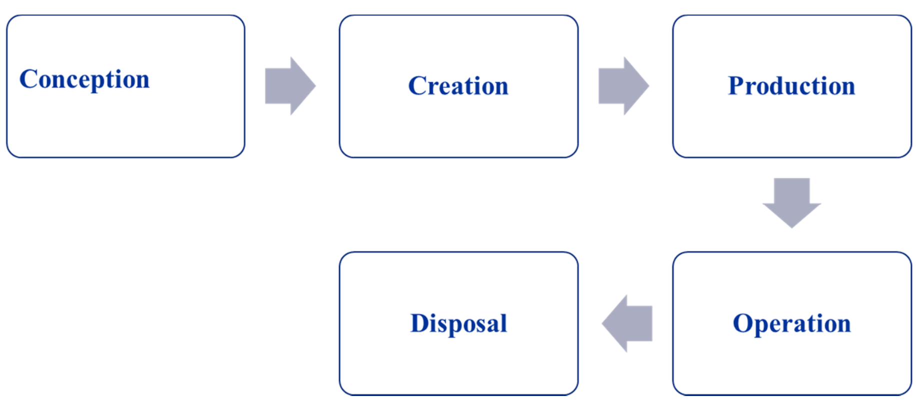
In order to avoid prohibited temperature rises in the electrical connections of the transformer, all screw-joints included should be checked and re-tightened based on readings from thermovision camera.

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 62-1995)
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

III. 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 to include feedback from the Asset Manager. By giving a feedback (based on the accurate measurements on lines of the method described above) we can optimize the operation of the equipment and improve its lifecycle.

Condition Monitoring Tests for Transformers and Reactors			
S. No.	Test Name	Acceptable Values	Frequency
1.	Tan Delta for Bushing & winding	0.007 (Maximum) – for bushing 0.005 (Maximum) – for winding Note: 1. For the values to be followed during warranty period has been indicated in the chapter-2. 2. Rate of Rise of Tan Delta (Bushing & Winding) shall not be more than 0.001 per year	Yearly (bushing) 4 yearly (winding)
3.	Capacitance for Bushing	- 5 % to + 5 % Variation from Factory Test results	Yearly
4.	Capacitance for Winding	- 5 % to + 10 % Variation from Factory Test results	4 Yearly
5.	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
6.	Magnetic Balance Test	Value of supply voltage in one phase is equal to sum voltage induced in other	SOS

	(Three Phase) on transformer	two phase. When supply voltage in middle limb, voltage induced in outer limbs should equal and roughly half of the supply voltage.		
7.	Winding resistance (Resistance converted to 75 ºC)	± 5% difference between phases or from Factory tests		SOS
8.	Voltage Ratio (All Taps) on transformer	±0.5% difference from nameplate specifications		SOS
9.	IR Value of Winding Min	Unless otherwise recommended by the manufacturer, 500 Mega-ohm for 66 kV and above voltage class		SOS
10.	Polarization Index (Ratio of IR values at 10 min to 1 min)	Polarization Index	Insulation Condition	SOS
		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	
11.	Core Insulation Test (Between core to clamp; clamp to tank; & core to tank)	Minimum 1 Giga Ohm at 2.5/ 3.5 kV DC for 1 minute		SOS
12.	Neutral Earthpit Resistance Value	Below 1 ohm		Yearly
13.	Turret/ Neutral CT Ratio Errors	± 3%		SOS
14.	Vibration Level for reactors	200 Microns (Peak to Peak) 60 Microns (Average)		SOS
15.	Sweep Frequency Response Analysis Tests (20 Hz to 2 MHz)	In general, changes of ±3 dB (or more) in following frequency range may indicate following faults:		SOS
		Frequency Range	Probable Fault	
		5 Hz to 2 KHz	Shorted turns, open circuit, residual magnetism or c movement	
		50 Hz to 20 KHz	Bulk movement of windings relative to each	

<table>
<tr><td rowspan="9"></td><td rowspan="9"></td><td colspan="2"></td><td>other</td><td rowspan="9"></td></tr>
<tr><td colspan="2">500 Hz to 2 MHz</td><td>Deformation within a winding</td></tr>
<tr><td colspan="2">25 Hz to 10 MHz</td><td>Problems with winding leads and/or test lead placement</td></tr>
<tr><td>Dry (at commissioning)</td><td rowspan="2"><0.5%</td><td><5%</td></tr>
<tr><td>Normal in operation</td><td></td></tr>
<tr><td>Wet</td><td>2-4%</td><td>6-20%</td></tr>
<tr><td>Extremely Wet</td><td>>4.5%</td><td>>30%</td></tr>
<tr><td>16.</td><td>Short Circuit Impedance on transformer</td><td colspan="3">± 3% of nameplate specifications</td><td>SOS</td></tr>
<tr><td>17.</td><td>DGA of tank oil & OLTC oil</td><td colspan="3">As laid down under concerned clause</td><td>Half Yearly</td></tr>
<tr><td>18.</td><td>Oil parameters of tank oil</td><td colspan="3"></td><td>Yearly</td></tr>
<tr><td rowspan="6">19.</td><td rowspan="6">Thermo-vision Scanning</td><td colspan="3">Temperature rise above ambient (°C)/Criticality</td><td rowspan="6">Half Yearly</td></tr>
<tr><td colspan="2">0-10</td><td>Minor</td></tr>
<tr><td colspan="2">11-39</td><td>Intermediate</td></tr>
<tr><td colspan="2">40-75</td><td>Serious</td></tr>
<tr><td colspan="2">>76</td><td>Critical</td></tr>
<tr><td colspan="3">Note: Comparison to be made with similar joints/items of the same transformer and values are to be nearly matching</td></tr>
</table>

SPECIFIC TECHNICAL REQUIREMENT

1.0 Technical Particulars/ Parameters of 500 MVA, (765/√3)/(400/√3)/33 kV 1-Ph Auto-Transformer

S. No.	Description	Unit	Parameters
1.	Voltage ratio (Phase Voltage)	kV	(765/√3)/(400/√3)/33 kV
2.	Single / Three Phase Design		1 (Single)
3.	Type of Transformer		Auto transformer
4.	Rated Capacity		
	HV	MVA	500
	IV	MVA	500
	LV (Tertiary)	MVA	5 MVA active loading
5.	Applicable Standard		IEC-60076 / IS 2026
6.	Cooling		ONAN / ONAF / (OFAF or ODAF) OR ONAN / ONAF1 / ONAF2
7.	Rating at different cooling	%	60 / 80 / 100
8.	Cooler Bank Arrangement		2 X 50%
9.	Frequency	Hz	50
10.	Tap Changer		No
11.	Impedance at 75 Deg C		
	HV – IV	%	14.0
	HV – LV (minimum)	%	195.0
	IV – LV(minimum)	%	180.0
12.	Tolerance on Impedance (for HV-IV)	%	As per IEC
13.	Service		Outdoor
14.	Duty		Continuous
15.	Overload Capacity		IEC-60076-7 / IS 6600
16.	Max. temperature rise over 50 deg C ambient temperature	^{O}C	
i)	Top oil measured by thermometer	^{O}C	50
ii)	Average winding measured by resistance method	^{O}C	55
iii)	Winding hot spot	^{O}C	66
17.	Tank Hotspot Temperature	^{O}C	95
18.	Max. design Ambient temp	^{O}C	50
19.	Windings		

i)	Lightning Impulse Withstand Voltage		
	HV	kV_p	1950
	IV	kV_p	1300
	LV	kV_p	250
	Neutral	kV_p	170
ii)	Switching Impulse withstand Voltage	kV_p	
	HV	kV_p	1550
	IV	kV_p	1050
	LV	kV_p	-
	Neutral	kV_p	-
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	-
	IV	kV_{rms}	570
	LV	kV_{rms}	95
	Neutral	kV_{rms}	70
iv)	Neutral		Solidly Earthed
v)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vi)	Tertiary Connection		Ungrounded Delta
vii)	Tan delta of windings at ambient Temperature	%	≤ 0.5
20.	Vector Group (3 –ph)		YNaOd11
21.	Bushing		
i)	Rated voltage		
	HV	kV	800
	IV	kV	420
	LV	kV	52
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	2500
	IV	A	2500
	LV	A	3150
	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
	LV	kV_p	-
	Neutral	kV_p	-
v)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	970
	IV	kV_{rms}	695
	LV	kV_{rms}	105
	Neutral	kV_{rms}	77
vi)	Minimum total creepage distances		
	HV	mm	24800
	IV	mm	13020
	LV	mm	1612
	Neutral	mm	1116
vii)	Max Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
	Neutral		
22.	Max Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100
23.	Max Noise level at rated voltage and at principal tap		
i)	At ONAN condition	dB	70
ii)	Max Noise level at rated voltage and at principal tap at 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	80
ii)	Max. Load Loss at rated current and frequency and at 75^{O} C for HV and IV windings	kW	450
iii)	Max I^2R loss at rated current and frequency and at 75^{O} C for HV and IV windings	kW	335
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	10

2.0 Technical Particulars / Parameters of 500 MVA (3-phase) and 167 MVA (1-phase), 400/220/33 kV Auto Transformer

S. No.	Description	Unit	Technical Parameters	
1.	Rated Capacity			
	HV	MVA	500	167
	IV	MVA	500	167
	LV (Tertiary)	MVA	5 MVA active loading	
2.	Voltage ratio (Line-to-Line)		400/220/33	
3.	Single / Three Phase Design		3 (Three)	1 (Single)
4.	Applicable Standard		IEC 60076	
5.	Frequency	Hz	50	50
6.	Cooling and Percentage Rating at different cooling		ONAN/ONAF/(OFAF or ODAF) : 60% / 80% /100% OR ONAN/ONAF1/ONAF2: 60% / 80% /100%	
7.	Cooler Bank Arrangement		2 X 50%	
8.	Tap Changer		No	
9.	Impedance at 75 Deg C		Constant Ohmic impedance type	Constant percentage impedance type
	HV – IV		12.5	12.5
	HV – LV(minimum)		45.0	45.0
	IV – LV(minimum)		30.0	30.0
10.	Tolerance on Impedance (HV-IV)	%	As per IEC	
11.	Service		Outdoor	
12.	Duty		Continuous	
13.	Overload Capacity		IEC-60076-7	
14.	Temperature rise over 50 deg C ambient temp			
i)	Top oil measured by thermometer	^{o}C	50	
ii)	Average winding measured by resistance method	^{o}C	55	
iii)	Winding hot spot	^{o}C	66	
15.	Tank Hotspot Temperature	^{o}C	95	
16.	Windings			
i)	Lightning Impulse withstand Voltage			
	HV	kV_p	1300	
	IV	kV_p	950	

	LV	kV_p	250
	Neutral	kV_p	95
ii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	395
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
iv)	Neutral Grounding		Solidly grounded
v)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vi)	Tertiary Connection		Ungrounded Delta
vii)	Tan delta of winding	%	≤0.5
17.	Vector Group (3 –ph) (unless specified differently elsewhere)		YNaOd11
18.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	245
	LV	kV	52
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	1250
	IV	A	2000
	LV	A	3150
	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)	Minimum total creepage distances			
	HV	mm	10500	
	IV	mm	6125	
	LV	mm	1300	
	Neutral	mm	900	
vii)	Max Partial discharge level at U_m			
	HV	pC	10	
	IV	pC	10	
	LV	pC	10	
	Neutral		-	
19.	Max Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100	
20.	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	80	
21.	**Maximum Permissible Losses of Transformers**		**500 MVA**	**167 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	90	45
ii)	Max. Load Loss at rated current and at 75^{O} C for HV and IV windings	kW	475	200
iii)	Max I^2R loss at rated current and at 75^{O} C for HV and IV windings	kW	385	150
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	15	6

3.0 Technical Particulars / Parameters of 315 MVA (3-phase) & 105 (1-phase), 400/220/33 kV Auto Transformer

Clause No.	Description	Unit	Technical Parameters	
1.	Rated Capacity			
	HV	MVA	315	105
	IV	MVA	315	105
	LV (Tertiary) :	MVA	5 MVA active loading	
2.	Voltage ratio (Line-to-Line)		400/220/33	
3.	Single / Three Phase Design		3 (Three)	1 (Single)
4.	Applicable Standard		IEC 60076	
5.	Frequency	Hz	50	50
6.	Cooling & Percentage Rating at different cooling		ONAN/ONAF/(OFAF or ODAF) : 60% / 80% /100% OR ONAN/ONAF1/ONAF2: 60% / 80%/100%	
7.	Cooler Bank Arrangement		2 X 50%	
8.	Tap Changer		No	
9.	Type of Transformer		Constant Ohmic impedance type	Constant percentage impedance type
10.	Impedance at 75 Deg C			
	HV - IV		12.5	12.5
	HV - LV(minimum)		60.0	45.0
	IV - LV(minimum)		45.0	30.0
11.	Tolerance on Impedance (HV-IV)	%	As per IEC	
12.	Service		Outdoor	
13.	Duty		Continuous	
14.	Overload Capacity		IEC-60076-7	
15.	Temperature rise over 50deg C ambient Temp			
i)	Top oil measured by thermometer	^{O}C	50	
ii)	Average winding measured by resistance method	^{O}C	55	
iii)	Winding hot spot	^{O}C	66	
16.	Tank Hotspot Temperature	^{O}C	95	
17.	Windings			

i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	950
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	395
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
iv)	Neutral Grounding		Solidly grounded
v)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform
vi)	Tertiary Connection		Ungrounded Delta
vii)	Tan delta of winding	%	≤ 0.5
18.	Vector Group (3 –ph) (unless specified differently elsewhere)		YNaOd11
19.	Bushing		
i)	Rated voltage		
	HV	kV	420
	IV	kV	245
	LV	kV	52
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	1250
	IV	A	1250
	LV	A	3150
	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)	Minimum total creepage distances	mm/kV	31	
vii)	Max Partial discharge level at U_m			
	HV	pC	10	
	IV	pC	10	
	LV	pC	10	
	Neutral		-	
20.	Max Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100	
21.	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	80	
22.	**Maximum Permissible Losses of Transformers**		**315 MVA**	**105 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	75	30
ii)	Max. Load Loss at rated current and at 75^o C for HV and IV windings	kW	440	140
iii)	Max. I^2R Loss at rated current and at 75^O C for HV and IV windings	kW	330	105
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	10	6

4.0 Technical Particulars/ Parameters of 315 MVA & 200 MVA, 400/132/33 kV 3-Phase Auto Transformer

Clause No.	Description	Unit	Technical Parameters	
1.	Rated Capacity			
	HV	MVA	315	200
	IV	MVA	315	200
	LV (Tertiary) :	MVA	5 MVA active loading	
2.	Voltage ratio (Line-to-Line)		400/132/33	
3.	Single / Three Phase Design		3 (Three)	
4.	Applicable Standard		IEC 60076	
5.	Frequency	Hz	50	
6.	Cooling & Percentage Rating at different cooling		ONAN/ONAF/(OFAF or ODAF) : 60% / 80%/100% OR ONAN/ONAF1/ONAF2: 60% / 80%/100%	
7.	Cooler Bank Arrangement		2 X 50%	
8.	Type of Transformer		Constant Ohmic impedance type	Constant percentage impedance type
9.	Impedance at 75 Deg C			
i)	HV – IV			
	Max. Voltage tap	%	10.3	13.0
	Principal tap	%	12.5	12.5
	Min. Voltage tap	%	15.4	14.0
ii)	HV – LV			
	Principal tap (minimum)	%	45.0	40.0
iii)	IV – LV			
	Principal tap (minimum)	%	30.0	25.0

iv)	Tolerance on Impedance (HV-IV)	%	As per IEC / IS
10.	Service		Outdoor
11.	Duty		Continuous
12.	Overload Capacity		IEC-60076-7 / IS 6600
13.	Temperature rise over 50 deg C ambient temp.		
i)	Top oil measured by thermometer	^{O}C	50
ii)	Average winding measured by resistance method	^{O}C	55
iii)	Winding hot spot	^{O}C	66
14.	Tank Hotspot Temperature	^{O}C	95
15.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	IV	kV_p	650
	LV	kV_p	250
	Neutral	kV_p	95
ii)	Switching Impulse withstand Voltage		
	HV	kV_p	1050
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	570
	IV	kV_{rms}	275
	LV	kV_{rms}	95
	Neutral	kV_{rms}	38
iv)	Neutral Grounding		Solidly grounded
v)	Insulation		
	HV		Graded

	IV		Graded	
	LV		Uniform	
vi)	Tertiary Connection		Ungrounded Delta	
vii)	Tan delta of winding	%	≤ 0.5	
viii)	Vector Group (3 –ph) (unless specified differently elsewhere)		YNaOd11	
16.	Tap Changer		OLTC	
i)	Tap Range and no. of steps		± 10% of HV variation in the step of 1.25%, 16 steps	
ii)	Location of Tap changer		On the 132 kV side of the series winding	
iii)	Design		Constant flux voltage variation type as per cl. 6.2 of IEC 60076 part-I	
iv)	Tap control		Full capacity - on load tap changer suitable for group / independent, remote /local electrical and local manual operation and bi-directional power flow	
17.	Bushing			
i)	Rated voltage			
	HV	kV	420	
	IV	kV	145	
	LV	kV	52	
	Neutral	kV	36	
ii)	Rated current (Min.)		**315 MVA**	**200 MVA**
	HV	A	1250	1250
	IV	A	2000	1250
	LV	A	3150	2000
	Neutral	A	2000	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)	Minimum total creepage distances	mm/kV	31	
vii)	Max Partial discharge level at U_m			
	HV	pC	10	
	IV	pC	10	
	LV	pC	10	
18.	Max Partial discharge level at $1.58 * U_r / \sqrt{3}$	pC	100	
19.	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	80	
20.	**Maximum Permissible Losses of Transformers**		**315 MVA**	**200 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	75	68
ii)	Max. Load Loss at rated current and at 75^{O} C for HV and IV windings	kW	440	350

iii)	Max. I^2R Loss at rated current and at 75^O C for HV and IV windings	kW	330	270
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	10	8

5.0 Technical Particulars/ Parameters of 200 MVA & 160 MVA, 220/132/33 kV 3-Phase Auto Transformer

Cl. No.	Description	Unit	TECHNICAL PARAMETERS	
1.	Rated Capacity			
	HV	MVA	200	160
	IV	MVA	200	160
	LV (Tertiary)* (see note)	MVA	5 MVA active loading	
2.	Voltage ratio	kV	220/132/33	
3.	Single / Three Phase Design		3 (Three)	
4.	Applicable Standard		IEC 60076 /IS 2026	
5.	Frequency	Hz	50	
6.	Cooling & Percentage Rating at different cooling		ONAN/ONAF/(OFAF or ODAF) : 60% / 80%/100% OR ONAN/ONAF1/ONAF2: 60% / 80%/100%	
7.	Cooler Bank Arrangement		2 X 50%	
8.	Type of Transformer		Constant Ohmic impedance type	Constant percentage impedance type
9.	HV-IV Impedance at 75 Deg C			
i)	Max. Voltage tap	%	10.3	13.0
ii)	Principal tap	%	12.5	12.5
iii)	Min. Voltage tap	%	15.4	14.0
iv)	Tolerance on Impedance	%	As per IEC	
10.	Service		Outdoor	
11.	Duty		Continuous	
12.	Overload Capacity		IEC 60076-7 / IS 6600	

13.	Temperature rise over 50 deg C Ambient Temp		
i)	Top oil measured by thermometer	^{o} C	50
ii)	Average winding measured by resistance method	^{o} C	55
iii)	Winding hot spot	^{o} C	66
14.	Tank Hotspot Temperature	^{o} C	95
15.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kVp	950
	IV	kVp	650
	LV	kVp	250
	Neutral	kVp	95
ii)	Switching Impulse withstand Voltage		
	HV	kVp	750
iii)	One Minute Power Frequency withstand Voltage		
	HV	kVrms	395
	IV	kVrms	275
	LV	kVrms	95
	Neutral	kVrms	38
iv)	Neutral Grounding		Solidly grounded
v)	Insulation		
	HV		Graded
	IV		Graded
	LV		Uniform

vi)	Tertiary Connection		Delta
vii)	Tan delta of winding	%	≤0.5%
16.	Vector Group (3 –ph) (unless specified differently elsewhere)		YNa0d11
17.	Tap Changer		OLTC
i)	Tap Range and no. of steps		–5% to +10% of HV variation in the step of 1.25%, 12 Steps
ii)	Location of Tap changer		On the 132 kV side of the series winding
iii)	Design		Constant flux voltage variation type as per cl. 6.2 of IEC 60076 part-I
iv)	Tap control		Full capacity - on load tap changer suitable for group / independent, remote /local electrical and local manual operation and bi-directional power flow
18.	Bushings		
i)	Rated voltage		
	HV	kV	245
	IV	kV	145
	LV	kV	52
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	800
	IV	A	1250
	LV	A	800
	Neutral	A	1000
iii)	Lightning Impulse withstand Voltage		

	HV	kVp	1050
	IV	kVp	650
	LV	kVp	250
	Neutral	kVp	170
iv)	Switching Impulse withstand Voltage		
	HV	kVp	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kVrms	505
	IV	kVrms	305
	LV	kVrms	105
	Neutral	kVrms	77
vi)	Minimum total creepage distances		
	HV	mm	6125
	IV	mm	3625
	LV	mm	1300
	Neutral	mm	900
viii)	Max Partial discharge level at U_m		
	HV	pC	10
	IV	pC	10
	LV	pC	10
19.	Max Partial discharge level at 1.5 $*Um/\sqrt{3}$	pC	100
20.	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	75

21.	**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^{O} C for HV and IV windings	kW	260	200
iii)	Max. I^2R Loss at rated current and at 75^{O} C for HV and IV windings	kW	190	145
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	8	6

* Note: Tertiary may be avoided if not specifically required by the utility and manufacturer can design the transformer without tertiary with 3 limbs.

6.0 Technical Particulars / Parameters of 100 MVA, 220/132 kV 3-Phase Auto Transformer

Cl. No.	Description	Unit	TECHNICAL PARAMETERS
1.	Rated Capacity	MVA	100
2.	Voltage ratio	kV	220/132
3.	Single / Three Phase Design		3 (Three)
4.	Applicable Standard		IEC 60076 /IS 2026
5.	Frequency	Hz	50
6.	Cooling and Percentage Rating at different cooling		ONAN/ONAF/(OFAF or ODAF) : 60% / 80%/100% OR ONAN/ONAF1/ONAF2: 60% / 80%/100%
7.	Cooler Bank Arrangement		2 X 50%
8.	Type of Transformer		Constant Ohmic impedance type
9.	HV-LV Impedance at 75 Deg C		
i)	Max. Voltage tap	%	10.3
ii)	Principal tap	%	12.5
iii)	Min. Voltage tap	%	15.4
iv)	Tolerance on Impedance	%	As per IEC
10.	Service		Outdoor
11.	Duty		Continuous
12.	Overload Capacity		IEC 60076-7
13.	Temperature rise over 50 deg C Ambient Temp		
i)	Top oil measured by thermometer	^{O} C	50
ii)	Average winding measured by resistance method	^{O} C	55
iii)	Winding hot spot	^{O} C	66
14.	Tank Hotspot Temperature	^{O} C	95

15.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kVp	950
	LV	kVp	650
	Neutral	kVp	95
ii)	Switching Impulse withstand Voltage		
	HV	kVp	750
iii)	One Minute Power Frequency withstand Voltage		
	HV	kVrms	395
	LV	kVrms	275
	Neutral	kVrms	38
iv)	Neutral Grounding		Solidly grounded
v)	Insulation		
	HV		Graded
	LV		Graded
vi)	Tan delta of winding	%	≤0.5%
16.	Vector Group (3 –ph) (unless specified differently elsewhere)		YNa0d11
17.	Tap Changer		OLTC
i)	Tap Range and no. of steps		–5% to +10% of HV variation in the step of 1.25%, 12 Steps
ii)	Location of Tap changer		On the 132 kV side of the series winding

iii)	Design		Constant flux voltage variation type as per cl. 6.2 of IEC 60076 part-I
iv)	Tap control		Full capacity - on load tap changer suitable for group / independent, remote /local electrical and local manual operation and bi-directional power flow
18.	Bushings		
i)	Rated voltage		
	HV	kV	245
	LV	kV	145
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	800
	LV	A	1250
	Neutral	A	1000
iii)	Lightning Impulse withstand Voltage		
	HV	kVp	1050
	LV	kVp	650
	Neutral	kVp	170
iv)	Switching Impulse withstand Voltage		
	HV	kVp	850
v)	One Minute Power Frequency withstand Voltage		
	HV	kVrms	505
	LV	kVrms	305

	Neutral	kVrms	77
vi)	Minimum total creepage distances	mm/kV	31
viii)	Max Partial discharge level at U_m		
	HV	pC	10
	LV	pC	10
19.	Max Partial discharge level at $1.5*Um/\sqrt{3}$	pC	100
20.	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	75
21.	**Maximum Permissible Losses of Transformers**		
i)	Max. No Load Loss at rated voltage and frequency	kW	20
ii)	Max. Load Loss at rated current and at 75^{O} C	kW	220
iii)	Max. I^2R Loss at rated current and at 75^{O} C	kW	165
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	5

7.0 Technical Particulars / Parameters of 50 MVA, 132/66 kV 3-Phase Auto Transformer

Cl. No.	Description	Unit	TECHNICAL PARAMETERS
1.	Rated Capacity	MVA	50
2.	Rated Voltage ratio (HV/LV) (Line-to-Line)	kV	132/66
3.	Single / Three Phase Design		Three
4.	Applicable Standard		IEC 60076 / IS 2026
5.	Frequency	Hz	50
6.	Cooling		ONAN/ONAF
7.	Rating at different cooling	%	60 / 100
8.	Cooler Bank Arrangement		1 x 100%
9.	Type of Transformer		Constant Ohmic impedance type
10.	HV-LV Impedance at 75 Deg C		
i)	Max. Voltage tap	%	8.26
ii)	Principal tap	%	10
iii)	Min. Voltage tap	%	12.34
iv)	Tolerance on Impedance	%	As per IEC
11.	Service		Outdoor
12.	Duty		Continuous
13.	Overload Capacity		IEC 60076-7 / IS 6600
14.	Temperature rise over 50 deg C Ambient Temp		
i)	Top oil measured by thermometer	^{O} C	50
ii)	Average winding measured by resistance method	^{O} C	55
iii)	Winding hot spot	^{O} C	66
15.	Tank Hotspot Temperature	^{O} C	95

16.	Windings		
i)	Lightning Impulse withstand Voltage		
	HV	kV_p	650
	LV	kV_p	325
	Neutral	kV_p	95
ii)	Switching Impulse withstand Voltage		
	HV	kV_p	540
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	275
	LV	kV_{rms}	140
	Neutral	kV_{rms}	38
iv)	Neutral Grounding		Solidly grounded
	Insulation		
	HV		Graded
	LV		Graded
v)	Tan delta of winding	%	≤0.5
17.	Vector Group (3 –ph) (unless specified differently elsewhere)		YNa0
18.	Tap Changer		OLTC
i)	Tap Range and no. of steps		–5% to +10% of HV variation in the step of 1.25%, 12 steps
ii)	Location of Tap changer		On the 66 kV side of the series winding
iii)	Design		Constant flux voltage variation type as per cl. 6.2 of IEC 60076 part-I
iv)	Tap control		Full capacity on load tap changer suitable for

			group/independent, remote /local electrical and local manual operation and bi-directional power flow
19.	Bushings		
i)	Rated voltage		
	HV	kV	145
	LV	kV	72.5
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	800
	LV	A	1250
	Neutral	A	2000
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	650
	LV	kV_p	325
	Neutral	kV_p	170
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	305
	LV	kV_{rms}	155
	Neutral	kV_{rms}	77
v)	Minimum total creepage distances	mm/kV	31
viii)	Max Partial discharge level at U_m		
	HV	pC	10
	LV	pC	10
	Neutral	pC	-

20.	Max Partial discharge level at 1.5*Um/√3	pC	100
21.	Max Noise level at rated voltage and at principal tap at no load and all cooling active	dB	75
22.	**Maximum Permissible Losses of Transformers**		
i)	Max. No Load Loss at rated voltage and frequency	kW	14
ii)	Max. Load Loss at rated current and frequency and at 75^{O} C	kW	95
iii)	Max. I^2R Loss at rated current and frequency and at 75^{O} C	kW	76
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	2

8.0 Technical Particulars / Parameters of 50 MVA & 31.5 MVA, 132/33 kV, 3-Phase Power Transformer

Cl. No.	Description	Unit	TECHNICAL PARAMETERS	
1.	Rated Capacity	VA	50	31.5
2.	Voltage ratio (HV/LV) Line-to-line	kV	132/33	
3.	Single / Three Phase Design		3 (Three)	
4.	Applicable Standard		IEC 60076 / IS 2026	
5.	Frequency	Hz	50	
6.	Cooling		ONAN/ONAF	
7.	Rating at different cooling	%	60 / 100	
8.	Cooler Bank Arrangement		1 X 100%	
9.	Type of Transformer		Constant Ohmic impedance type	
10.	HV-LV Impedance at 75 Deg C			
i)	Max. Voltage tap	%	10.3	
ii)	Principal tap	%	12.5	
iii)	Min. Voltage tap	%	15.4	
iv)	Tolerance on Impedance	%	As per IEC	
11.	Service		Outdoor	
12.	Duty		Continuous	
13.	Overload Capacity		IEC 60076-7 / IS 6600	
14.	Temperature rise over 50deg C ambient temp.			
i)	Top oil measured by thermometer	^{o}C	50	
ii)	Average winding measured by resistance method	^{o}C	55	
15.	Windings			

i)	Lightning Impulse withstand Voltage		
	HV	kV_p	650
	LV	kV_p	170
	Neutral	kV_p	95
ii)	Switching Impulse withstand Voltage		
	HV	kV_p	540
iii)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	275
	LV	kV_{rms}	70
	Neutral	kV_{rms}	38
iv)	Neutral Grounding		Solidly grounded
v)	Insulation		
	HV		Graded
	LV		Uniform
vi)	Tan delta of winding	%	≤0.5%
16.	Vector Group (3 –ph) (unless specified differently elsewhere)		YNynO
17.	Tap Changer		OLTC
i)	Tap Range and no. of steps		–5% to +10% of HV variation in the step of 1.25%, 12 steps
ii)	Location of Tap changer		On Neutral side of 132 kV winding
iii)	Design		Constant flux voltage variation type as per cl. 6.2 of IEC 60076 part-I
iv)	Tap control		Full capacity on load tap changer suitable for

			group/independent, remote /local electrical and local manual operation and bi-directional power flow.
18.	Bushings		
i)	Rated voltage		
	HV	kV	145
	LV	kV	36
	Neutral	kV	36
ii)	Rated current (Min.)		
	HV	A	800
	LV	A	1250
	Neutral	A	1250
iii)	Lightning Impulse withstand Voltage		
	HV	kV_p	650
	LV	kV_p	170
	Neutral	kV_p	170
iv)	One Minute Power Frequency withstand Voltage		
	HV	kV_{rms}	305
	LV	kV_{rms}	77
	Neutral	kV_{rms}	77
v)	Minimum total creepage distances	mm/kV	31
vi)	Max Partial discharge level at U_m		
	HV	pC	10
19.	Max Partial discharge level at 1.5*Um/√3	pC	100
20.	Max. Noise level at rated voltage and at principal tap at no load and all cooling active	dB	75

21.	**Maximum Permissible Losses of Transformers**		**50 MVA**	**31.5 MVA**
i)	Max. No Load Loss at rated voltage and frequency	kW	25	18
ii)	Max. Load Loss at rated current and frequency and at 75^{O} C	kW	125	110
iii)	Max. I^2R Loss at rated current and frequency and at 75^{O} C	kW	105	93.5
iv)	Max. Auxiliary Loss at rated voltage and frequency	kW	3	2

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) is 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.

9.0 Technical Particulars / Parameters of Generator Transformers

(For Thermal Power Plants)

Sl. no.		MVA RATING	HV VOLTAGE	LV VOLTAGE**	LV VOLTAGE**	LV VOLTAGE**
	RATING OF GT FOR 500 MW Generator Unit	**200MVA***	**420kV**	**21kV**	-	-
	RATING OF GT FOR 660 MW Generator Unit	**260/ 265 MVA***	**420kV**	-	**20kV, 21kV, 22 kV, 23.5kV, 24kV**	-
	RATING OF GT FOR 800 MW Generator Unit	**315 MVA***	**420kV**	-	-	**23.5kV, 27kV**
1	Vector group	YNd 11 (Three numbers single phase units shall form a three phase bank)				
		(HV neutral shall be made at site by the Bidder. LV side delta shall be made by employer).				
2	Duty	Continuous				
3	Impedance at 75 deg C	**FOR 200 MVA GT IN 500 MW UNIT**		**FOR 260 MVA GT IN 660 MW UNIT**		**FOR 315 MVA GT IN 800 MW UNIT**
	On principal Tap	13.5% (With +/- 5 % tol.)		15% (With +/- 5 % tol.)		16% (With +/- 5 % tol.)
	On other Taps	12% to 15% without any further tol.		12.5% to 17.5% without any further tol.		14.4% to 17.6% without any further tol.
4	Maximum design Ambient temperature	50°C				
5	Permissible Temperature rise over an ambient temp. of 50°C					
	Winding (by resistance method)	40°C				
	Top oil (by thermometer)	35°C				
	Cooling system	OFAF/ODAF				
6	Short circuit withstand time	3 sec.				
7	Bushing CT details	As per System Requirement				
8	Noise Level	As per NEMA TR- 1				
		HV VOLTAGE	**HV Neutral VOLTAGE**	**LV VOLTAGE**	**LV VOLTAGE**	**LV VOLTAGE**

9	**Winding Details**						
	Lightning impulse withstand voltage	kVp	1425	95	125	170	170
	Chopped Wave lightning impulse withstand voltage	kVp	1570	-	138	187	187
	Switching Impulse withstand voltage	kVp	1175	-	-	-	-
	One min power frequency withstand voltage (AV test)	kVrms	630/38*	38	50	70	70
	Insulation	-	Graded	-	Uniform	Uniform	Uniform
10	**Bushing Details**						
	Rated Voltage	kV	420	36	36	36	36
	Rated Current	Amps					
	For 200MVA GT IN 500 MW UNIT		1250	1250	12500	-	-
	For 260MVA GT IN 660 MW UNIT		1600	1250	-	16000	-
	For 315MVA GT IN 800 MW UNIT		2000	1250	-	-	20000
	Lightning impulse withstand voltage	kVp	1550***	170	170	170	170
	Switching Impulse withstand voltage	kVp	1175	-	-	-	-
	One min power frequency withstand voltage	kVrms	750	77	77	77	77
	Minimum total Creepage distance	mm	25 mm/kV and 31 mm/kV depending upon location				
	*** The bushing shall be suitable for chopped wave lightning impulse test on						

	transformer at 1570 KVp.	
11	**Tap changer Details**	
	Tap Change Type	Off Circuit Tap Changer (OCTC)
	Tap range	±10% in steps of 2.5% on HV neutral side for 200 MVA, ±5% in steps of 2.5% on HV neutral side for 260 MVA and 315 MVA transformers.
	NOTE:	
A	* MVA RATING IN VWO (VALVE WIDE OPEN) CONDITION OF TURBINE	
B	** LV VOLTAGE OF GT AS PER GENERATION VOLTAGE BY GENERATOR MANUFACTURER.	

Other Requirements

1) Minimum phase spacing of the isolated phase bus ducts shall be about 1800 mm. LV Terminal spacing shall match this. Exact value would be intimated to successful bidder during detailed engineering.

2) Ground and Phase Clearance :

   The minimum electrical clearance between any earthed object and live part for 400 kV shall be 3500 mm.

3) The impedance of each single-phase unit shall have to be identical as far as possible and variation of impedance of any single-phase unit shall be within ± 5% of impedance of other two units.

Technical Particulars / Parameters of Typical 400 kV Class Generator Transformers for Hydro Power Stations

Sl. No.	Description	Unit	Technical Parameters
1	Rated continuous MVA at max. ambient temperature:	MVA	As specified
2	Rated voltages		
2.1	- HV winding	kV	420/√3
2.2	- LV winding	kV	As per Generator Voltage
3	Highest voltage of equipment Um for		
3.1	- HV winding	kV	420/√3
3.2	- LV winding	kV	As per Generator Voltage
4	Maximum temperature rise, at rated power		
4.1	- top oil (measured by thermometer)	^{0} C	55
4.2	- windings (measured by resistance)	^{0} C	60
5	Type of cooling	-	OFWF /ODWF
6	GSU Transformer is a single phase, 50Hz, Separte winding transformer	-	Yes
7	Power frequency withstand voltage		
7.1	- HV winding / Bushing	kV (r.m.s)	695/750
7.2	- HV neutral winding / Bushing	kV (r.m.s)	As per specification
7.3	- LV winding / Bushing	kV (r.m.s)	As per specification
8	Lightning impulse withstand voltage		
8.1	- HV winding / Bushing	kV (Peak)	1425/1550

8.2	- HV neutral winding / Bushing	kV (peak)	As per specification
8.3	- LV winding / Bushing	kV (peak)	As per specification
9	Switching impulse withstand voltage of H.V Winding and Bushing	kV (peak)	1050/1175
10	Vector group		YNd11
11	% impedance voltage at rated power referred to 75°C winding temperature	-	As per IEC 60076-5
12	Short circuit withstand capacity		
12.1	-Short circuit apparent power	-	As per table-2 of IEC 60076-5
12.2	-Short circuit level of the system connected on HV side	kA	63 (1 sec)
13	Max. flux density at rated voltage and frequency	Tesla	Not to exceed 1.7 Tesla
14	Type of Insulatiuon		
14.1	- HV winding	-	Minimum Class A (winding insulation shall be and able to withstand 420kV continuously)
14.2	- LV winding	-	Minimum Class A (Uniformly insulated)
15	Material of the winding conductor	-	Copper
16	No. Of Oil-water Coolers	-	2 per transformer'

17	No. Of Oil Pumps	-	2 per transformer'
18	Oil Quality	-	As per IEC 60296-2003
19	Hotspot Temperature measuring system	-	
19.1	No of fibre sensors in each transformer	-	As per specification'
19.2	Temperature measuring range	-	0^0 C to 150^0 C
20	Type of Conservator	-	Air Bag type
21	Type of Bushing		
21.1	- HV terminal	-	Oil/Oil bushing or Oil/SF6 Bushing or Oil/Air Bushing depending upon the connection arrangement
21.2	- LV Terminal	-	Oil / Air Bushing
21.3	- Neutral Terminal	-	Oil / Air Bushing
22	Continuous on-line moisture-in-oil measuring system & DGA	-	As per specification
23	Rails	-	As per specification
24	Core material	-	High grade CRGO
25	Buchholtz relay, WTI, OTI, flow switch & PRD included in supply	-	Yes
26	Ports for Oil sampling, DGA & Moisture-in-oil system	-	Yes
27	Standards applicable as per specification	-	Yes

28	Whether Transportation weight of the Transformer complied to 70R specification as per ITB or not	-	Yes
29	Short circuit testing requirement	-	As per specification
30	Provision of nitrogen injection system for transformer fire fighting protection	-	Yes
31	Limit of hot spot temperature for which the transformer is designed as per applicable standard	^{0}C	not more than 98^{0}C

Technical Particulars/ Parameters of Reactors

1.0 Technical Particulars/ Parameters of 765 kV Shunt Reactor (80 & 110 MVAR)

S. No.	Description	Unit	Parameters	
1.	Rated Capacity at 765/√3 kV	MVAR	**80**	**110**
2.	Rated Voltage (U_n)	kV	765/√3	765/√3
3.	Maximum continuous operating voltage (U_m)	kV	800/√3	800/√3
4.	Connection (3 Phase Bank)		Star with neutral brought out	Star with neutral brought out
5.	Cooling System		ONAN	ONAN
6.	Frequency	Hz	50	50
7.	No of Phases		1 (SINGLE)	1 (SINGLE)
8.	Service		Outdoor	Outdoor
9.	Duty		Continuous at 800/√3kV	Continuous at 800/√3kV
10.	Permissible current unbalance among different phases		±1%	±1%
11.	Crest value of third harmonic content in phase current at rated voltage with sinusoidal wave form		≤ 3% of the crest value of fundamental	≤ 3% of the crest value of fundamental
12.	Range of constant impedance (However, complete saturation characteristics of the Reactors upto 2.5 p.u. Voltage shall be furnished)		Up to 1.25 Um	Up to 1.25 Um
13.	Tolerance on current		(i) 0 to +5% for a single phase unit (ii) ±1% for between units	(i) 0 to +5% for a single phase unit (ii) ±1% for between units
14.	Ratio of zero sequence reactance to positive reactance		Between 0.9 & 1.0.	Between 0.9 & 1.0.

	(X0/X1)			
15.	Temperature rise over 50 deg C Ambient Temp. and at 800/√3 kV			
i)	Top oil measured by thermometer	^{o}C	40	40
ii)	Average winding measured by resistance method	^{0}C	45	45
iii)	Winding hot spot	^{0}C	59	59
16.	Max. design Ambient temp	^{o}C	50	50
17.	Windings			
i)	Lightning Impulse withstand Voltage			
	HV	kV_p	1950	1950
	Neutral	kV_p	550	550
ii)	Switching Impulse withstand Voltage			
	HV	kV_p	1550	1550
	Neutral		-	-
iii)	One Minute Power Frequency withstand Voltage			
	HV	kV_{rms}	830kV rms (Ph Earth) for 5 min (to be tested)	830kV rms (Ph Earth) for 5 min (to be tested)
	Neutral	kV_{rms}	230	230
iv)	Winding Connection		STAR (3-Phase)	STAR (3-Phase)
v)	Neutral		Solidly Earthed	Solidly Earthed
vi)	Whether neutral is to be brought out		Yes (through 145kV class bushing)	Yes (through 145kV class bushing

vii)	Tan delta of windings at ambient Temperature (No temperature correction factor shall be applied)		< 0.005	< 0.005
18.	Bushing			
i)	Rated voltage			
	HV	kV	800	800
	Neutral	kV	145	145
ii)	Rated current (Min.)			
	HV	A	2500	2500
	Neutral	A	1250	1250
iii)	Lightning Impulse withstand Voltage			
	HV	kV_p	2100	2100
	Neutral	kV_p	650	650
iv)	Switching Impulse withstand Voltage			
	HV	kV_p	1550	1550
	Neutral		-	-
19.	**Maximum Permissible Losses of Reactor**		**110 MVAR**	**80 MVAR**
i)	Max. Load Loss at rated current and frequency and at 75^{o} C	kW	120	60
ii)	Max. I^2R Loss at rated current and frequency and at 75^{o} C	kW	98	52

2.0 Technical Particulars / Parameters of 420kV Shunt Reactor (63, 80 & 125 MVAR)

Clause No.	Description	Unit	Parameters
1.	Rated Voltage, U_r (1p.u)	kV	420
2.	Rated Capacity at 420 kV	MVAR	125/80/63
3.	Standard		IEC 60076-6
4.	Connection (3 Phase)		Star
5.	Cooling System		ONAN
6.	Frequency	Hz	50
7.	No. of Phases		3 (THREE)
8.	Service		Outdoor
9.	Permissible current unbalance among different phases	%	±2
10.	Crest value of third harmonic content in phase current at rated voltage with sinusoidal wave form	%	≤ 3% of the crest value of fundamental
11.	Range of constant impedance (However, complete saturation characteristics of the Reactors upto 2.5 p.u. Voltage shall be furnished)		Up to 1.5 p.u. voltage
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 deg C Ambient Temp at rated voltage		
	Top oil measured by thermometer	^{0}C	40
	Average winding measured by resistance method	^{0}C	45
15.	Max. design Ambient temp	^{0}C	50
16.	Windings		
a)	Lightning Impulse withstand Voltage		
	HV	kV_p	1300
	Neutral	kV_p	550
b)	Switching Impulse withstand Voltage		

	HV	kV_p	1050
c)	Power Frequency withstand Voltage		
	Neutral	kVrms	230
d)	Tan delta of windings		< 0.005
17.	Bushing		
a)	Rated voltage		
	HV	kV	420
	Neutral	kV	145
b)	Rated current (Min.)		
	HV	A	800
	Neutral	A	800
c)	Lightning Impulse withstand		
	HV	kVp	1425
	Neutral	kVp	650
d)	Switching Impulse withstand volatge		
	HV	kVp	1050
e)	Power Frequency withstand Voltage		
	HV	kVrms	695
	Neutral	kVrms	305
f)	Minimum total creepage distances		
	HV	mm	10500
	Neutral	mm	3625
g)	Tan delta of bushings		
	HV		< 0.004
	Neutral		< 0.004
h)	Max Partial discharge level at U_r		
	HV	pC	10
	Neutral	pC	10
18.	Maximum Partial discharge level at1.58 $U_r / \sqrt{3}$	pC	100

19.	Vibration and Tank stress level at rated voltage and frequency		Max: $\leq$ 200 microns peak to peak Average: ≤60 microns peak to peak. Stress: ≤2.0 kg/sq.mm at any point on tank	
20.	Maximum Noise level at rated voltage and frequency	dB	80	
21.	Maximum Permissible Losses of Reactor at rated Voltage Frequency and at 75^{O} C (kW)		**Load Loss**	**I^2R**
i)	63MVAR, 420kV 3-Ph Reactor	kW	100	57
ii)	80MVAR, 420kV 3-Ph Reactor	kW	115	65
iii)	125MVAR, 420kV 3-Ph Reactor	kW	160	90

3.0 Technical Particulars / Parameters of 245kV Shunt Reactor (25 MVAR)

S.No.	Description	Unit	Parameters
1.	Rated Voltage, U_r (1p.u)	kV	245
2.	Rated Capacity at 245 kV	MVAR	25
3.	Standard		IEC 60076-6
4.	Connection (3 Phase)		Star
5.	Cooling System		ONAN
6.	Frequency	Hz	50
7.	No of Phases		3 (THREE)
8.	Service		Outdoor
9.	System Fault Level	kA	40
10.	Permissible current unbalance among different phases	%	±2
11.	Crest value of Third Harmonic content in phase current at rated voltage with sinusoidal waveform	%	≤ 3% of the crest Value of fundamental
12.	Range of constant Impedance (However, complete saturation characteristics of the Reactors up to 2.5 p.u. Voltage shall be furnished)		Up to 1.4 p.u. voltage
13.	Tolerance on current	%	0 to +5%
14.	Ratio of zero sequence reactance to positive reactance (X0/X1)	Range	0.9 - 1.0
15.	Temperature rise over 50 deg C Ambient Temp at rated voltage		
(a)	Top oil measured by thermometer	^{0} C	40
(b)	Average winding measured by resistance method	^{0} C	45
16.	Max. design Ambient temp	^{0} C	50
17.	Windings		
a)	Lightning Impulse withstand Voltage		
	HV	kV_p	950
	Neutral	kV_p	170

b)	Switching Impulse withstand Voltage		
	HV	kV_p	750
c)	Power Frequency withstand Voltage Neutral	kVrms	70
d)	Tan delta of windings		< 0.005
18.	Bushing		
a)	Rated voltage		
	HV	kV	245
	Neutral	kV	36
b)	Rated current (Min.)		
	HV	A	800
	Neutral	A	800
c)	Lightning Impulse withstand Voltage		
	HV	kVp	1050
	Neutral	kVp	170
d)	Switching Impulse withstand Voltage		
	HV	kVp	750
e)	Power Frequency withstand Voltage		
	HV	kVrms	505
	Neutral	kVrms	77
f)	Minimum total creepage distances		
	HV	mm	6125
	Neutral	mm	900
g)	Tan delta of bushings		
	HV		< 0.004
h)	Max. Partial discharge level at U_r		

	HV	pC	10	
19.	Max. Partial discharge level at 1.58 U_r / √3	pC	100	
20.	Vibration and Tank stress level at rated voltage and frequency		Max: ≤ 200 microns peak to peak Average: ≤60 microns peak to Peak Stress: ≤ 2.0kg/sq.mm at any point on tank.	
21.	Maximum Noise level at rated voltage and frequency	dB	75	
22.	Maximum Permissible Losses at rated voltage and frequency		**Load loss**	**I^2R loss**
	25MVAR, 3-Ph Reactor		50	28

Technical Particulars / Parameters of 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		Natural oil cooling (ONAN)
4.	Cooling medium		Insulating oil
5.	Frequency	Hz	50
6.	No of Phases		1 (SINGLE)
7.	Service		Outdoor
8.	Type		Oil filled outdoor application
9.	Insulation		Graded
10.	Max. continuous current (rms)		10 A
11.	Rated short time current (rms) (10secs.)		60A
12.	Rated impedance at rated short time and continuous current		To be specified by the utility as per requirement
13.	Max. temperature rise over ambient temperature of 50°C at rated voltage		
i)	of winding measured by resistance	Deg C	50
ii)	of top oil measured by thermometer	Deg C	45
14.	Insulation level for winding		

(a)	Lightning Impulse withstand Voltage		
i)	Line side	kV_p	550
ii)	Ground side	kV_p	95
(b)	One Minute Power Frequency withstand Voltage		
iii)	Line side	kVrms	230
iv)	Ground side	kVrms	38
15.	**Bushing**		
(a)	Rated Voltage		
i)	Line side	kV	145
ii)	Ground side	kV	24
(b)	Lightning Impulse withstand Voltage		
i)	Line side	kV_p	650
ii)	Ground side	kV_p	125
(c)	One Minute Power Frequency withstand Voltage		
i)	Line side	kVrms	305
ii)	Ground side	kVrms	50
(d)	Creepage (total minimum)		
i)	Line side	mm	3625
ii)	Ground side	mm	600
16.	Method of grounding		Solidly connected between neutral of shunt reactor and earth
17.	Whether neutral is to be brought out		Yes (through 24kV

TECHNICAL PARAMETERS OF BUSHING CURRENT TRANSFORMERS & NEUTRAL CURRENT TRANSFORMERS

1.0 Parameters of Current Transformer for 105 MVA(1-ph) & 315 MVA(3-ph) 400/220/33 kV and 3-ph 200 MVA, 400/132/33 kV Transformers

Description	Current Transformer Parameters (Transformer)			
	HV Side	IV Side	Neutral Side	Outdoor type Neutral Current Transformer (for each bank of three 1-ph units)
a) **Ratio**				
CORE 1	1000/1	1000/1	1000/1	1000/1
CORE 2	600/1	1000/1	-	-
b) **Minimum knee point voltage or burden and accuracy class**				
CORE 1	1000V, PX / PS	1000V, PX / PS	1000V, PX / PS	1000V, PX / PS
CORE 2	0.2S Class 20VA ISF≤5	0.2S Class 20VA ISF≤5		
c) **Maximum CT Secondary Resistance**				
CORE 1	2.5 Ohm	2.5 Ohm	2.5 Ohm	2.5 Ohm
CORE 2	-	-	-	-
d) **Application**				
CORE 1	Restricted Earth Fault	Restricted Earth Fault	Restricted Earth Fault	REF (High Impedance)
CORE 2	Metering	Metering	-	-
e) **Maximum magnetization current (at knee point voltage)**				
CORE 1	60 mA	60 mA	60 mA	60 mA
CORE 2	-	-	-	-

2.0 Parameters of Current Transformer for 500MVA (1-ph), 765/400/33 kV; 500MVA (3-ph) & 167 MVA (1-ph), 400/220/33 kV and 160 MVA, 220/66 kV Transformers

Description	Current Transformer Parameters (Transformer)			
	HV Side	**IV Side**	**Neutral Side**	**Outdoor type Neutral Current Transformer** (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	Restricted Earth Fault	Restricted Earth Fault	REF (High Impedance)
CORE 2	Metering	Metering	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	25 mA	25 mA	25 mA	25 mA
CORE 2	-	-	-	-

3.0 Parameters of Current Transformer for 3-ph 315 MVA, 400/132/33 kV & 80 MVA 220/66 kV Transformers

Description	Current Transformer Parameters (Transformer)			
	HV Side	HV Neutral side (for 80 MVA)	IV (for 315 MVA)/LV(for 80 MVA) Side	Neutral Side
Ratio				
CORE 1	1600/1	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	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	Restricted Earth Fault	Restricted Earth Fault	REF (High Impedance)
CORE 2	Metering	Metering	-	-
Maximum magnetization current (at knee point voltage)				
CORE 1	25 mA	25 mA	25 mA	25 mA
CORE 2	-	-	-	-

4.0 Parameters of Current Transformers for 200 MVA & 160MVA 220/132/33 kV; 100MVA, 220/132kV & 100 MVA, 132/66 kV 3-Ph Transformers

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

5.0 Parameters of Current Transformer for 50 MVA & 31.5 MVA 132/33kV 3-Ph Transformers

Description	Current Transformer Parameters (Transformer)			
	HV Side	**HV Neutral Side**	**LV Side**	**LV Neutral Side**
(a) Ratio				
CORE 1	300/1	300/1	1000/1	1000/1
CORE 2	300/1	-	1000/1	-
(b) Minimum knee point voltage or burden and accuracy class				
CORE 1	600V, PX / PS	600V, PX / PS	1000V, PX / PS	1000V, PX / PS
CORE 2	0.2S Class 15VA ISF ≤ 5	-	0.2S Class 15VA ISF ≤ 5	-
(c) Maximum CT Secondary Resistance				
CORE 1	1.5 Ohm	1.5 Ohm	1.5 Ohm	1.5 Ohm
CORE 2	-	-	-	-
(d) Application				
CORE 1	Restricted Earth Fault	Restricted Earth Fault	Metering	Restricted Earth Fault
CORE 2	Metering			-
(e) Maximum magnetization current (at knee point voltage)				
CORE 1	100 mA	100 mA	100 mA	100 mA
CORE 2	-	-	-	-

6.0 Parameters of Current Transformers for 1-ph, 80 & 110 MVAR, 765 kV Shunt Reactors

Description	**Current Transformer Parameters (Shunt Reactor)**	
	Line Side	Neutral Side
(a) 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
(b) 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
(c) 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
(d) 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 for Common Neutral Side (for each bank of three nos. single phase reactors) & 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

Note:

i) Rated continuous thermal current rating shall be 200% of rated primary current.

7.0 Technical Parameters of Current Transformers for 3-phase 125, 80 & 63 MVAR, 420 kV Shunt Reactor & Neutral Grounding Reactor (NGR)

		Shunt Reactor	NGR
	Line Side	Neutral Side	Earth Side
(a) Ratio			
CORE 1	200/1A	200/1A	200/1A
CORE 2	200/1A	To be decided by contractor for WTI	-
CORE 3	200/1A	3000-2000-500/1A	-
CORE 4	200/1A	3000-2000-500/1A	-
(b) Minimum knee point voltage or burden and accuracy class			
CORE 1	200V, PX / PS Class	200V, PX / PS Class	200V, PX / PS Class
CORE 2	200V, PX / PS Class	To be decided by contractor 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	-
(c) Maximum CT Secondary Resistance			
CORE 1	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	-

(d) 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	-
(e) Application			
CORE 1	Reactor Differential	Reactor Differential	Restricted earth fault
CORE 2	Restricted earth fault	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	-

8.0 Technical Parameters of Current Transformers for 3-phase 25 MVAR, 245 kV Shunt Reactor

	Line Side	Neutral Side
CORE 1	200/1A	200/1A
CORE 2	200/1A	200/1A
CORE 3	200/1A	200/1A
CORE 4	-	To be decided by contractor for WTI
(b) Minimum knee point voltage or burden and accuracy class		
CORE 1	200V, PX / PS Class	10 VA, 1.0
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 contractor for WTI
(c) Instrument security factor (max.)		
CORE 1	-	20
CORE 2	-	-
CORE 3	-	-
CORE 4	-	-
(d) Maximum CT Secondary Resistance		
CORE 1	1 Ohm	-
CORE 2	1 Ohm	1 Ohm
CORE 3	1 Ohm	1 Ohm
CORE 4	-	-
(e) Exciting current(max.) at 50V		
CORE 1	60mA	-
CORE 2	60mA	60mA
CORE 3	60mA	60mA
CORE 4	-	-
(f) Application		
CORE 1	Differential protection(High	Metering

	impedance)	
CORE 2	Restricted earth fault protection	Restricted earth fault
CORE 3	Backup impedance protection	Differential protection(High impedance)
CORE 4	-	Winding temp. Indication (on one phase only)

Note for CTs for Shunt Reactor and NGR:

i) For PX / PS class CT's, Dimensioning parameter "K", Secondary VA shall be considered 1.5 and 20 respectively.

ii) Rated continuous thermal current rating shall be 200% of rated primary current.

iii) In case of single phase reactor, Common Neutral Side shall be out door type.

Annexure-C

Guaranteed and Other Technical Particulars for Power Transformers/Reactors

A. GENERAL

Item	Description	Unit	Offered by manufa-cturer
1.	General Information i) Supplier ii) Manufacturer iii) Place of Manufacture iv) Type of transformer (Core/Shell)		
2.	Applications i) Indoor/Outdoor ii) 2wdg/3wdg/Auto		
3.	iii) GT/Step-down/ICT/Station Start-up/Auxiliary/ Rail Trackside Supply		
4.	Corrosion Level at Site i) Light ii) Medium iii) Heavy iv) Very Heavy		
5.	Applicable Standards i) IEC: 60076 ii) IS : 2026 iii) As per list given in		
6.	Full load rating (HV/IV/LV)	MVA	
7.	3Phase/Bank of Three Phase/Single Phase (A,B,C)		
8.	Rated No Load Voltages (HV/IV/LV)	kV	
9.	Currents (HV/IV/LV) at normal tap	Amp	
10.	Rated Frequency	Hz	
11.	Connections and phase displacement symbols (Vector Group)		
12.	Weight Schedules (Minimum with no negative tolerance)		
	i) Active part	kg	
	ii) Oil	kg	
	iii) Tank and Fittings	kg	
	iv) Total 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	
13.	Transport limitation		

14.	Whether the offered transformer can be transported on Indian Railways to destination		
15.	LV Winding i) Stabilizing tertiary (Yes/No) ii) Loaded (Yes/No)		
16.	Tappings i)OLTC/OCTC Ii)Tappings on 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	 %	
17.	Impedance and Losses		
	i) Calculated I^2R Loss at rated tap and 75 ^0C	kW	
	ii) Eddy current and stray loss at rated tap and 75 ^0C (indicative)	kW	
	iii) Calculated Load Loss(I^2R+Eddy and Stray) at rated tap and 75 ^0C	kW	
	iv) Guaranteed Load loss at rated tap and 75 ^0C (Max)	kW	
	v) Guaranteed Impedance (Base MVA at Principal tap)	%	
	a) Tolerance	%	
	vi) Impedance at extreme tappings a) Max. Voltage tap b) Min. Voltage tap	%	
	i) Tolerance	%	
	vi) Regulation at full load at 75 ^0C winding temperature at: a) upf b) 0.8 pf	%	
	vii) Guaranteed No Load Loss (max)	kW	
	viii)Calculated Fan Loss	kW	
	ix) Calculated Pump Loss	kW	
	x) Guaranteed Auxiliary Loss (Max)	kW	
	xi) Guaranteed maximum Magnetizing Current at rated Voltage	%	
	xii) Efficiency : At 100% load upf 0.8 lead	%	

	At 75% load: 0.8 lag, upf, 0.8 lead At 50% load: 0.8 lag, upf, 0.8 lead 0.8 lag		
	xiii) Load for Maximum efficiency	%	
18.	Any limitations in the performance of the required test? If Yes, State limitations		
19.	Deviations from specifications (if any , annexure no.)		
20.	Fault level of system	MVA	
21.	Withstand time for three phase short circuit at terminals	msec	
22.	Over excitation withstand time: 125% 140% 150% 170%	msec	
23.	Max value of tan δ for each winding (IEC)		

B. MAGNETIC SYSTEM

Item	Description	Unit	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.	CRGO : i) Thickness, mm ii) Max. Specific loss at 1.7 T, 50Hz, in Watts/kg iii) Grade of core as per BIS iv) Insulation between core lamination		
4.	Minimum Gross Area of: i) Core	cm^2	

	ii) Limb iii) Yoke iv) Unwound limb (May be verified during manufacturing stage – at the discretion of buyer)		
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 using input from item -5)	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.	Maximum Sound Level	dB	
16.	Core Isolation test	kV	
17.	Core bolt insulation withstand voltage for one minute	kV	

C. CONDUCTING SYSTEM

Item	Description	Unit	Offered by manufacturer			
			HV	IV	LV	Reg
1.	Type of Winding Helical/Disc/Layer/inter wound					
2.	Type of Conductor PICC/CTC/CTCE/CTCEN/BPICC					
3.	Minimum Yield Strength of Conductor 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				
5.	Bare Weight of copper without paper insulation and lead (Minimum)	kg				
6.	Per Phase Maximum resistance of winding at rated tap at 75 ^0C	ohm				
7.	Number of Turns/Phase					
8.	Insulating material used for HV/IV/LV					
9.	Insulating material used between : i) HV and IV winding ii) IV and LV winding iii) LV winding and core					
10.	Details of special arrangement provided to improve surge voltage distribution in the winding					
11.	Dielectric Shielding used: i) Interleaved winding ii) Wound in Shield iii) Others					
12.	Maximum current density under short circuit: i) HV ii) IV iii)LV	A/mm^2				
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.	Test voltages: i) Lightning withstand test voltage ii) Power frequency withstand voltage a) Wet for one minute b) Dry for one minute iii) Switching surge withstand voltage iv) Visible corona discharge voltage	kV				
15.	Partial discharge level	pC				
16.	Noise level when energized at normal voltage and frequency without load	dB				

D. COOLING SYSTEM

Item	Description	Unit	Offered by manufac-turer
1.	Type of Cooling		
2.	Temperature gradient between windings and oil		
3.	Time in minutes for which the transformer can run at full load without exceeding maximum permissible temperature at reference ambient temperature when supply to fans is cut off	min	
4.	Percentage Rating Corresponding to Cooling Stages (HV/IV/LV)		
5.	Guaranteed Maximum Temperature rise at 1000 mts. altitude 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	
6.	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		
7.	Cooling Fans: i) Type ii) Size iii) Rating(kW) iv) Supply voltage v) Quantity (Running + Standby)		

	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		
8.	Oil Pumps: i) Type ii) Size iii) Rating(LPM and kW) iv) Supply voltage v) Quantity (Running + Standby) vi) Efficiency of motor at full load vii) Temperature rise of motor at full load viii) BHP of driven equipment		
9.	Coolers (Oil to Air): i) Quantity (Running + Standby) ii) Type and Rating		
10.	Coolers (Oil to Water): i) Quantity (Running + Standby) ii) Type and Rating iii) Oil flow rate iv) Water flow rate v) Nominal Cooling rate vi) Material of tube	 lpm lpm kW	
11.	Radiators: i) Width of elements (mm) ii) Thickness (mm) iii) Length (mm) iv) Numbers		
12.	Guaranteed cooler loss at rated output, normal ratio, rated voltage, rated frequency at ambient temperature of 50°C	kW	

E. DIELECTRIC SYSTEM

Item	**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	Yes/ No						
	If yes, Details							
5	Insulation Levels		HV	IV	LV	HV -N	IV- N	
	i) 1.2/50 µs Impulse	kV_p						
	ii) Chopped Impulse	kV_p						
	iii) Switching Impulse	kV_p						
	iv) AC (Short duration/ long duration)	kV_{rms}						
	v) Maximum PD level at 1.5 pu	pC						

F. ACCESSORIES

Item	Description	Unit	Offered by manufacturer
1.	Tap Changers		
	i) Control a. a-Manual b-Automatic b. c-Remote d-Local		
	ii) Voltage Class and Current Rating of Tap Changers		
	iii) Make and Model		
	iv) Make and Type of AVR		
	v) Power Supply for control motor		
	vi) No of Phase/Voltage/Frequency		
	vii) Rated Voltage for control circuit	V	
	viii) Phase/Voltage/Frequency		
2.	Tank		
	i) Tank Cover: Conventional/Bell/Bottom Plate	mm	
	ii) Material of plate for tank		
	iii) Plate thickness : side, bottom, cover	mm	
	iv) Rail Gauge AXB	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	mm of Hg	
	viii) Tank/Radiators/Conservator/Accessories	mm	

	ix) Radiator fins / conservator plate thickness					
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: Porcelain/OIP/RIP					
	iii) Bushing housing - Porcelain / polymer					
	iv)Rated Voltage Class	kV				
	v) Rated Current	A				
	vi)Rated 1.2/50 μs Impulse Withstand	kV_p				
	vii) Rated One minute AC withstand, Dry	kV_{rms}				
	viii) Minimum Creepage Distance	mm				
	ix) Quantity of oil in bushing and specification of oil used					
	x) Make and Model					
	xi) Terminal Pad details					
	xii)Nos. of Cores					
	xiii) Weight of assembled bushings	kg				
	xiv) Free space required above the tank top for removal of core					
	xv) Whether terminal connector for all bushings included in the scope of supply					
	xvi) BCT Requirements					
	xvii) Lightning impulse withstand voltage	kV				
	xviii) Switching surge withstand voltage	kV				
4.	Indicative					
	i) Winding temperature thermometer/ indicator: Range Accuracy					
	ii) Oil temperature thermometer/ indicator: Range Accuracy					

	iii) Remote Oil / Winding Temp. Indicator: Range Accuracy		
	iv) Temperature sensors by fiber optic		
	v) Oil actuated/gas operated relay		
	vi) Oil level Indicators: Main Conservator OLTC Conservator		
	vii) Oil Sight Window: Main Tank Main Conservator OLTC Conservator		
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.	Pressure Relief Device: i) Number of PRDs provided ii) Operating pressure of relief device		
8.	Dehydrating Breathers		
9.	Tap Changer protective device		
10.	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	 Ω A	
11.	Transformer Oil i) Grade as per IEEMA spec / IEC60296 / as per specification ii) Inhibited/ un-inhibited/ Standard/High 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	

	viii) Tan delta at 90°C ix) Resistivity x) Breakdown strength xi) Interfacial tension at 20 °C	 Ω-cm kV N/m	
12.	Press Board: i) Make ii) type		
13.	Conductor Insulating Paper i) Kraft paper ii) Thermally upgraded Kraft paper iii) Nomex		
14.	Provision for fire protection system (as per spec)		
15.	Insulation of core bolts, washers, end plates etc.		
16.	Vacuum withstand capacity of : i) Main tank ii) Radiators and accessories		
17.	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		
18.	Lifting Jacks i) Number of jacks included ii) Type and Make iii) Capacity iv)Pitch v) Lift vi)Height in close position		

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

Annexure-D

Test Plan for Transformers

No.	Test	U_m ≤ 170kV	U_m > 170kV
1.	Measurement of winding resistance	Routine	Routine
2.	Voltage ratio measurement	Routine	Routine
3.	Polarity test	Routine	Routine
4.	No-load loss and current measurement	Routine	Routine
5.	Magnetic balance test (for three phase Transformer only)	Routine	Routine
6.	Short Circuit Impedance and load loss measurement	Routine	Routine
7.	Measurement of insulation resistance & Polarization Index	Routine	Routine
8.	Measurement of insulation power factor and capacitance between winding to earth and between windings	Routine	Routine
9.	Measurement of insulation power factor and capacitance of bushings	Routine	Routine
10.	Full wave lightning impulse test for the line terminals (LI)	Routine	-
11.	Induced voltage withstand test (IVW)	Routine	-
12.	Applied voltage test (AV)	Routine	Routine
13.	Induced voltage test with PD measurement (IVPD)	Routine	Routine
14.	On-load tap changer test(Ten complete cycle before LV test)	Routine	Routine
15.	Gas-in-oil analysis	Routine	Routine
16.	Core assembly dielectric and earthing continuity test	Routine	Routine
17.	Oil leakage test on transformer tank	Routine	Routine
18.	Appearance, construction and dimension check	Routine	Routine

19.	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)	Routine	Routine
20	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.	Routine	Routine
21.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine	Routine
22.	High voltage with stand test on auxiliary equipment and wiring after assembly	Routine	Routine
23.	Tank vacuum test	Routine	Routine
24.	Tank pressure test	Routine	Routine
25.	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
26	Switching impulse test for the line terminal (SI)	Type	Routine
27.	Line terminal AC withstand voltage test (LTAC)	Routine	Type
28.	Measurement of transferred surge on LV or Tertiary as applicable due to HV lightning impulse and IV lighting impulse (as applicable)	Type	Type
29.	Lightning impulse test for the neutral terminals (LIN)	Type	Type
30.	Temperature rise test	Type	Type
31.	Measurement of Zero seq. reactance (for three phase Transformer only)	Type	Type
32.	Measurement of harmonic level in no load current	Type	Type
33.	Measurement of acoustic noise level	Type	Type
34.	Measurement of power taken by fans and oil pumps (Not applicable for ONAN)	Type	Type
35.	Dynamic Short circuit withstand test (as specified in the specification)	Type	Type

Test Plan for Reactor

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.	Core assembly dielectric and earthing continuity test	Routine
7.	High voltage with stand test on auxiliary equipment and wiring after assembly	Routine
8.	Chopped wave lightning impulse test for the line terminals (LIC)	Routine
9.	Lightning impulse test on Neutral (LIN)	Routine
10.	Switching impulse test	Routine

11.	Separate source voltage withstand test	Routine
12.	Short time over voltage Test (830kVrms)	Routine
13.	Induced over voltage test with Partial Discharge measurement (IVPD)	Routine
14.	Gas-in-oil analysis	Routine
15.	2-Hour excitation test except type tested unit	Routine
16.	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
17.	Temperature rise test	Type
18.	Measurement of harmonic content of current (Measured in Cold state)	Type
19.	Measurement of acoustic noise level (Measured in Cold and Hot state of temperature rise test)	Type
20	Knee point voltage measurement of reactor (Measured in Cold and Hot state of temperature rise test)	Type
21.	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine

22.	Oil leakage test on Reactor tank	Routine
23.	Appearance, construction and dimension check	Routine
24.	Tank vacuum test	Routine
25.	Tank vacuum test	Routine

Tests on NGR (as applicable)

1.	Measurement of winding resistance	Routine
2.	Measurement of Impedance by V/I	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 vacuum test	Routine

Annexure-E

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub Vendor	Manuf-acture	Customer
A	Raw Material & Components							
I.	Winding Conductor (PICC)/ (CTC)/ Lead wires	1. Visual & Dimensional check of Bare Conductor. Thickness & width of bare conductor, Covered width & thickness	One sample per type per lot	IS 1897 IS 13730 IS 7401	Bare conductor Width /thick (mm) Tolerance (in ± mm) Up to 3.15 - 0.03 316 to 6.30 - 0.05 6.31 to 12.5 - 0.07 12.51 to 16 - 0.10 > 16 mm - 0.10 Insulated conductor Covering thick(mm) Tolerance (%) 0.25 to 0.5 - -10 0.51 to 1.25 - -7.5 Over 1.25 - -5	P	V	W
		2. Resistivity at 20 deg.C		IS 13730	For annealed conductor 0.01727 ohm/mm^2/ m(max) at 20 deg For half hard conductor 0.01777 ohm-mm^2/ m (max)	P	V	-
		3. Insulation for bunched conductor a). No. of conductors. b). Thickness & width of bare conductor, Covered width & thickness c). Voltage test between strands		IS 13730	As per approved drawing	P	V	W
		4.Tesile strength and elongation test		IS 7404 IS 13730	Thickness (mm) tensile strength (N/m^2) elongation % Up to 2.5 205-265 30 min >2.5-5.6 205-255 32 min	P	V	--
		5. Hardness test		IS 7404 IS 13730	Max hardness should be RF 65, when measured in Rockwell 'F" scale	P	V	--
		6. 0.2% Proof strength of work hardened conductor		IS 7404 IS 13730	As per design requirement	P	V	--

*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	Manuf-acturer	Customer
		7. Radius of corner of bare conductor		IS 7404 IS 13730	Thickness (mm) Over/Up to Corner Radius(mm) Up to 1.0 - 0.50 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)	P	V	V
		8. Copper purity		As per plant standard	OEM Standard	V	V	V
		9. Oxygen Content						
		10. Epoxy Bonding Strength (Bonded CTC)						

Sr. No.	Items/Components	List of Tests	Sampling Rate	Reference/Standards	Acceptable Value			
II (a)	Kraft Insulating Paper	1. 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	1. Paper to be smooth, unglazed surface & free from dust particles	P	V	--
		2. Density			2. 0.8 ±0.05 gm/ cm^3			
		3. Substance (grammage)			3. Thick (µm) Sub (g/cm^3) Tolerance 50 40 10 65 52 05 75 60 05 90 72 05			
		4. Moisture Content			4. 8 % max			
		5. Tensile Index MD			5. 93 NM/gm (min)			
		6. Tensile Index CD			6. 34 NM/gm (min)			
		7. Elongation at Break MD			7. NA			
		8. Elongation at Break CD			8. NA			
		9. Electric Strength in Air			9. NA			
		10. Ash Content			10. 1 % max			
		11. PH of Aqueous extract			11. 6 to 8			
		12. Conductivity of Aqueous extract			12. 10 mS/m (max)			
		13.Air Permeability			13. 0.5 to 1.0 µm/Pa.s			
		14.Tear Index MD			14. 5 mN m^2/g (min)			
		15.Tear Index CMD			15. 6 mN m^2/g (min)			
		16. Water Absorption (Klemn Method)			16. 10 %			
		17.Heat Stability a.) Reduction of Degree of Polymerization b.) Reduction of Bursting Strength c.) Increase of Conductivity of Aqueous extract.			17. Type test report			
		18.DP Value			18. As per Manufacturer's std. practice			
		19.Storage Period			19. As per Manufacturer's std. practice			
		20.Storage in controlled Environment			20. As per Manufacturer's std. practice			
II (b)	Thermally upgraded paper / Aramid Paper	Manufacturer's std. practice			As per Manufacturer's std. practice			

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub Vendor	Manuf-acturer	Customer
III.	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 Check points:	Each Lot	IS 3024 IEC 60404 ASTM 4343	As per approved design	P	V	--
		1. Visual, Dimension & Thickness	One sample per lot		1. Visually defect free, as per design requirement			
		2. Cutting Burr			2. Less than 25 micron burr / As per IS / mutual agreement while ordering			
		3. Bend / Ductility test			3. As per IS 649			
		4. Surface insulation resistivity check			4. 10 Ωcm2 min average 05 Ωcm2 min individual			
		5 Aging test (type test)			5. 4 % max increase in specific measured loss			
		6. Test on stacking factor			6. As per table no. 4 of IS 3024			
		7. Test for specific Watt loss test	One sample from offered lot	IS 3024	Losses as per grade of CRGO lamination used	--	P	V
		8. Grade of CRGO		Approved drg./Document	Approved drg./Document/Manufacturer standard	V	V	V
		9. Permeability at 800 A/m		Test Method IS 3024/IS 649		V	V	V
		10. Compliance to Quality Control Order of DHI		IS 3024		V	V	V

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*R*		
						Sub Vendor	\Manuf-acturer	Customer
IV.	Pre-compressed Press Board	1. Visual & dimensional check, thickness, width and length.	One sample of each size(thickness) per lot of pressboard	IEC 60641-3-1 IEC 60641-2, Methods of Test	1. No surface defects	P	V	V
		2. Apparent Density			2. Up to 1.6 mm TK -1.0-1.2 >1.6-3 mm TK -1.1-1.25 >3-3.6 mm TK -1.15-1.30 >6-8 mm TK -1.2-1.3			
		3. Compressibility C			3. Up to 1.6 -10 %; >1.6-3 mm - 7.5 % >3-3.6 mm - 5 %; >6-8 mm TK -4 %			
		4. Reversible part Compressibility			4. Up to 1.6 -45 %; >1.6-3 mm - 50 % >3-3.6 mm - 50 %; >6-8 mm TK -50 %			
		5. Oil Absorption			5. Up to 1.6 mm TK -11 min > 1.6-3 mm TK - 9 min > 3 - 3.6 mm TK -7 min > 6-8 mm TK - 7 min			
		6. Moisture Content			6. 6 % max. / As per relevant std. & Manufacturer's std. practice			
		7. Shrinkage MD, CD & PD			7. MD - 0.5 % max, CD- 0.7 % max, Thick -5 % max			
		8. pH of aqueous extract			8. 6-9 for solid boards			
		9.conductivity of aqueous extract			9. 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			
		10. Electric Strength in Air			10. 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			
		11.Electric Strength in Oil			11. Up to 1.6 - 40 kV/ mm > 1.6-3 mm - 35 kV/mm > 3-3.6 mm - 30 kV / mm > 6-8 mm TK - 30 kV/mm			
		12. Ash Content			12. 1 % maximum			
		13. Elongation MD, CD			MD CD 13. Up to 1.6 - 3 % 4 % >1.6-3 mm - 3 % 4 % >3-3.6 mm - 3 % 4 % >6-8 mm TK -3 % 4 %			
		14. Tensile strength MD, CD			14. As per relevant std./ Manufacturer's std. practice			
		15. Ply Bond Resistance			15. As per relevant std. / Manufacturer's std. practice			
		16. Flexural strength MD, CD (Laminated Boards)			16. As per relevant std. / Manufacturer's std. practice			

***TC --- Test Certificate PD--> Perpendicular Direction CD--> Cross Direction

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub Vendor	Manuf-acturer	Customer
V.	Perma-wood	1. Visual & dimensional check, thickness, width & length.	One sample of each size per lot	IS 3513 IS 1708 IS 1736 IS 1998	1. Shall be free from surface defect	P	V	--
		2. Density			2. 0.8 to 1.3 gm/cc			
		3. Moisture content			3. IS 3513/IS1708			
		4. Oil Absorption at 90 °C			4. Min 5%			
		5. Electric Strength at 90 °C			5. Min 60 KV			
		6. Tensile strength			6. Min for LD - 700 KV /cm^2			
		7. Compressive strength test			7. Min for LD - 1400 KV /cm^2			
		8. Shear strength age-wise			8. Min for LD - 450 KV /cm^2			
		9. Thickness			9. Thickness (mm) Tolerance (+/- mm) 10 to 25 - 1.2 26 to 50 - 1.4 51 to 150 - 2.0			
		10. Shrinkage 11. pH Value		Approved document	Plant standard	V	V	
VI.	Porcelain Bushings (Hollow)	1. Visual & dimensional check.	10% Sample per lot As per IS/ IEC	IS 3347/ IEC 60137	1. As per approved drawing. IS 3347	P	V	--
		2. Power frequency voltage withstand test			2. As per IS 3347/ IEC 60137			
VII(a)	Polyester Resin Impregnated Glass Fiber Tape	1. Visual Check	Each lot	IS 15208	1. Free from visual defect	P	V	--
		2. Verification of shelf life			2. 12 months			
		3. Thickness			3. 0.25 to 0.35 mm (±0.07)			
		4. Width			4. 20 to 50 mm (±2)			
		5. Tensile Strength			5. Min 200 N/mm			
		6. Resin Content			6. 27 (±3%)			
		7. Softening point of resin			7. Max 200 °C			
		8. Storage Condition			8. As per cl. 15.3 of IS 15208			
VII(b)	Lacquer	Manufacturer's std. practice			As per Manufacturer's std. practice	V	P	--
VIII.	Synthetic Rubber Bonded Cork sheet (SRBC)	1. Visual check, thickness, length, width	One sample per lot	IS 4253	1. Free from surface defect	P	V	--
		2. Hardness			2. 70 ± 10 IRHD			
		3. Compression set			3. 85 % max			
		4. Side flow under compression			4. NA			
		5. Tensile strength			5.1550 kPa (min)			
		6. Flexibility			6. Should be satisfactory when bent through 1800 round the material of diameter three times the thickness of the specimen			
		7. Storage Period (to be specified) IS 4253			7. To be specified in IS 4253			
		8. Compressibility			8. 25-35 %			
		9. Recovery			9. 80 % min			
		10. Aging in Oil-Finish, Flexibility & change in volume			10. Change in volume 15 % max for 70 hours at 100 deg c in oil			
		11. Ph value			11. 5-8.5			

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub	Manuf-acturer	Customer
IX.	Condenser Bushing (Both OIP & RIP)	Routine Test	100%	IS 2099 IEC 60137		P		
		(1) Measurement of dielectric dissipation factor and capacitance			1. Tan Delta - 0.4%		P	W
		(2) Dry power frequency voltage withstand test			2. As per approved GTP		V	--
		(3) Measurement of partial discharge			3. As per IEC - No flash-over/ puncture		V	--
		(4) Pressure test			4. No leakage		V	--
		(5) Tightness test			5. No leakage		V	--
		(6) Creepage distance			6. As per approved GTP		V	W
		(7) Visual & dimensional check			7. As per approved drawing		V	W
		(8) Method & Positioning of Storage			8. As per bushing manufacturer's guideline		P	--
X.	Buchholz Relay / Oil Surge Relay	1. Type & make	100%	IS 3637	1. As per approved drawing	P	V	--
		2. Porosity			2. No leakage			
		3. High voltage			3. 2 KV for 1 min. withstand			
		4. Insulation resistance			4. Min 10 MΩ by 500 V DC megger			
		5. Element test			5. No leakage at 1.75 Kg/cm^2 oil pressure for 15 mins			
		6. Gas volume test at 5° ascending towards conservator			6. GOR - 1: 90 to 165 CC GOR - 2: 175 to 225 CC GOR - 3: 200 to 300 CC			
		7. Loss of oil & Surge test			7. GOR - 1: 70 to 130 CC GOR - 2: 75 to 140 CC GOR - 3: 90 to 160 CC			
		8. Contact Rating						
XI.	Bimetallic Terminal Connector	1. Dimensional	100%	IS 5561	1. As per approved drawing	P	V	--
		2. Visual check			2. Free form defects			
		3. Tensile strength			3. As per type test report			
		4. Resistance			4. As per type test report			
XII.	Marshalling Box	1. Dimension & Visual check	100%	Approved drawing and specification	1. As per approved drawing	P	V	--
		2. 2kV test for Auxiliary wiring			2. 1 min withstand			
		3. Paint shade & Thickness			3. As per approved drawing			
		4. Wiring routing check			4. Firm and aesthetic			
		5. Functional Check			5. As per approved drawing			
		6. Component type & make			6.As per approved drawing			
		7. DOP check by thin paper insertion method			7. As per technical specification			
		8. IP Protection verification			8. As per type test report / approved drawing			
XIII.	Remote Tap Changer Control Cabinet	1. Dimension & Visual Check	100%	Approved drawing and specification	1. As per approved drawing	P	P	--
		2. 2kV test for Auxiliary wiring			2. 1 min withstand			
		3. Paint shade & Thickness			3. As per approved drawing			
		4. Wiring routing check			4. Firm and aesthetic			
		5. Functional Check			5. As per approved drawing			
		6. Verification of BOQ			6. As per approved drawing			

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub Vendor	Manuf-acturer	Customer
XIV.	Air cell (Flexi Air Separator)	1. Make, Visual & Dimensions 2. Pressure test at 0.105 Kg/cm^2 3. 10 times inflation and deflation test at 0.105 Kg/cm^2	100%	IS 3400	1. As per approved drawing 2. No leakage for 24 hours 3. No deformation	P P P	P V V	V V V
XV.	Roller Assembly	1. Visual & Dimensions. 2. Mech. Properties & Chemical composition of raw material used for shaft & roller forging	One sample per melt/ heat treatment batch	IS 8500	1. Free from surface defect 2. 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	P	V	--
XVI.	Oil & winding Temperature Indicator	1. Type & make 2. Calibration 3. 2kV HV test for 1 min between all terminals & earth 4. Switch contact operation test 5. Contact Rating	100%	--	1. As per approved drawing 2. ± 1.5% of FSD 3. Withstand for 1 min 4. operation within ± 2° C of setting	P	P	--
XVII.	Pressure Relief Device/ Sudden pressure rise relay	1. Type & Make 2. Operating air pressure 3. Switch/contact testing 4. HV test 5. Functional test/Calibration 6. Contact Rating	100%	IS 2500	1. As per approved drawing & free from defect 2. No leakage 3. Satisfactory operation at pressure release 4. 2 kV withstand for 1 min	P	P	--
XVIII.	Magnetic Oil Level Gauge (MOG)	1. Type & make 2. Dial Calibration for level 3. 2kV HV test for 1 min between all terminal & earth 4. Leak test 5. Switch/contact operation test 6. Contact Rating	100%	--	1. As per approved drawing & free from defect 2. Check pointer position for Max, Min and center level 3. Withstand for 1 minute 4. No leakage at 4 kg/cm^2 5. Operate at Min level indication	P	P	--
XIX.	Valves	1. Type, make & Visual 2. Leakage test / Seepage test	100%	IS 778	1. As per approved drawing & free from defect 2. No leakage	P	P	--
XX.	Transformer Oil	Routine Test	100%	as per applicable standard	As per technical specification	P	V	W

Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub Vendor	Manuf-acturer	Customer
XXI.	Tank & Accessories	1. Check for a fit up for butt welds on tank walls, base & cover	100%	CBIP manual 2013	1. Check for proper welding	P	P	--
		2. DP test on Butt welds after fit up & load bearing welds			2. Check for proper welding			
		3. Visual & Dimensional check after final welding			3. Free from defect			
		4. Air leakage test on assembled tank with turrets & on conservator			4. No leakage			
		5. Visual check of paint shade, paint film thickness & film adhesion, primer application			5. Paint thickness Outside: 155 micron Inside : 30 micron No peel-off			
		6. WPS (Weld procedure specification) approval			6. Details to be furnished As per Specification/ASME Sec IX			
		7. PQR (Process Qualification Record)			7. Details to be furnished As per Specification/ASME Sec IX			
		8. Welders Qualification			8. Details to be furnished As per Specification/ASME Sec IX			
		9. UT (Ultrasonic test) of tank base joint.			9. Details to be furnished As per Specification/ASME Sec IX			
		10. RT (Radiography test) of tank base joint.			10. Details to be furnished As per Specification/ASME Sec IX			
		11. Verification of PWHT (Post weld heat treatment)			11. Details to be furnished As per Specification/ASME Sec IX			
		12. Surface cleaning by Shot/sand blasting			12. Details to be furnished as per specification			
		13. Tank - 13.1 Pressure test (PT) 13.2 Vacuum test (VT) 13.3 Adhesion test 13.4 Visual Inspection inside transformer tank before PT & VT test	one per design	CBIP manual 2013	13.1 Twice the normal head + 30 KN/m2 for 1 hr. Withstand 13.2 760 mm of Hg for 1 hr. withstand 13.3 Details to be furnished as per mfr's std. 13.4 Inputs required as per specification	P	W	W

XXII.	Radiators	1. DP test on lifting lugs 2. Surface cleaning of header support and bracing details by sand/shot blasting 3. Air pressure test on elements 4. Dimensional check after final welding 5. Air pressure test on radiator assembly by water dipping method 6. Visual check of paint shade, paint film thickness & film adhesion 7. WPS (Weld procedure specification) approval 8. PQR (Process Qualification Record) 9. Welders Qualification	100% Test Test	IEEMA Standard # 9 BS EN 50216-1	1. No welding defect 2. Free from surface defect 3. As per relevant standards /CBIP 4. As per approved drawing 5. 2 kg/cm^2 for 30 minutes - no leakage 6. As per tech spec, coating thickness more than 70 micron 7. Details to be furnished, if applicable as per Specification/ASME Sec IX 8. Details to be furnished, if applicable as per Specification/ASME Sec IX 9. As applicable As per Specification/ASME Sec IX	P W	W V	W V
XXIII.	OLTC	1. Auxiliary circuit insulation test at 2kV for 1min. 2. Function test on OLTC 3. Pressure test on diverter switch oil compartment 4. Mech. Operation test 5. Sequence test 6. Visual & Dimensional check 7. Operational test on Surge relay 8. Milli volt drop/contact resistance measurement after Mechanical test. 9. Condition of Silver plating on contacts 10. Measurement of Tan delta 11. Helium Test (barrier board leakage test)	100%	IEC 60214	1. To Withstand for 1 min 2. Satisfactory working as per drawing approved 3. No leakage 4. Satisfactory operation for 1 complete cycle 5. Switching time within permissible limit 6. Free from defects 7. Satisfactory working of trip & reset 8. As per standard 9. Good condition 10. To be provided (value to be used for benchmark) as per mfr's std. 11. To be provided as per mfr's std.	P	P	V

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Sr. No.	Item/Components	List of Tests	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
						Sub Vendor	Manuf-acturer	Customer
XXIV.	Cooling Fans	1. Type & Make 2. Power consumption, rating test 3. HV test 4. Insulation resistance value	100%	IS 2312	1. As per approved drawing 2. As per approved drawing 3. 1.3 kV for 1 min or 1.8 kV for 5 sec 4. 10 MΩ min with 500 V DC megger	P	P	V
XXV.	Nitrile Rubber Gasket	1.Dimensions 2.Shore Hardness 3.Tensile Strength 4.Compression set test 5. Elongation at break 6. Accelerated aging in air 7. Accelerated aging in oil 8. Shelf Life	1 sample/ Lot	BS 2751	1. Within tolerance 2. 70 ± 5 IRHD 3. 12.5 N/mm2 min 4. 20% max 5. 250% min 6. Max change in harness - 10 IRHD 7. Change in weight - 5 to 8.5% Change in thickness - 4% max Change in width & length - 0.2% max 8. Not more than 12 months???	P	P	--
XXVI.	Bushing CT	1. Dimensions 2. Verification of terminal marking & polarity 3. Overvoltage inter-turn test 4. Determination of error 5. HV Test	100%	IS 2705	1. As per approved drawing 2. As per IS 2705 3. Rated current withstand for 1 min 4. As per IS 2705 5. 3 kV AC for 1 min withstand	P	P	--
XXVII.	Remote Temperat ure	1. HV test 2. Calibration accuracy check 3. IR value	100%	---	1. 500 V AC for 1 min withstand 2. ± 1% of FSD 3. 10 MΩ min with 500 V DC megger	P	P	--
XXVIII	Oil pump	1. No load test 2. HV test 3. Oil pressure test 4. Locked rotor test	100%	---	1. Satisfactory performance & no load losses within limit 2. 2 kV AC for 1 min withstand 3. 5 Kg/cm^2 at 90° C for 30 mins withstand 4. Satisfactory operation of protection	P	P	--
XXIX.	Oil flow Indicator	1. Type & Make 2. Dial & Calibration 3. Contact Rating	100%	---	As per standard document	P	V	V
XXX.	Power/Control Cable	Review of Supplier's TC for physical & electrical tests as per specification/drg.	Random	---	As per approved document	P	V	V

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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 No of turns / disc						
1	Lamination for core						
	Visual check	One sample of each lot of CRGO	--	Prime CRGO and Free from defect	--	P	V
	Dimensional check	One sample of each lot of CRGO	--	As per design drawings	--	P	V
	Check for burr	One sample of each lot of CRGO	--	Less than 20µn	--	P	V
	Edge bow	One sample of each lot of CRGO	IS 3024	As per IS 3024	--	P	V
2	Core Building						
	Visual check	100%	--	Free from defect	--	P	W
	Total stack height	100%	As per design drawings	within specified tolerance of design	--	P	W
	Core Diameter	100%	As per design drawings	within specified tolerance of design	--	P	W
	Leg Centre & Leg length	100%	As per design drawings	within specified tolerance of design	--	P	W
	Assembly of limb Insulation & plates	100%	Design drawing	As per design	--	P	V
	Rectangularity of Core Assembly	100%	Design drawing	As per design	--	P	V
	Check for Overlaps & air gap at joints	100%	Design drawing	As per design	--	P	V
	Leaning of Core	100%	Design drawing	No leaning	--	P	V
	Earthing of Core	100%	Design drawing	Proper connection	--	P	V
	Limb Clamping & Binding	100%	Design drawing	As per design drawings	--	P	V
	Insulation test between core & core clamp / frame	100%	As per specification	shall withstand 2 kV for 1 min	--	P	W
	Yoke Bolt Tightness	100%	Design drawing	As per design		P	V
	Loss measurement on built up core assembly OR validation by software	100%	As per specification / GTP	Within limit as per GTP	--	P	W
	Built-up core sample collection for watt loss verification	1 sample per transformer	To be furnished	As per declared/offered value of Watt loss value	--	P	V

Sr. No.	Item/Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub Vendor	Manufacturer	Customer
3	Nos of discs	100%	As per approved drawings / Factory drawing	As per Factory drawing	--	P	V
	No of turns / disc						
	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
	Brazing procedure and brazer's qualification	--	Customer approval	As per approval	--	P	V
	Visual inspection of brazed joints	100%	As per brazing procedure	As per approval	--	P	V
	Visual check for transposition	100%	As per design drawings	As per design	--	P	V
	Insulation arrangement	100%	As per design drawings	As per design	--	P	V
	Lead & coil identification & marking	100%	As per design drawings	As per design	--	P	V
	Continuity test	100%	--	No breaking of continuity	--	P	V
	Coil clamping for shrinking & shrunk coil height	100%	As per design drawings	As per design		P	V
	Inter-turn Insulation	100%	As per design drawings	As per design	--	P	V
4	Core Coil Assembly						
	Visual check for inter-coil insulation	100%	--	As per design	--	P	W
	Lead & coil identification & marking	100%	--	As per design	--	P	W
	Brazing / Crimping of Joints	100%	--	Shall be smooth and no sharped age	--	P	W
	Visual check for completeness and	100%	--	Complete assembly shall be free from dust / particles	--	P	V
	Ratio test	100%	As per IS 2026 / IEC 60076	Tolerance as per standards	--	P	V
	Magnetic balance test	100%	As per IS 2026 / IEC 60076	Tolerance as per standards	--	P	V
	Magnetizing current test	100%	As per IS 2026 / IEC 60076	Tolerance as per standards	--	P	V
	Alignment of Spacers/Blocks	100%	--	Aligned	--	P	V
	HV test	100%	Manufacturer's standard	10kV for 1 min withstand	--	P	W

Sr. No.	Item/Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub Vendor	Manufacturer	Customer
5	Connections and checks before tanking						
	OLTC fitting & connections	100%	Manufacturer standard	Manufacturer standard	--	P	---
	Check for cable sizes	100%	As per design drawings	As per design	--	P	V
	Check for clearance from tank walls	100%	As per design drawings	As per design	--	P	V
	Visual checks for crimped joint	100%	--	Shall be smooth and no sharped age	--	P	V
	Visual checks for bushing CT assembly tightness	100%	--	Assembly tightness	--	P	V
	Ratio test	100%	As per IS 2026 / IEC 60076	Tolerance as per standards	--	P	V
6	Tank						
	Thickness of walls	100%	As per approved drawings	As per approved drawings	--	P	V
	Dimensions	100%	As per approved drawings	As per approved drawings	--	P	V
	Visual internal Inspection	100%	As per approved drawings	As per approved drawings		P	V
	Pressure test	100%	As per CBIP	To withstand, permanent deflection shall not exceed as per specification	--	P	W
	Vacuum test	100%	As per CBIP	To withstand, permanent deflection shall not exceed as per specification	--	P	W
7	Opening, Tanking and Oil filling						
	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	V
	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	V

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Sr. No.	Item/Process	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*		
					Sub Vendor	Manufacturer	Customer
7	Cleanliness of tank before tanking	100%	Manufacturer standard	Shall be clean.	--	P	---
	Tanking of active parts and check for clearance from tank walls & Core/frame earthing.	100%	As per design drawings	As per design	--	P	V
	10kV HV test between (i) Core & end frame (ii) Core & yoke bolts (iii) End frame and yoke bolts	100%	As per specification	To withstand 10kV for 1 min	--	P	V
	Check for oil quality before impregnation	100%	As per specification	As per specification	--	P	V
	Proper scarfing of insulation during tapping of terminal gear joints, position of leads.	100%	Manufacturer standard	Manufacturer standard		P	V
	Oil filling & Air release	100%	Manufacturer standard	Manufacturer standard	--	P	---
	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	Description of Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
C	**Acceptance Tests**		100%	IS:2026 / IEC 60076 / specification	As per applicable standard		
	1	Resistance of each winding.		IS:2026 / IEC 60076/ specification	As per applicable standard	P	W
	2	Turn ratio for all sets of windings on each tap, with percentage error / Voltage				P	W
	3	Polarity and phase relationship (Vector group)				P	W
	4	Impedance between each pair of winding / Impedance Voltage				P	W
	5	Excitation losses at 90, 100 and 110 % rated voltage measured by the average voltmeter method				P	W
	6	Regulation at rated load and unity, 0.9, 0.8 lagging P.F.				P	W
	7	Load losses, measured at rated frequency, by applying a primary voltage sufficient to produce rated current in the windings with secondary windings short circuited				P	W
	8	Separate source voltage with stand test.				P	W
	9	Induced over voltage with stand test (Line Terminal AC (LTAC) Test)				P	W
	10	Auxiliary losses (fans. Pumps etc.)				P	W
	11	SFRA test (after completion of all acceptance tests, with oil & without oil in case transportation is gas/air filled)				P	W
	12	Zero Sequence impedance test on three phase transformers				P	W
	13	Tests on tap-changer (IEC:60214)				P	W
	14	Tan delta & capacitance measurement test for bushings and windings				P	W
	15	Tests on transformer oil including DGA on selected sample as per IS: 9434/IEC: 60567, before and after temp rise test and at final stage before dispatch.				P	W
	16	Corrosive sulphur detection test as per ASTM D1275 subjecting oil for 150°C for 48 hrs. on oil being supplied at site				P	V

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

Sr. No.	Test	Description of Test	Sampling rate	Reference / Standard	Acceptable Value	Category of Responsibility*	
						Manufacturer	Customer
C	17	Tank leak test at 5 psi (35 kN/m2) for 12 hrs with oil & 1 hr with air Jacking test with Dye-Penetration of jacking pads (for welding check)		IS:2026 / IEC 60076/ specification	As per applicable standard	P	W
	18	Magnetic Balance & current test on all winding (for 3-ph)				P	W
	19	HV withstand test on auxiliary equipment and wiring				P	W
	20	Measurement of Insulation Resistance				P	W
	21	Measurement of acoustic noise level and Measurement of power taken by Fans & Pumps.				P	W
	22	Measurement of harmonics of no load current				P	W
	23	Measurement of Partial Discharges of transformer (Induced Voltage PD test)				P	W
	24	Measurement of no load current with 230V AC (for 1-ph) / 415 V AC (for 3-ph) supply on LV side.				P	W
	25	Tests on air cell				P	W
	26	Dielectric test as per IEC 60076-3				P	W
	27	Moisture content in active part measurement test			0.5 % max	P	W
	28	Core Isolation test & Repeat no load loss test after dielectric tests.				P	W
	29	Temperature rise test with DGA before and after test and measurement of tank surface temperature. (mutually agreed between purchaser and seller)				P	W
D	**Type Tests/Special test**		One from Lot or on each unit if mutually agreed between Manufacturer and Purchaser.				
	1	Temperature rise test with DGA before and after test and measurement of tank surface temperature.		IS:2026 / IEC 60076/IEC 61181	As per standards	P	W
	2	Lightning Impulse Voltage withstand test with chopped wave Switching Impulse Voltage withstand test		IS:2026 / IEC 60076	As per standards	P	W
	3	Vacuum and pressure test on tank		CBIP manual	Permanent deflection within limit as per length of plate used.	W	W
	4	Short circuit withstand capability test (Dynamic)		IS:2026 / IEC 60076	As per standards	P	W
	5	Tests on OLTC		IEC 60214	As per standards	P	W

Annexure–F

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

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)	(mm2)	(mm2)	(mm2)
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						
NET CORE AREA= 422554 x 0.96 mm^2 **=** 4056.52 cm^2						

CALCULATION OF FLUX DENSITY:

Phase voltage = 4.44 f x Bmax x A x N x 10^{-4}

f=50 Hz

A= 4056.52 cm^2

N= 72

Bmax = (11000)/(4.44*50*4056.52*72*10^{-4}) = 1.696 T

Cross section area of core = 4056.52 cm^2

Window height = 2000 mm

Yoke height =740 mm

Core Height = 2000 + (2 x 740)=3480 mm

Window width =810 mm

Limb pitch = 810 + 740 =1550 mm

There are 3 core heights and 4 window widths
Total periphery of the core= (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
=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=1.696T

Referring to supplier's curves for core losses against working flux density
The value of watts/kg. against 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
= 36.755 kW
Where the value of building factor taken is 1.11

Guaranteed No Load Loss = 39.0kW

Estimation of copper quantity during stage Inspection

A. Weight of bare copper by ID/OD METHOD

	Periphery (mm)	**Outer Dia (mm)**	**Radial depth (mm)**	**Mean dia (mm)**
OD of LV	**3035**	966.1	**77.60**	888.5
OD of HV	**4585**	1459.5	**169.50**	1290.0
OD of Reg	**4585**	1459.5	**169.50**	1290.0

No. of Turns:
LV: 72, HV: 811, Tap : 84
Type of Conductor in LV winding – CTC- Continuously Transposed Cable

No. of Coils in LV Winding =1
No. of Cables parallel in LV Winding =2
Type of Conductor in HV winding – Twin Paper (TP) insulated copper conductor
No. of Coils parallel in HV Winding =2
No. of Cables per turn in HV Winding=2
No. of strand 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 strand per cable in HV 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
= 4.967 x 1.789 mm
No. of strands/ cable = 77
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 strand
= ((4.967x1.789)-0.363)) x 77 = 656.27 mm^2
Area of each HV Cable = Strand area x No of strand /Cable
= (9.88x1.792-0.363) x 2 = 34.68 mm^2
Area of each Tap Cable = Strand area x No of strand /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 Turns x Area of cable x No. of cable 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 Turns x Area of cable x No. of cable 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 Turns x Area of cable x No. of cable 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 = 5720 gm/ meter
Measured bare cable Cu weight of HV winding per 595 mm
= 184 gm = 309.3 gm/meter
Measured bare cable Cu weight of Tap winding per 745 mm
= 160 gm = 214.8 gm/meter
Bare Cu Weight of LV winding
= 3 x π x Mean Diameter x Turns x No. of cable 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 Turns x No. of cable 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 Turns x No. of cable 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/No. of Strand per cable
= 0.005553ohm
Measured Resistance per strand of each HVcoil = 3.121 ohm (46 disc from HV center)
Measured Resistance per strand of each HVcoil = 0.26834 ohm (Last 4 disc of HV bottom)
So Total Measured Resistance per Stand of each HV coil = 3.38934 ohm (50 disc from HV centre)
So Total Measured Resistance per Cable of each HV coil = 1.69467 ohm (50 disc from HV centre)
Measured Resistance per cable of each Tap coil = 0.067465 ohm (2 disc of Tap coil)
So, Total Measured Resistance per cable of each Tap coil = 0.26986(8 disc of Tap coil)

Resistivity (p) 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 = p(L/A)

p : Resistivity, L : Length in Meters, A : Area of conductors in mm2

Length of each LV cable = 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

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. Vapour phase drying oven (adequately sized to accommodate offered transformer and have facility to record temperature, vacuum, moisture etc.)
3. Air Casters
4. Core cutting line (as 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. Faradays cage
17. Motor Generator Set/ Static Power System Set
18. Testing transformer
19. Capacitor bank

20. Impulse voltage generator
21. Capacitance & Tan delta bridge
22. Power Analyser
23. Current & Voltage transformer
24. Partial discharge measuring kit (for all manufacturers) & PD Diagnostic Kit (for 400 kV & above Transformer/reactor)
25. Temperature data logger
26. Noise measurement kit
27. Thermo vision camera
28. Loss measurement kit
29. Insulation tester
30. Winding resistance meter
31. Turn ratio meter
32. Transformer oil test lab
33. Dissolved Gas Analysis (DGA) test kit
34. Sweep Frequency Response Analyser (SFRA) kit
35. Frequency Domain Spectroscopy (FDS) kit
36. NABL Accredited lab
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
42. RSO Generator with Oscilloscope

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

A. Transformer must be manufactured in a bay having positive pressure w.r.t. external environment. Winding shall be manufactured in an air conditioned, dust free and humidity controlled environment. Further, there shall be humidity and dust free environment for following:

1. Insulation storage
2. Core storage
3. Glue stacking area
4. Core cutting line
5. Core building area
6. Core coil assembly area
7. Testing lab
8. 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 and completeness and signed by a responsible officer of the Contractor on his behalf. 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) Outline General Arrangement drawing of transformer showing

i) Plan
ii) Elevation
iii) End view
iv) Neutral formation of three phase bank
v) Delta formation of three phase bank

(b) List of all accessories with detailed weights, quantity of insulating oil, dimensions clearances, spacing of wheels in direction, centre of gravity, location of cooler etc.

(c)

(d) Rating & Diagram Plate

(e) Loading details for transformer foundation

(f) Foundation Plan showing reaction at points of support, clamping arrangement & location of jacking pads

(g) Technical Data requirement sheet of transformer

(h) Over fluxing withstand duration curve

(i) Schematic wiring diagram of cooling arrangement along with write up on scheme

(j) Schematic wiring diagram of OLTC along with write up on scheme

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

(l) Bushing Drawing showing electrical and mechanical characteristics

i) HV Bushing
ii) IV Bushing
iii) LV Bushing
iv) Neutral Bushing

(m) Assembly drawings of HV, IV & LV bushings

(n) Outline and General Arrangement of Cooler Control Cabinet

(o) Cooler Control cabinet schematic and wiring diagram

(p) Magnetisation Characteristics of bushing CTs and neutral CTs

(q) Hysteresis Characteristics of iron core

(r) Rating and Diagram Plate giving details of terminal marking and connection diagram

(s) Overall Transport Dimension Drawing of transformer

(t) Drawing showing typical sectional view of the windings with details of insulation, cooling circuit, method of cooling and core construction etc.

(u) Oil Flow Diagram

(v) Valve Schedule Plate drawing

(w) Twin Bi-directional Roller

(x) Connection Diagram of all protective devices to marshalling box showing physical location

(y) List of spares

(z) Technical Literature of all fittings and accessories

(aa) Calculation to support short circuit withstand capacity of transformer (bb) Calculation of hot spot temperature

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

(dd) Oil sampling Bottle details

(ee) Typical heating and cooling curves

(ff) GA of RTCC panel

(gg) Transformer oil storage tank drawing

(hh) GA drawing for bus duct termination (if applicable)

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

(jj) Alarm/Trip Indication Scheme

(kk) Tap Changer Control Scheme (if applicable)

(ll) Complete bill of material

(mm) Customer inspection schedule

(nn) Test procedure of transformer

(oo) Type test reports of transformer

(pp) O&M manual of transformer

Annexure – I

SCOPE OF DESIGN REVIEW

Sr. No.	Description
1.	Core and Magnetic Design
2.	Over-fluxing and Linear characteristics
3.	Inrush-current characteristics while charging
4.	Winding and winding clamping arrangements
5.	Short-circuit withstand capability considering inrush current.
6.	Thermal design including review of localized potentially hot area
7.	Cooling design
8.	Overload capability
9.	Eddy current losses
10.	Seismic design, as applicable
11.	Insulation co-ordination
12.	Tank and accessories
13.	Bushings
14.	Protective devices
15.	Radiators
16.	Sensors and protective devices– its location, fitment, securing and level of redundancy
17.	Oil and oil preservation system
18.	Corrosion protection
19.	Electrical and physical Interfaces with substation
20.	Earthing (Internal & External)
21.	Processing and assembly
22.	Testing capabilities
23.	Inspection and test plan
24.	Transport and storage
25.	Sensitivity of design to specified parameters
26.	Acoustic Noise
27.	Spares, inter-changeability and standardization
28.	Maintainability

29.	PRD and SPR (number & locations) and selection
30.	Conservator capacity calculation
31.	Winding Clamping arrangement details with provisions for taking it "in or out of tank"
32.	Conductor insulation paper details
33.	Location and numbers of Optical temperature sensors
34.	The design of all current connections
35.	Location & size of the Valves

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.

Annexure-K

PAINTING PROCEDURE

PAINTING	Surface preparation	Primer coat	Intermediate undercoat	Finish coat	Total dry film thick-ness (DFT)	Colour shade
Main tank, pipes, conservator tank, oil storage tank& DM Box etc. (external surfaces)	Shot Blast cleaning Sa 2 ½*	Epoxy base Zinc primer (30-40μm)	Epoxy high build Micaceous iron oxide (HB MIO) (75μm)	Aliphatic polyurethane (PU) (Minimum 50μm)	Minimum 155μm	RAL 7035
Main tank, pipes (above 80 NB), conservator tank, oil storage tank & DM Box etc. (Internal surfaces)	Shot Blast cleaning Sa 2 ½*	Hot oil proof, low viscosity varnish or Hot oil resistant, non-corrosive Paint	--	--	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.

Annexure–L

UNUSED INHIBITED INSULATING OIL PARAMETERS

Sl. No.	Property	Test Method	Limits
A	**Function**		
1a.	Viscosity at 100degC	ISO 3104 or ASTM D445 or ASTM D7042	(Max.) 3 mm^2/s
1b.	Viscosity at 40degC	ISO 3104 or ASTM D445 or ASTM D7042	(Max.)12 mm^2/s
1c.	Viscosity at -30degC	ISO 3104 or ASTM D445 or ASTM D7042	(Max.)1800 mm^2/s
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	ISO 3016 or ASTM D97	(Max.)- 40degC
4.	Water content a) for bulk supply b) for delivery in drums	IEC 60814 or ASTM D1533	(Max.) 30 mg/kg 40 mg/kg
5.	Electric strength (breakdown voltage)	IEC 60156	(Min.)50 kV(new unfiltered oil) / 70 kV (after treatment)
6.	Density at 20 deg C	ISO 3675 or ISO 12185 or ASTM D 4052	0.820 - 0.895 g/ml
7.	Dielectric dissipation factor (tan delta) at 90 deg C	IEC 60247 or IEC 61620 Or ASTM D924	(Max) 0.0025
8.	Negative impulse testing KVp @ 25 deg C	ASTM D-3300	145 (Min.)
9.	Carbon type composition (% of Aromatic, Paraffins and Naphthenic compounds)	IEC 60590 and IS 13155 or ASTM D 2140	Max.Aromatic : 4 to12 % Paraffins : <50% & balance shall be Naphthenic compounds.

B	**Refining/Stability**		
1.	Acidity	IEC 62021-1 or ASTM D974	(Max) 0.01 mg KOH/g
2.	Interfacial tension at 27degC	ISO 6295 or ASTM D971	(Min) 0.04 N/m
3.	Total sulphur content	BS 2000 part 373 or ISO 14596 or ASTM D 2622 or ISO 20847	0.05 % (Max.) (before oxidation test)
4.	Corrosive sulphur	IEC 62535	Non-Corrosive on copper and paper
		ASTM D1275B	Non-Corrosive
5.	Presence of oxidation inhibitor	IEC 60666 or ASTM D2668 or D4768	0.08% (Min.) to 0.4% (Max.) Oil should contain no other additives .Supplier should declare presence of additives, if any.
6.	2-Furfural content	IEC 61198 or ASTM D5837	25 Microgram/litre (Max.)
C	**Performance**		
1	Oxidation stability -Total acidity -Sludge - Dielectric dissipation factor (tan delta) at 90degC	IEC 61125 (method c) Test duration 500 hour IEC 60247	Max 0.3 mg KOH/g Max 0.05 % Max 0.05
2.	Oxidation stability	ASTM D2112 (a)	220 Minutes (Min.)
D	**Health, safety and environment (HSE)**		
1.	Flash point	ISO 2719	(Min.)135deg C
2.	PCA content	BS 2000 Part 346	Max 3%
3.	PCB content	IEC 61619 or ASTM D4059	Not detectable (Less than 2 mg/kg)
E	**Oil used (inhibited) 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)
F	**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		More than 0.04 N/m
G	**After filtration & settling and prior to energisation at site oil shall be tested for following:**		
1	Break Down voltage (BDV)	IS: 1866 / IEC 60422	70 kV (min.)
2	Moisture content at hot condition		5 ppm (max.)
3	Tan-delta at 90°C		0.005 (Max)
4	Interfacial tension		More than 0.04 N/m
5	*Oxidation Stability	Test method as per IEC 61125 method C, Test duration: 500hour for inhibited oil	
	a) Acidity		0.3 (mg KOH /g) (max.)
	b) Sludge		0.05 % (max.)
	c) Tan delta at 90 °C		0.05 (max.)
6	*Total PCB content		Not detectable (less than 2 mg/kg total)
	* Separate oil sample shall be taken and test results shall be submitted within 45 days after commissioning for approval of the utility		

Annexure - M

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 wires used for manufacturing the cables shall be true circular in shape before stranding and shall be uniformly good quality, free from defects. All aluminium used in the cables shall be of H2 grade.

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 plus or minus 2 mm.

1.13 **PVC Power Cables**

1.13.1 The PVC insulated 1100V grade power cables shall be of 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 70°C. The conductor shall be stranded aluminium. 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 contractor can used copper cable of required size.

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 over 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–N

SPARE TRANSFORMER/REACTOR UNIT STORAGE & CONNECTION ARRANGEMENT

1. Transformer/Reactor with Isolator switching arrangement:

The spare Transformer/Reactor unit shall replace any of the other units using isolator switching arrangement so as to avoid physical shifting of the Transformer/Reactor.

Connection of spare unit with other units shall be made by isolator switching arrangement. Neutral formation for spare unit shall be done by manual connection. The spare unit shall be completely erected and commissioned similar to the other units. The contractor shall carry out all pre-commissioning tests on the spare unit similar to the unit kept in service.

For this purpose, HV, IV and Neutral Connections of spare unit shall be extended up to the other unit(s) by forming auxiliary buses connection through flexible/rigid conductor. All associated materials like Bus post insulators, Aluminium tube, conductors, clamps & connectors, insulator strings, hardware, cables, support structures shall be required 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.
Any special maintenance procedure required shall be clearly brought out in the instruction manual.

2. Transformer/Reactor without isolator switching arrangement:

If there is space limitation, the spare Transformer/Reactor unit without isolator switching arrangement may be used. In case of failure of any of the running unit, this spare unit shall be physically shifted to replace faulty unit.

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.

All other items shall be suitably packed in reusable boxes. Arrangement shall be made to minimize moisture ingress inside the boxes. All pipes and radiators shall be provided with blanking plates during long duration storage to prevent entry of foreign material/ water.

Note: The above clauses may not be applicable for transformers/reactors with oil to SF6 bushings.

Annexure-O

VALVE SCHEDULE FOR GENERATOR TRANSFORMER IN HYDRO PLANTS

Sl. No.	Fittings
1	Drain valve on tank base
2	Drain valve on tank bottom
3	Drain valve on main conservator
4	Drain valve for aux. conservator of HV cable box, if applicable
5	Filter valve on tank at top and bottom
6	Sampling valve for cable box, if applicable
7	Pressure relief valve for tank cover and cable box
8	Oil inlet valve for tank & cable box, if applicable
9	Oil outlet valve for tank & cable box, if applicable
10	Water inlet valve
11	Water outlet valve
12	Sampling valve on tank top and bottom
13	Air release valve on cover
14	Air release plug on cooler, pipes and conservator
15	Drain plug cooler & pipes
16	Gas sampling valves
17	Non return valve
18	Conservator valve for connection to tank
19	Drain & filter valve for cable box
20	Valve for online moisture measurement
21	Valve for online DGA, if applicable
22	Valve for fire protection system, if applicable

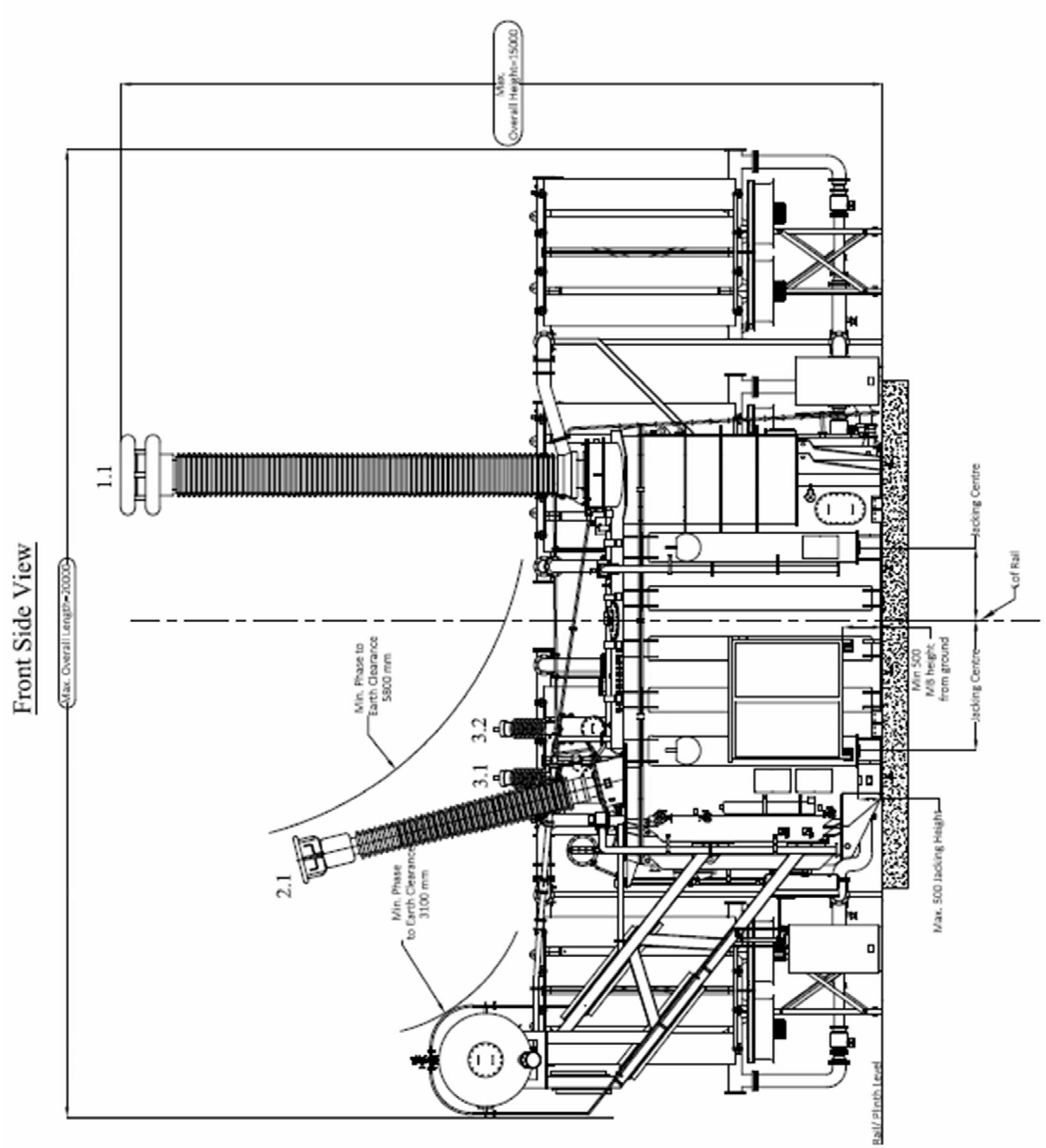
Annexure-P

For Standardization purposes, following typical General Arrangement (GA) and Foundation Plan drawings are provided:

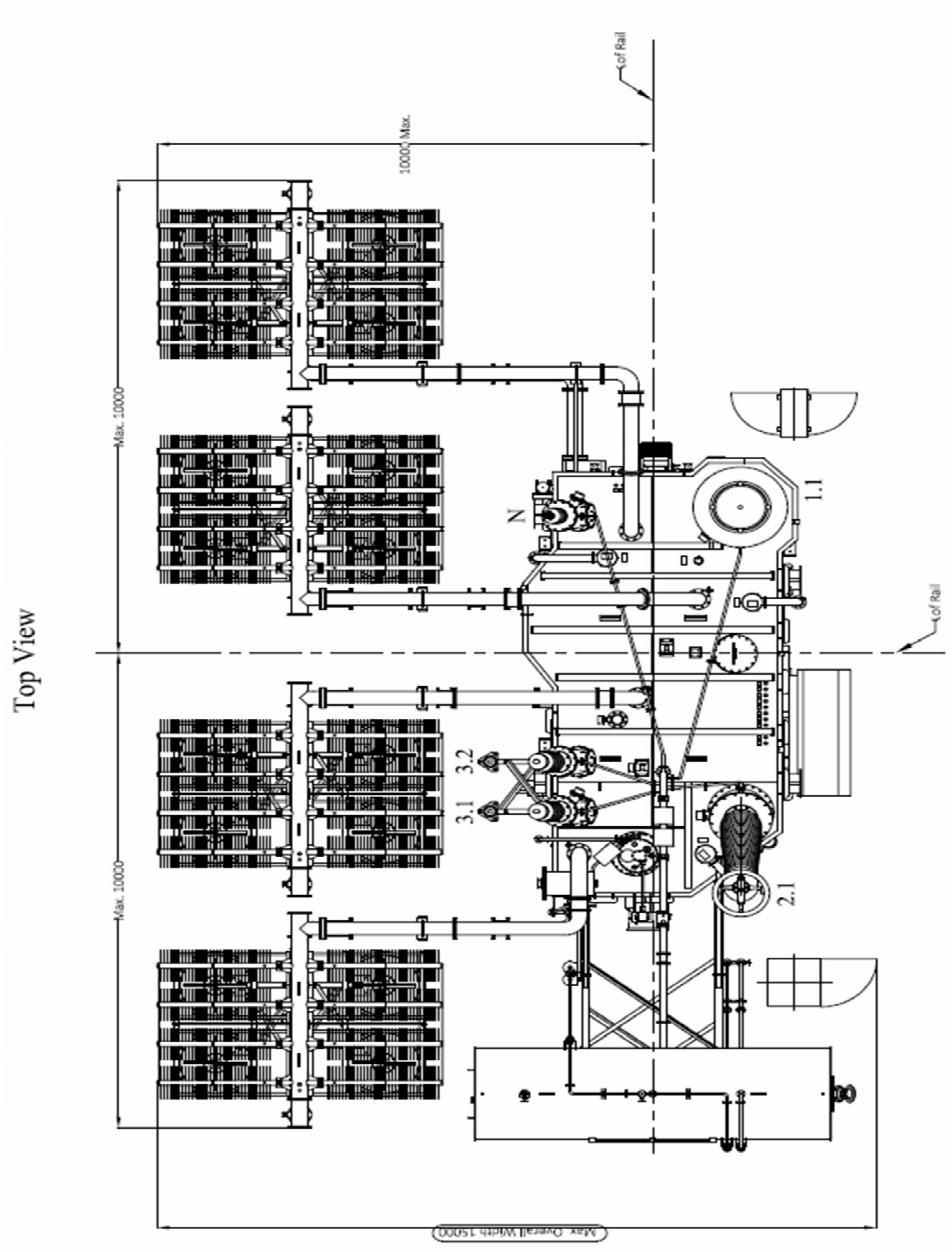
S. No.	Equipment Name	Drawing Name
1.	Single Phase 500 MVA, 765/400/33 kV Auto Transformer	General Arrangement: 1. Front Side View 2. Top View 3. Left Side View
		Foundation Plan
2.	Three Phase 500 MVA, 400/220/33 kV Auto Transformer	General Arrangement 1. Cooler Bank on LHS from HV Side 2. Top View 3. HV Right Side View
		Foundation Plan
3.	315 MVA, 400 kV Three Phase Auto Transformer	General Arrangement (Cooling Mounted Separately)
4.	167 MVA, 400/√3/220/√3/33 kV Single Phase Auto Transformer	General Arrangement
		Foundation Plan
5.	100 MVA, 220 kV Three Phase Auto Transformer	General Arrangement (Cooling Mounted Separately)
		General Arrangement (Cooling Mounted on Tank)
6.	200 MVA, 21/420/√3 kV Single Phase Generator Transformer	General Arrangement
		Foundation Plan
7.	200 MVA, 21/420/√3 kV Single Phase Generator Transformer	General Arrangement (With Unit Cooler)
		Foundation Plan (With Unit Cooler)
8.	315 MVA, 220 kV Three Phase Generator Transformer	General Arrangement
		Foundation Plan
9.	Single Phase 765/√3 kV Shunt Reactor	Foundation Plan
10.	Three Phase 420 kV Shunt Reactor	Foundation Plan

Note: 1. Dimensions are approximate.
2. All dimensions are in mm unless otherwise stated.

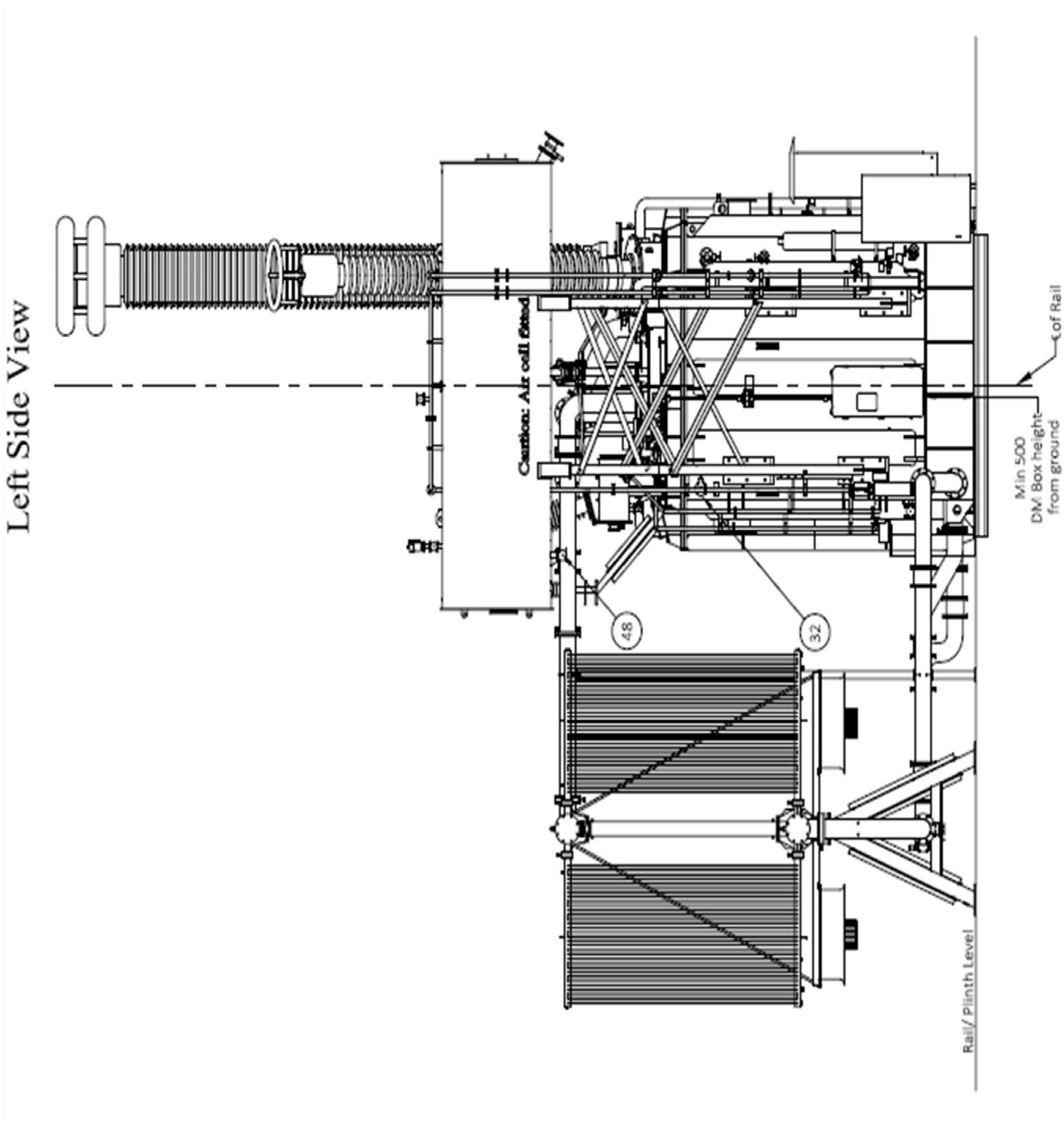
General Arrangement of Single Phase 500 MVA, 765/400/33 kV Auto Transformer



Front Side View

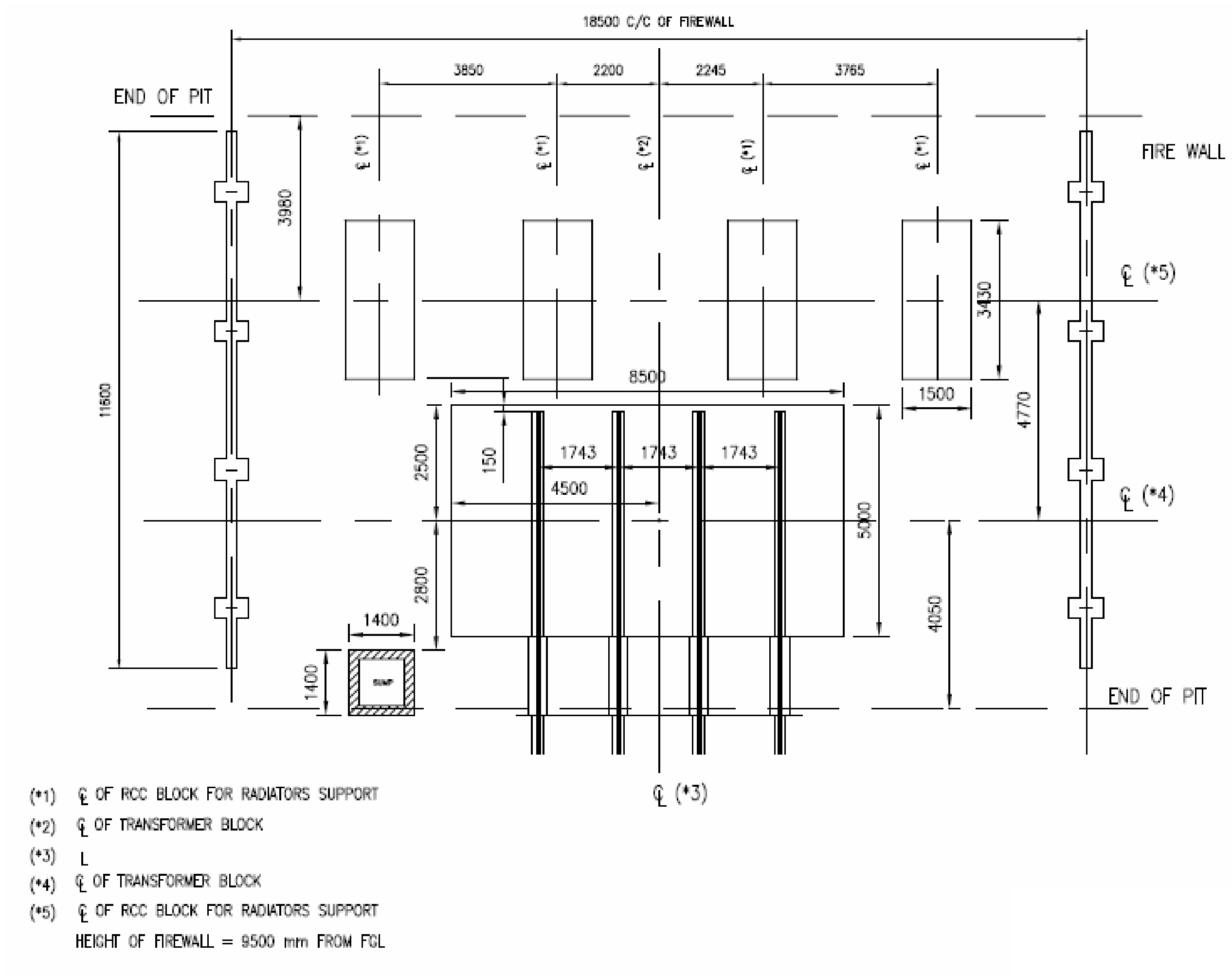

Top View
10000 Max.
Max. 10000
Max. 10000
N
1.1
3.2
3.1
2.1
Max. Overall Width 15000

Top View

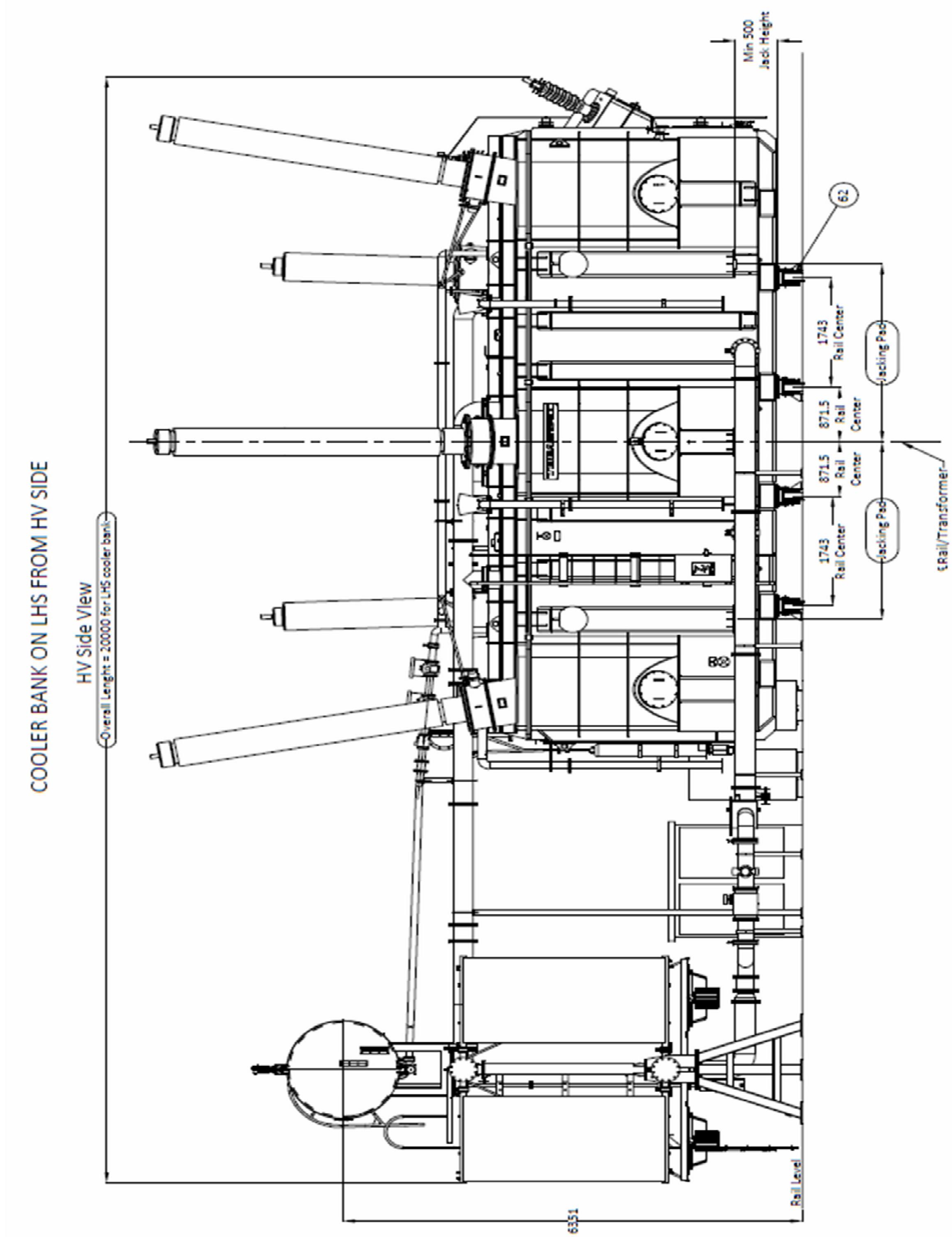


Left Side View

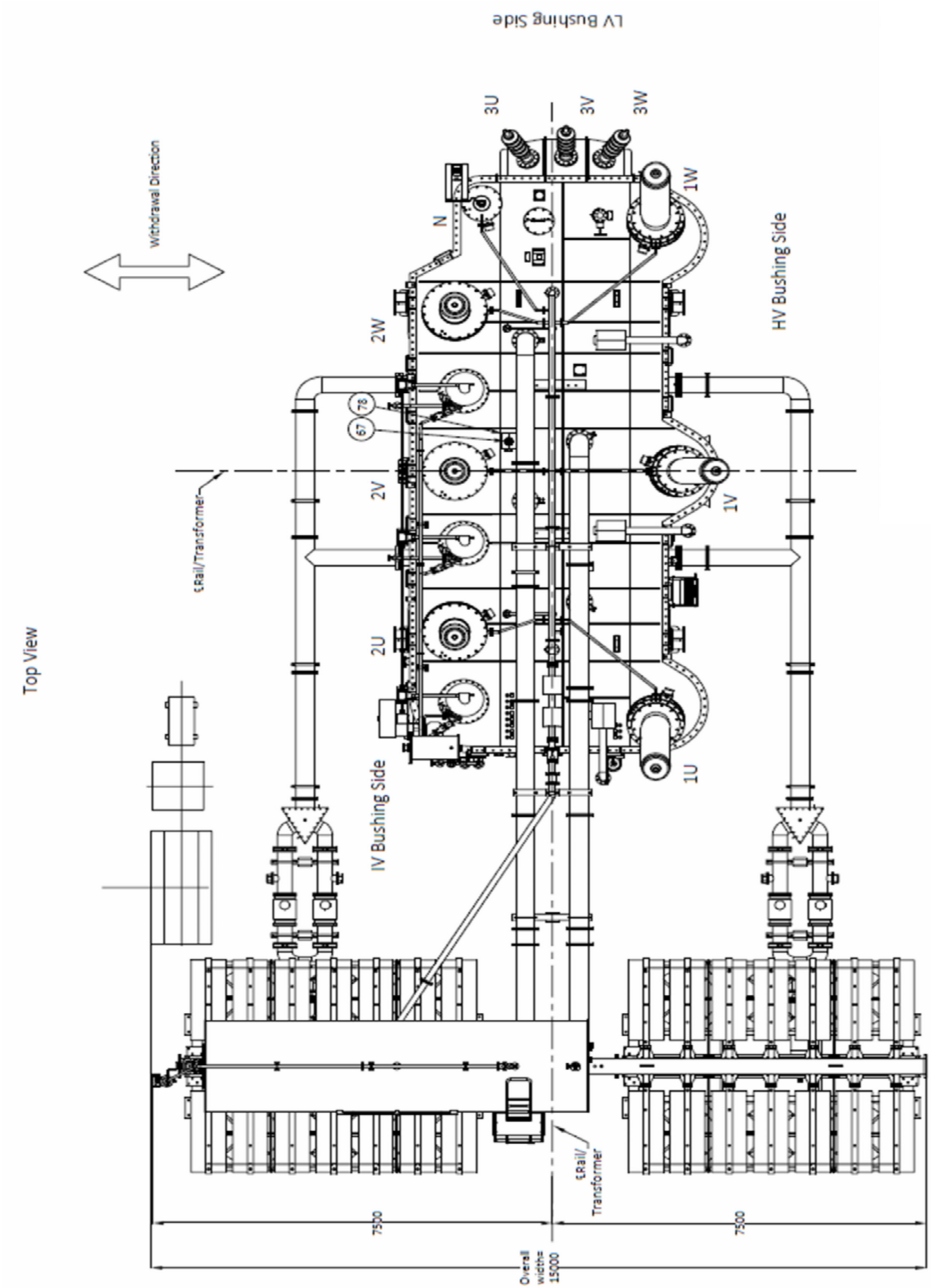
Foundation Plan of Single Phase 500 MVA, 765/400/33 kV Auto Transformer



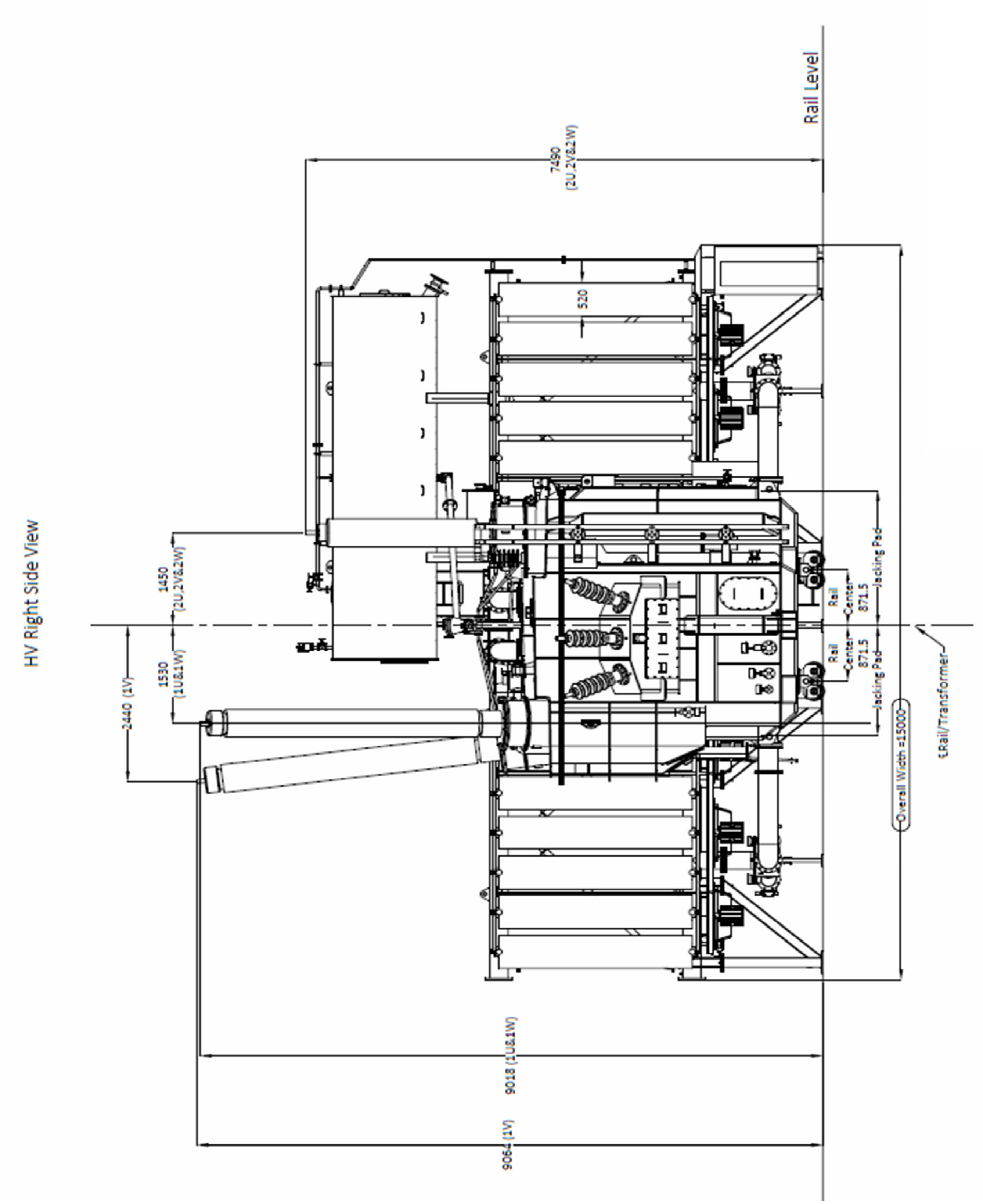
General Arrangement of Three Phase 500 MVA, 400/220/33 kV Auto Transformer



Cooler Bank on LHS from HV Side

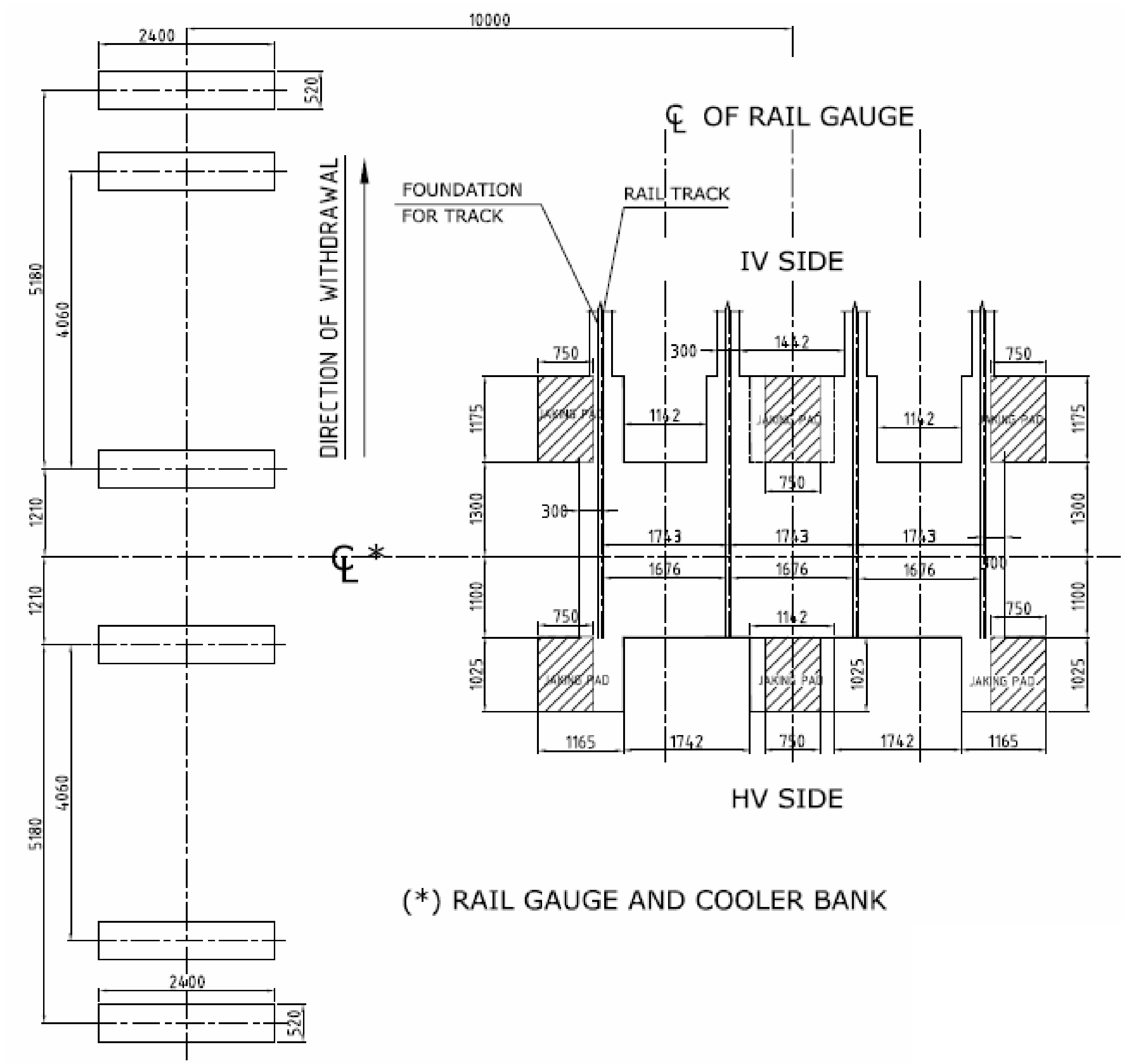

LV Bushing Side
3U
3V
3W
N
1W
Withdrawal Direction
HV Bushing Side
2W
78
67
2V
1V
€Rail/Transformer
2U
Top View
1U
IV Bushing Side
€Rail/
Transformer
7500
7500
Overall
width=
15000

Top View

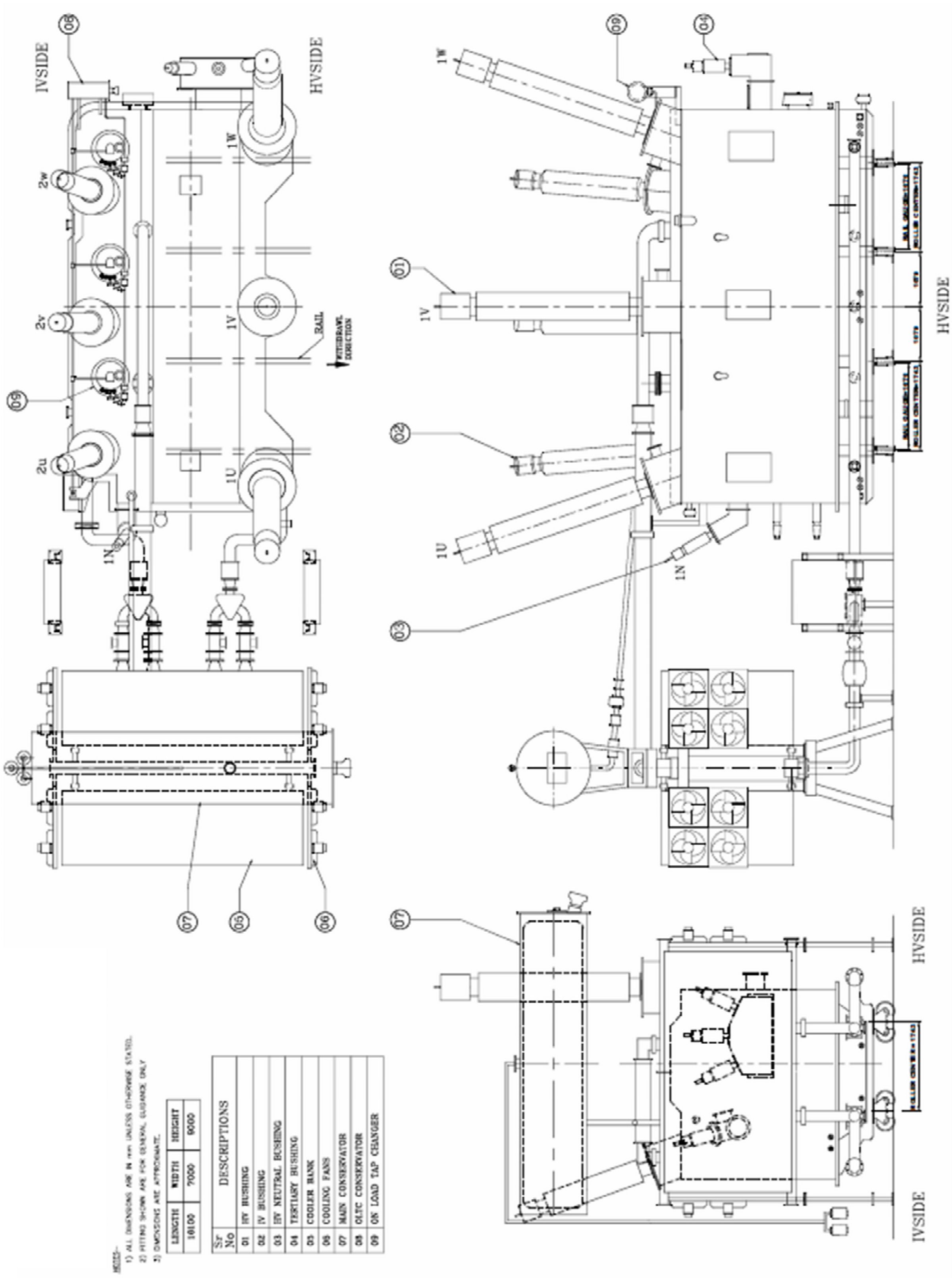


HV Right Side View

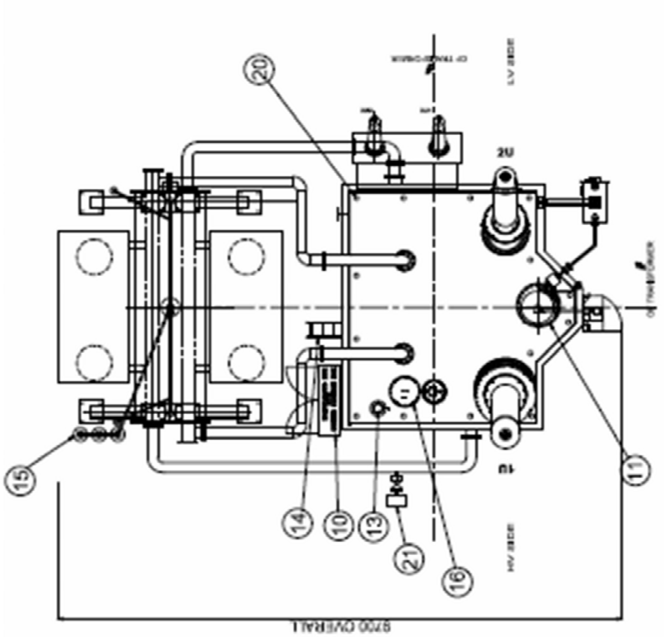
Foundation Plan of Three Phase 500 MVA, 400/220/33 kV Auto Transformer

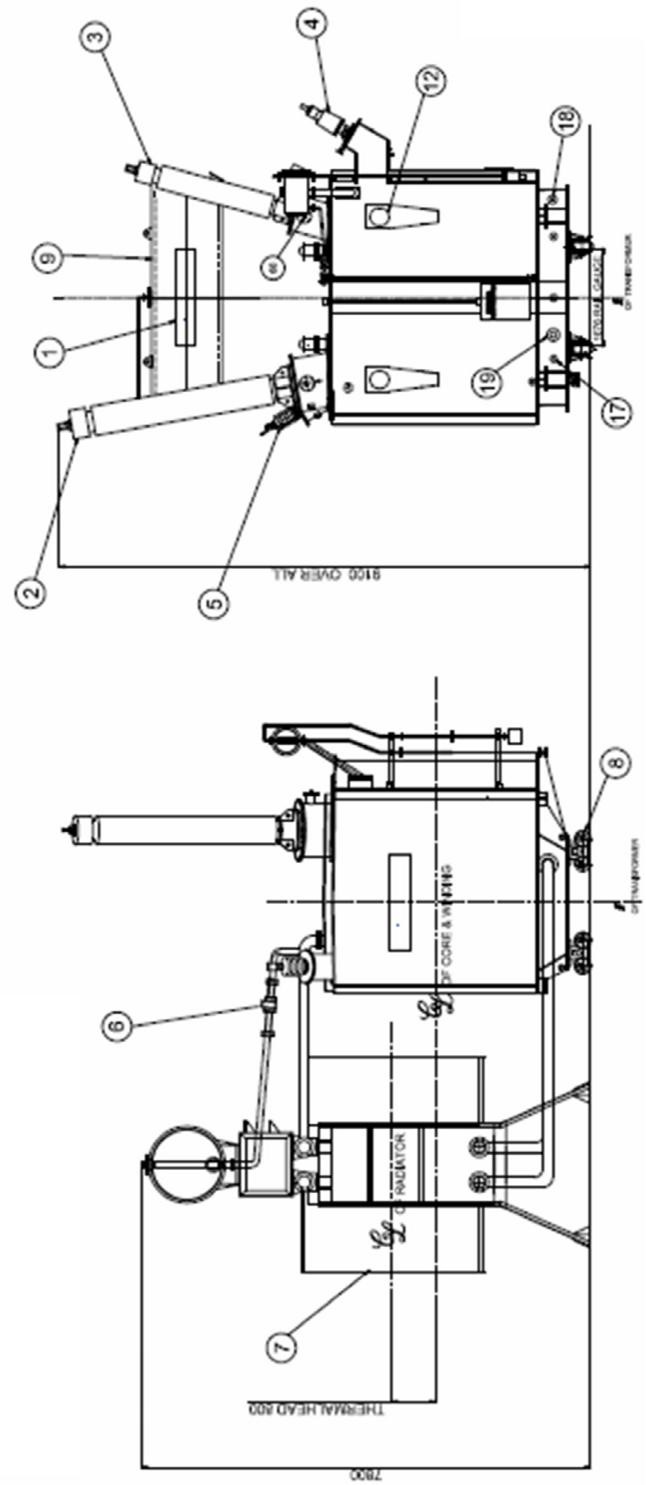


General Arrangement of 315 MVA, 400 kV Three Phase Auto Transformer (Cooling Mounted Separately)



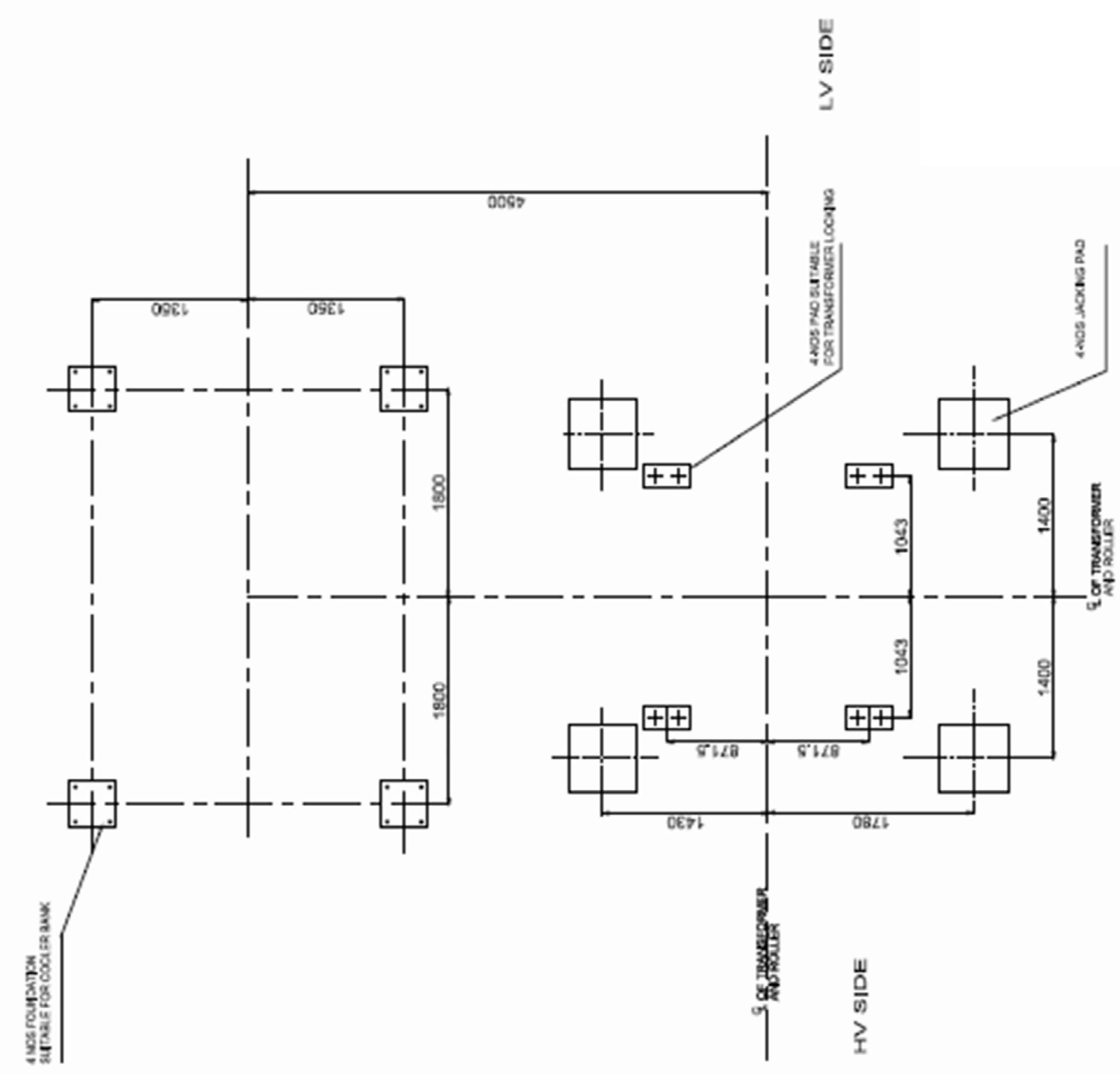
General Arrangement of 167 MVA, 400/√3/220/√3/33 kV Single Phase Auto Transformer



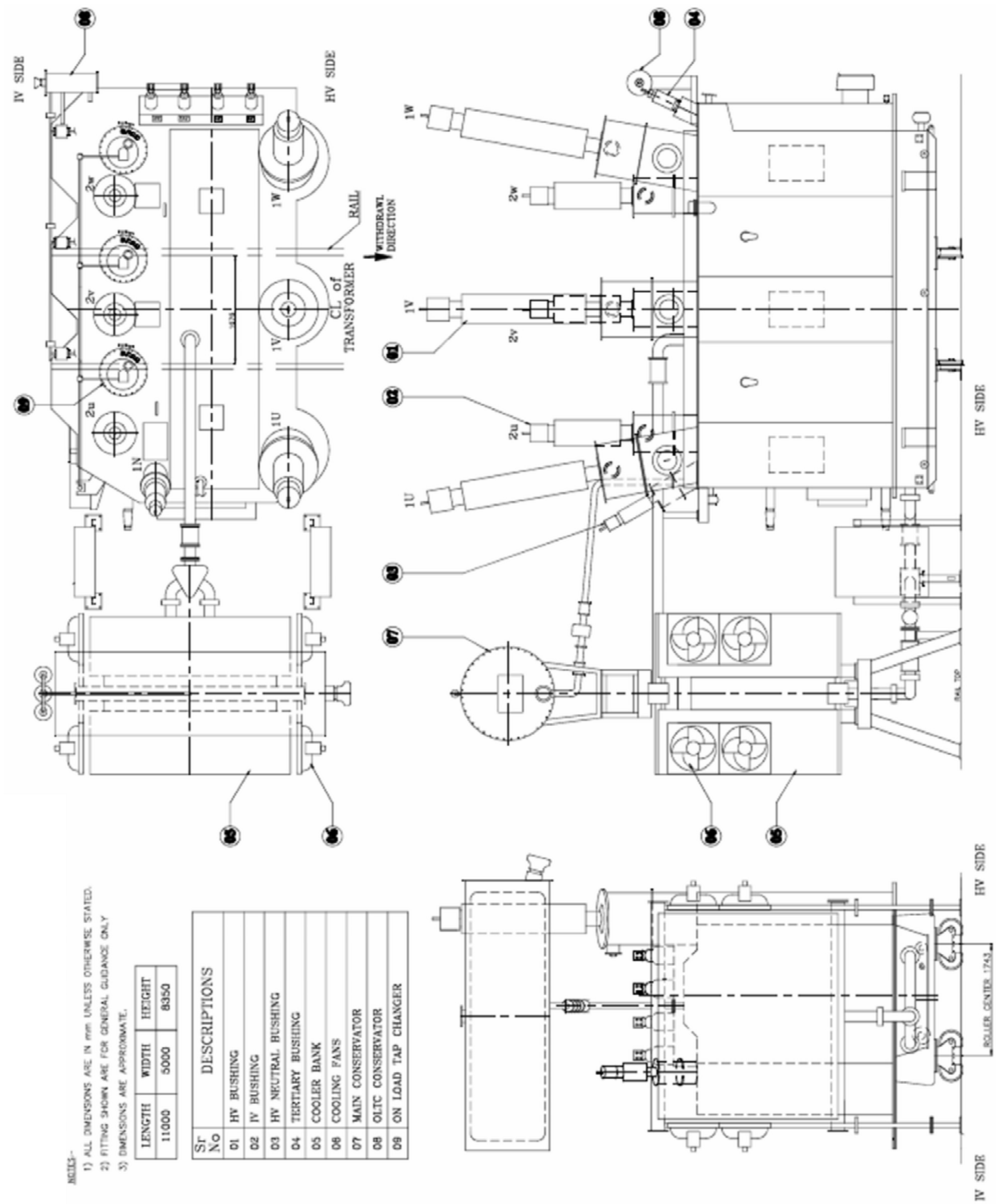


SL. NO.	DESCRIPTIONS
1	MANUFACTURER NAME PLATE
2	HV LINE BUSHINGS 420kV
3	IV BUSHING 245 kV
4	LV BUSHING 52 kV
5	NUTRAL BUSHING 36 kV
6	BUCHHOLZ RELAY
7	RADIATOR WITH FAN
8	280Ø BIDIRECTIONAL FLANGED TWIN ROLLER
9	MAIN CONSERVATOR WITH AIRCELL
10	MARSHALLING BOX WITH INSTRUMENTS & TEMPERATURE INDICATORS
11	ON LOAD TAP CHANGER
12	LIFTING BOLLARDS
13	PRESSURE RELEASE DEVICE WITH SPLASH GUARD
14	LADDER
15	BREATHER
16	INTERNAL EARTHING TERMINAL
17	PROVISION FOR FIRE PROTECTION SYSTEM
18	FILTER VALVE
19	DRAIN VALVE
20	PROVISION OF RAILING FOR SAFETY
21	DGA WITH VALVE

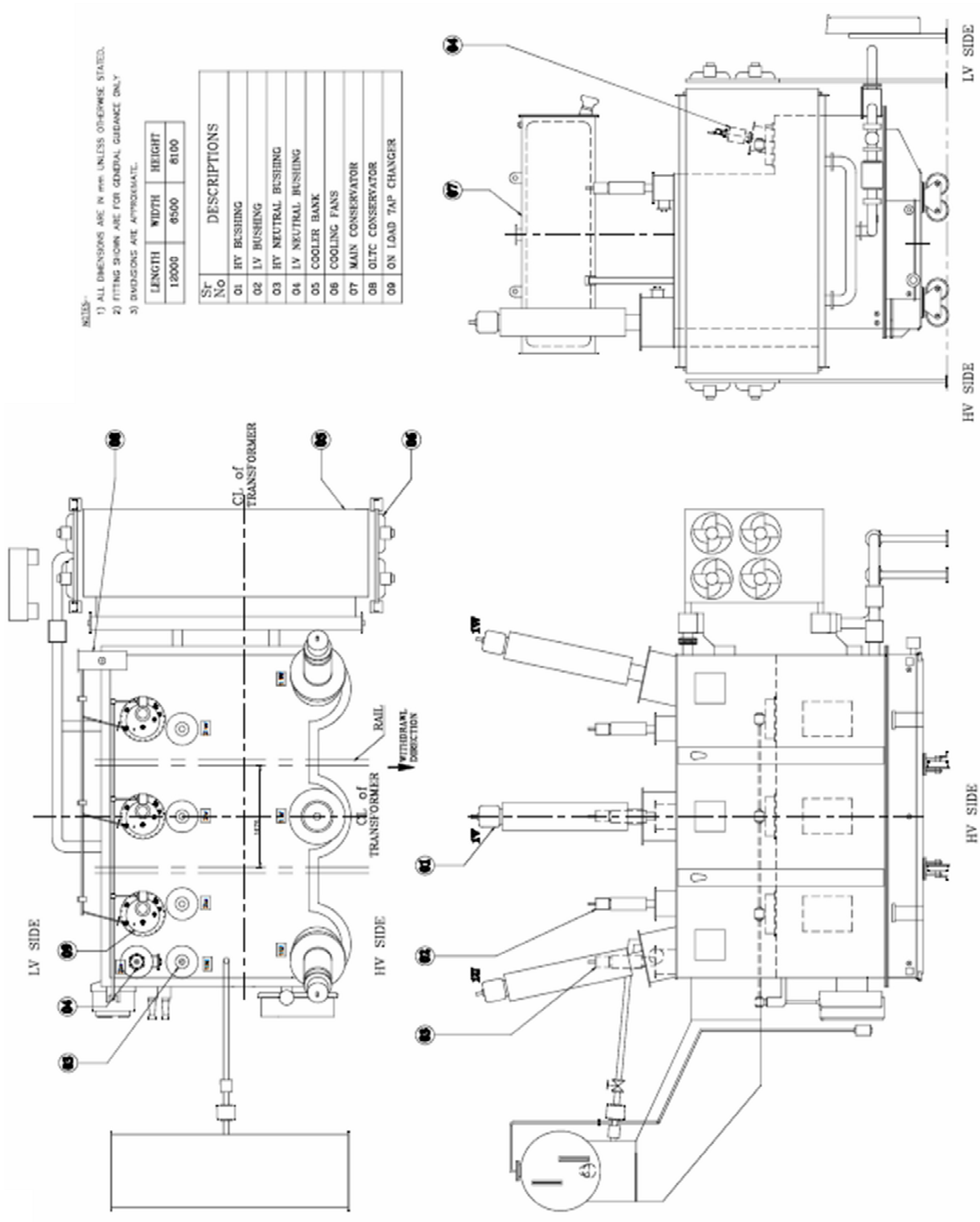
Foundation Plan of 167 MVA, 400/√3/220/√3/33 kV Single Phase Auto Transformer



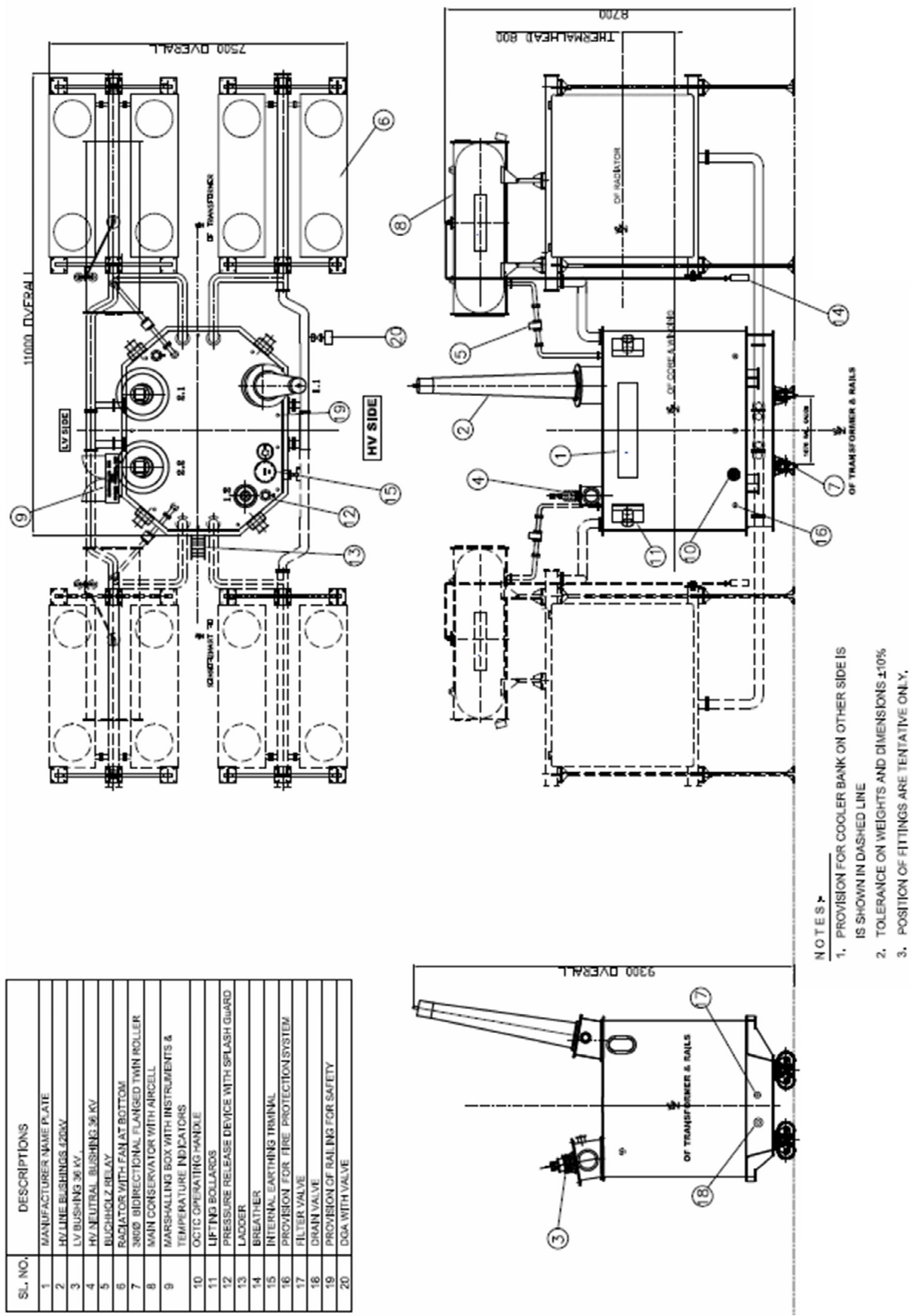
General Arrangement of 100 MVA, 220 kV Three Phase Auto Transformer (Cooling Mounted Separately)



General Arrangement of 100 MVA, 220 kV Three Phase Auto Transformer (Cooling Mounted on Tank)



General Arrangement of 200 MVA, 21/420/√3 kV Single Phase Generator Transformer

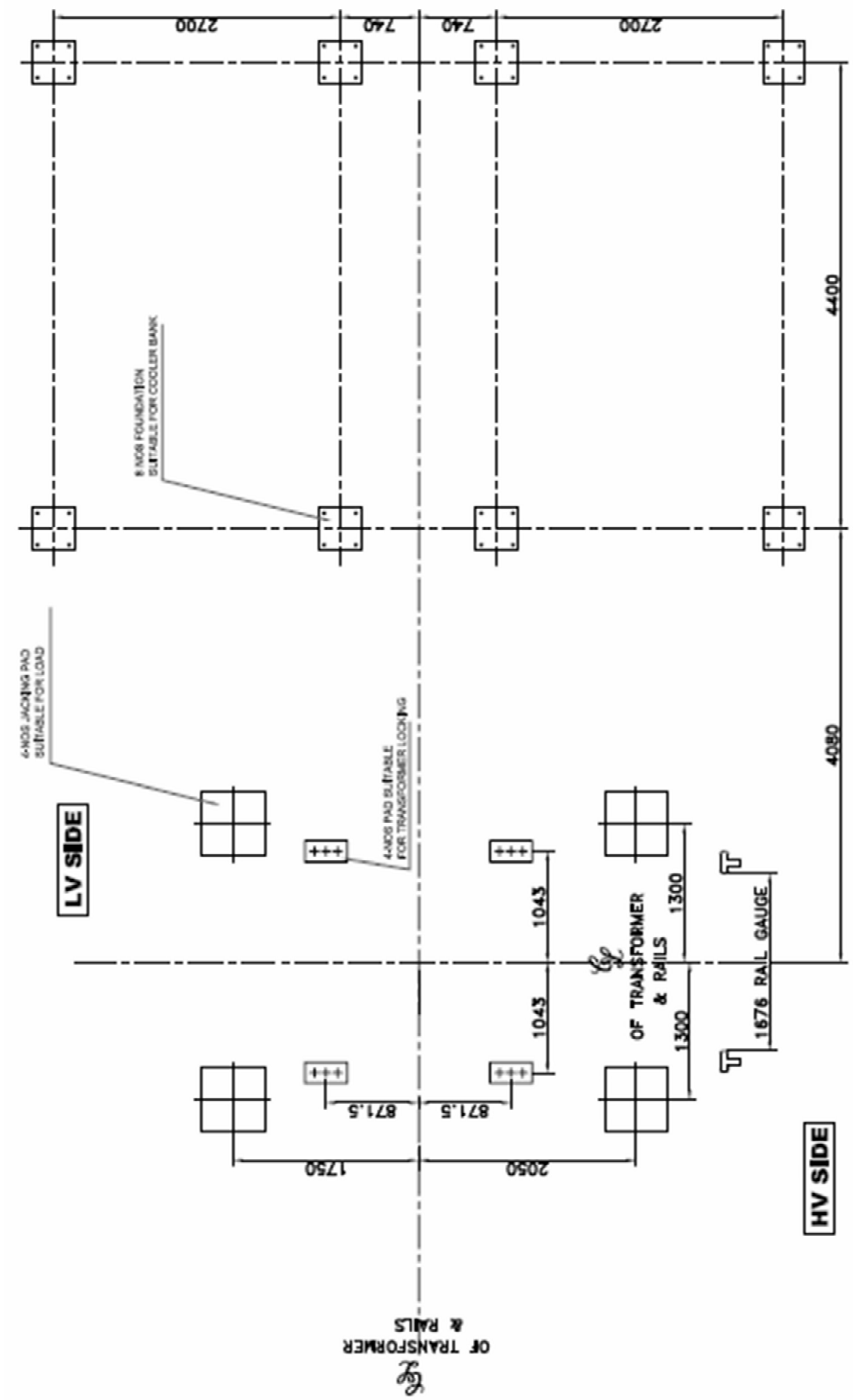


SL. NO.	DESCRIPTIONS
1	MANUFACTURER NAME PLATE
2	HV LINE BUSHINGS 420kV
3	LV BUSHING 36 kV
4	HV NEUTRAL BUSHING 36 KV
5	BUCHHOLZ RELAY
6	RADIATOR WITH FAN AT BOTTOM
7	360Ø BIDIRECTIONAL FLANGED TWIN ROLLER
8	MAIN CONSERVATOR WITH AIRCELL
9	MARSHALLING BOX WITH INSTRUMENTS & TEMPERATURE INDICATORS
10	OCTC OPERATING HANDLE
11	LIFTING BOLLARDS
12	PRESSURE RELEASE DEVICE WITH SPLASH GUARD
13	LADDER
14	BREATHER
15	INTERNAL EARTHING TRMINAL
16	PROVISION FOR FIRE PROTECTION SYSTEM
17	FILTER VALVE
18	DRAIN VALVE
19	PROVISION OF RAILING FOR SAFETY
20	DGA WITH VALVE

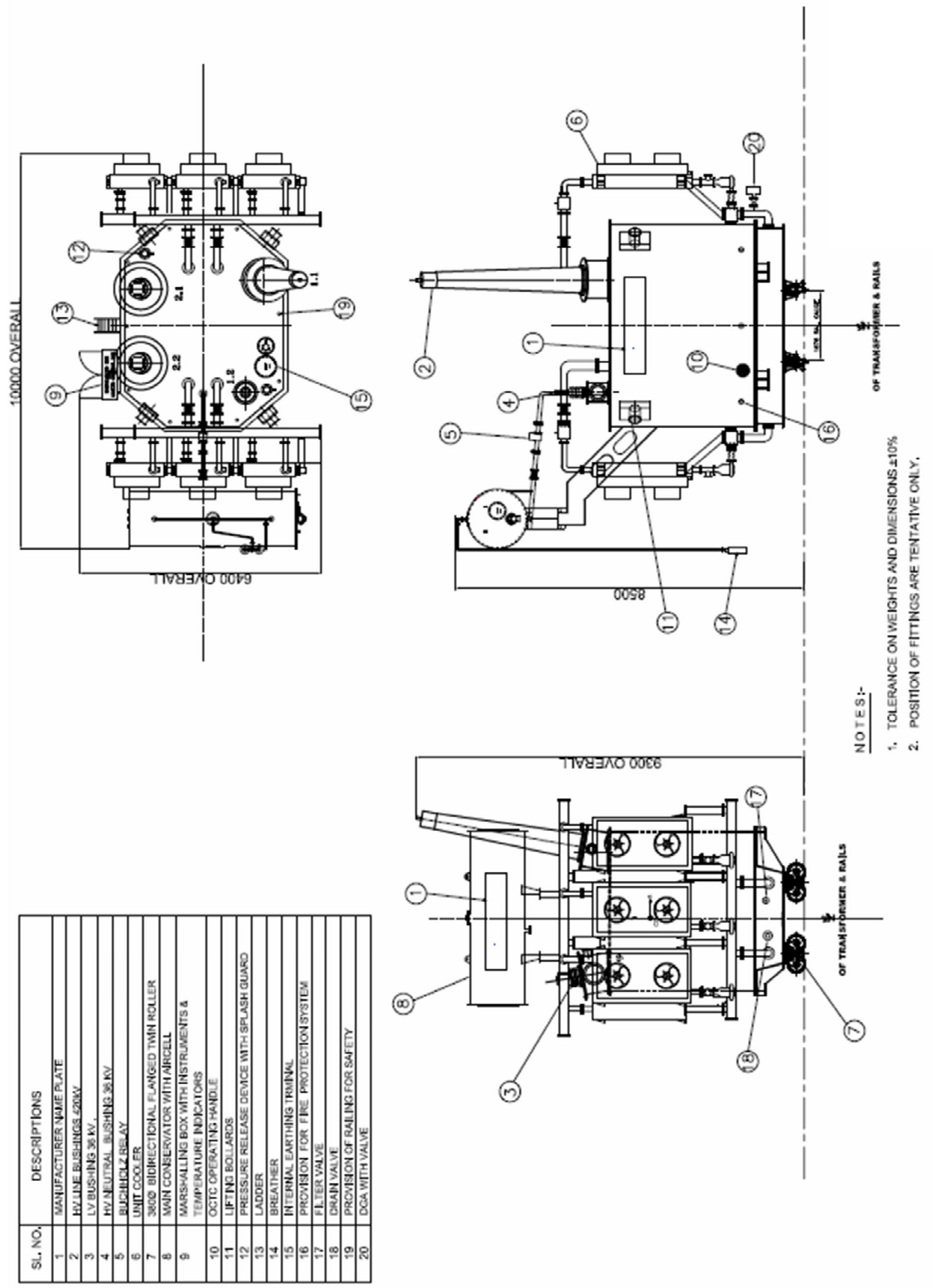
NOTES :-

1. PROVISION FOR COOLER BANK ON OTHER SIDE IS IS SHOWN IN DASHED LINE
2. TOLERANCE ON WEIGHTS AND DIMENSIONS ±10%
3. POSITION OF FITTINGS ARE TENTATIVE ONLY.

Foundation Plan of 200 MVA, 21/420/√3 kV Single Phase Generator Transformer



General Arrangement of 200 MVA, 21/420/√3 kV Single Phase Generator Transformer (With Unit Cooler)

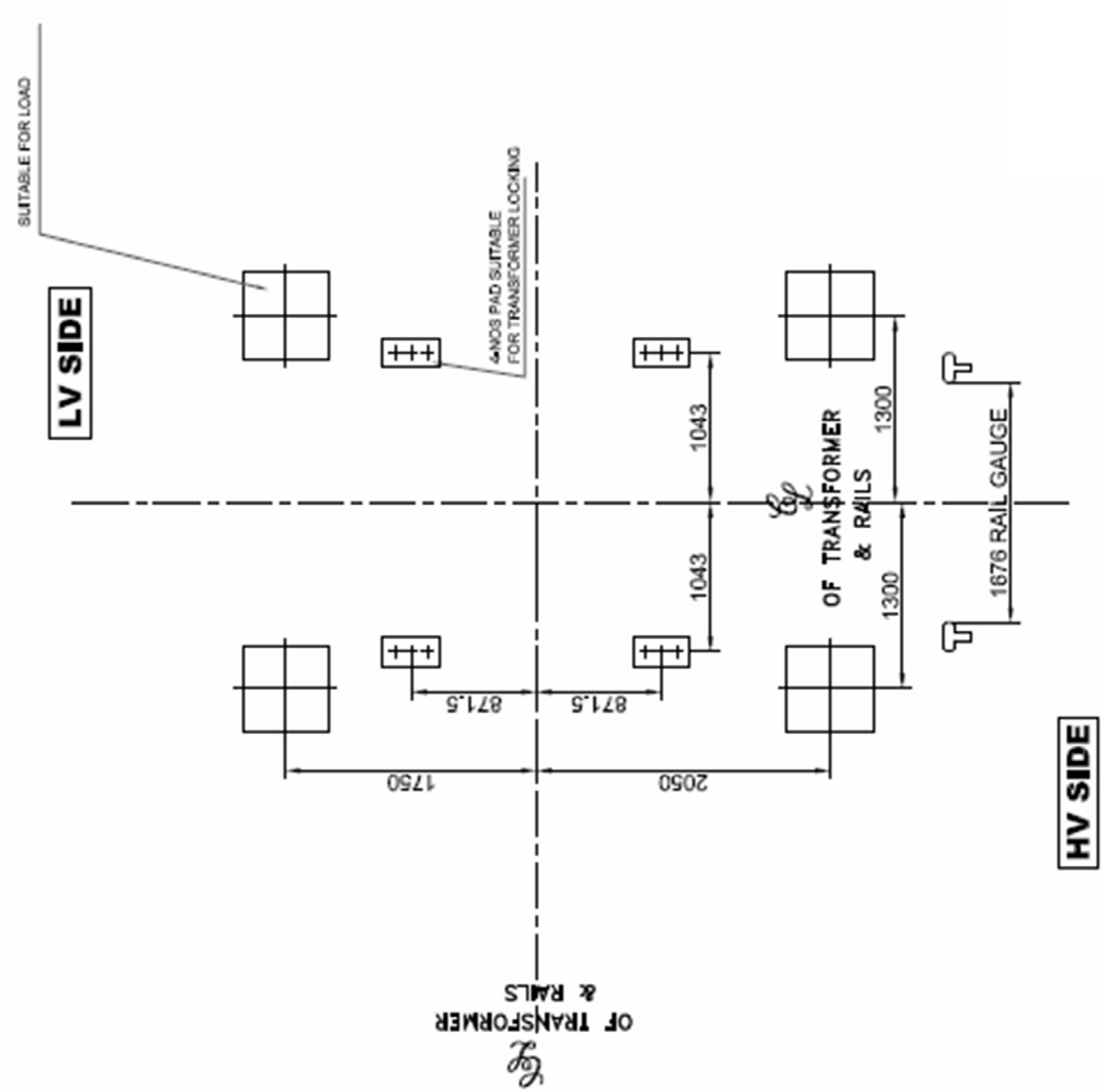


SL. NO.	DESCRIPTIONS
1	MANUFACTURER NAME PLATE
2	HV LINE BUSHINGS 420kV
3	LV BUSHING 36 kV
4	HV NEUTRAL BUSHING 36 kV
5	BUCHHOLZ RELAY
6	UNIT COOLER
7	360Ø BIDIRECTIONAL FLANGED TWIN ROLLER
8	MAIN CONSERVATOR WITH AIRCELL
9	MARSHALLING BOX WITH INSTRUMENTS & TEMPERATURE INDICATORS
10	OCTC OPERATING HANDLE
11	LIFTING BOLLARDS
12	PRESSURE RELEASE DEVICE WITH SPLASH GUARD
13	LADDER
14	BREATHER
15	INTERNAL EARTHING TERMINAL
16	PROVISION FOR FIRE PROTECTION SYSTEM
17	FILTER VALVE
18	DRAIN VALVE
19	PROVISION OF RAILING FOR SAFETY
20	DGA WITH VALVE

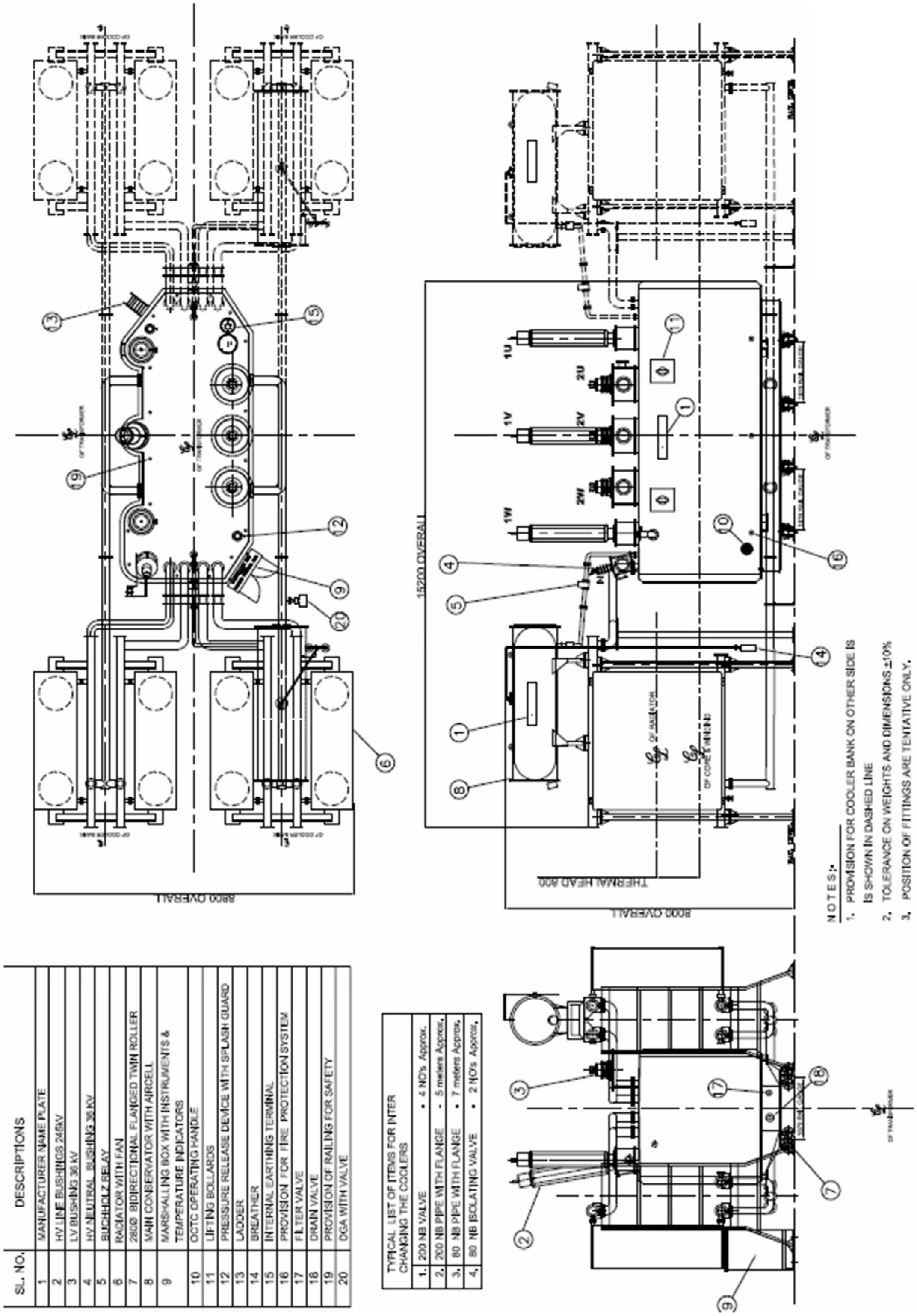
NOTES:-

1. TOLERANCE ON WEIGHTS AND DIMENSIONS ±10%
2. POSITION OF FITTINGS ARE TENTATIVE ONLY.

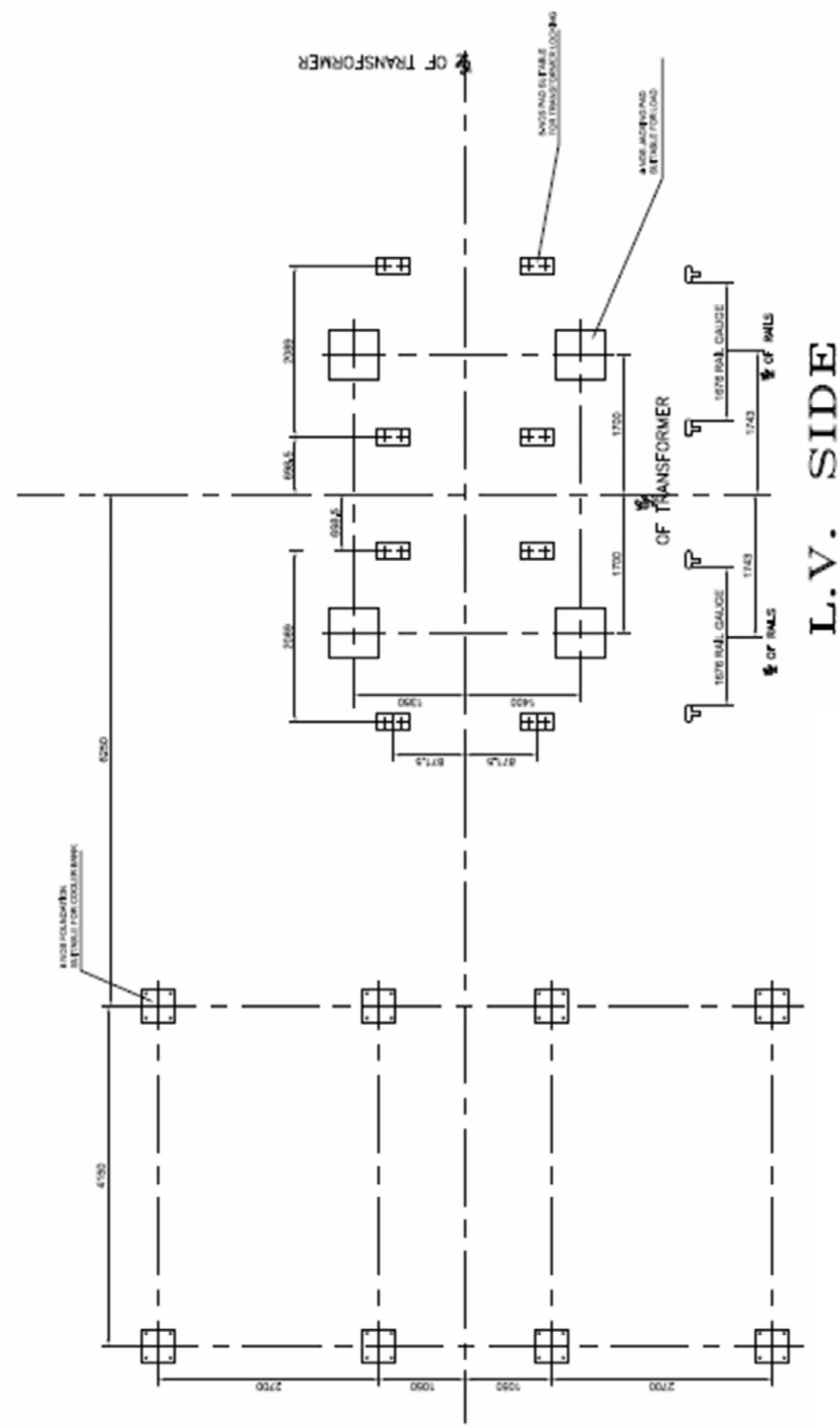
Foundation Plan of 200 MVA, 21/420/√3 kV Single Phase Generator Transformer (With Unit Cooler)



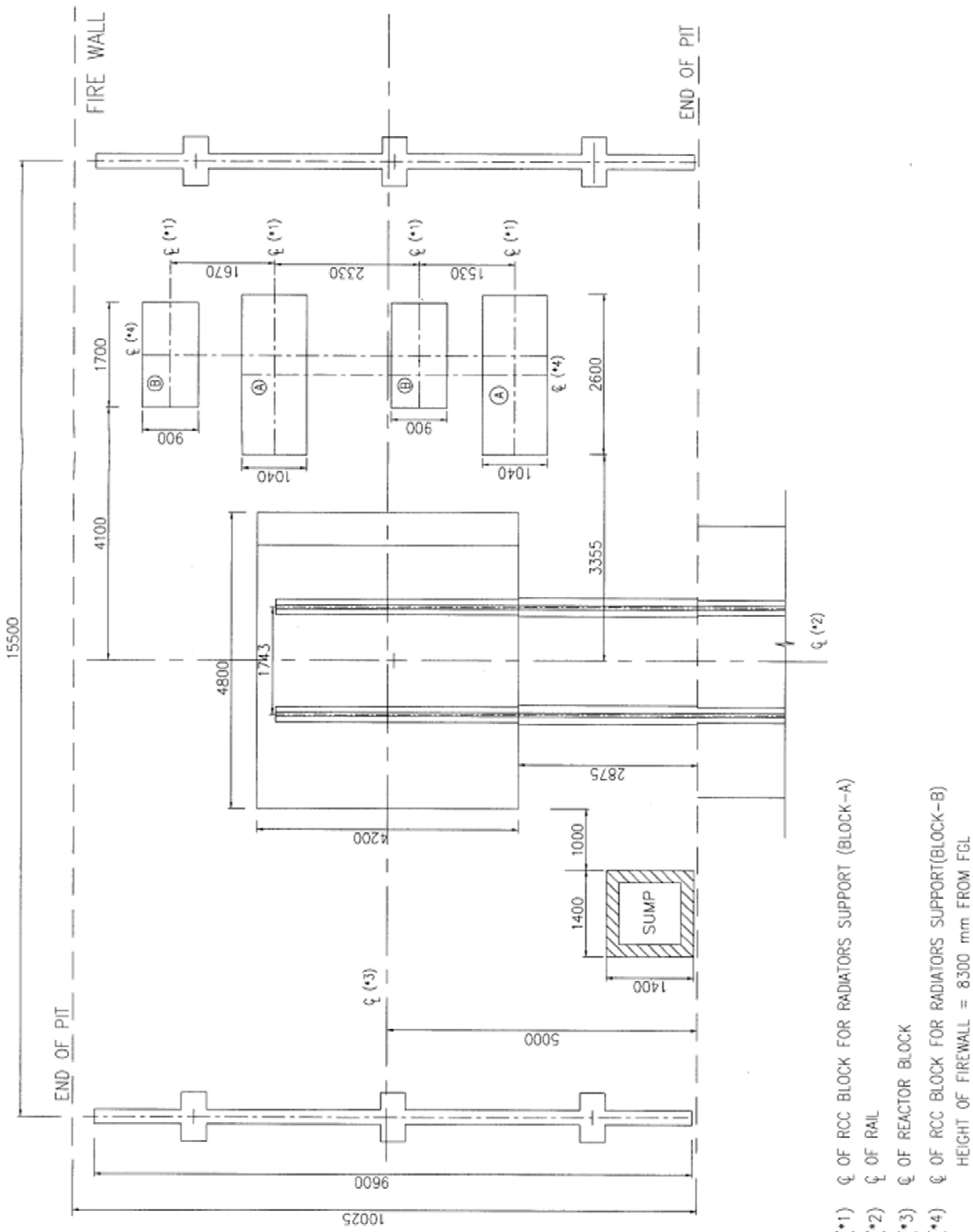
General Arrangement of 315 MVA, 220 kV Three Phase Generator Transformer



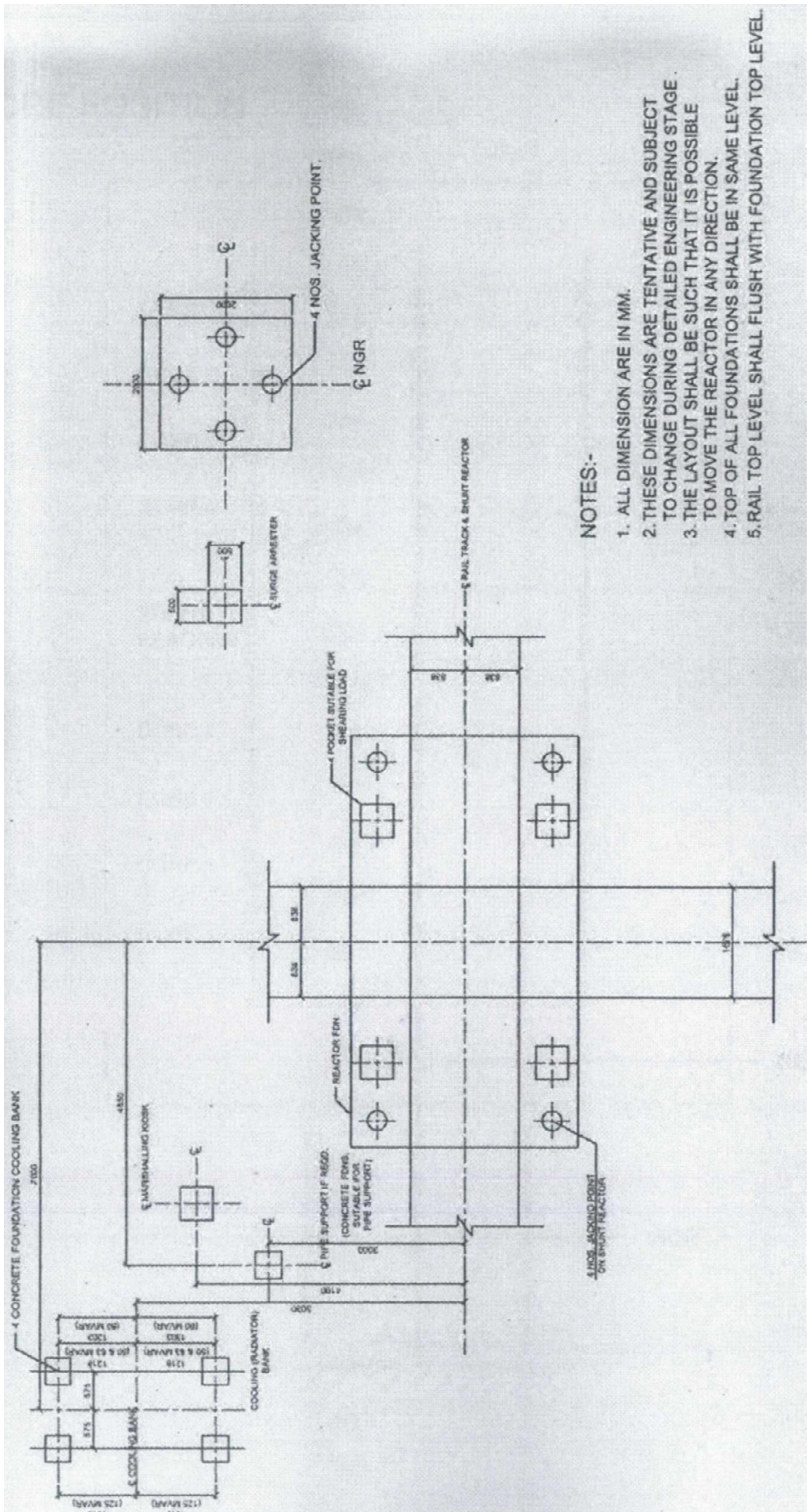
Foundation Plan of 315 MVA, 220 kV Three Phase Generator Transformer



Foundation Plan of Single Phase 765/√3 kV Shunt Reactor

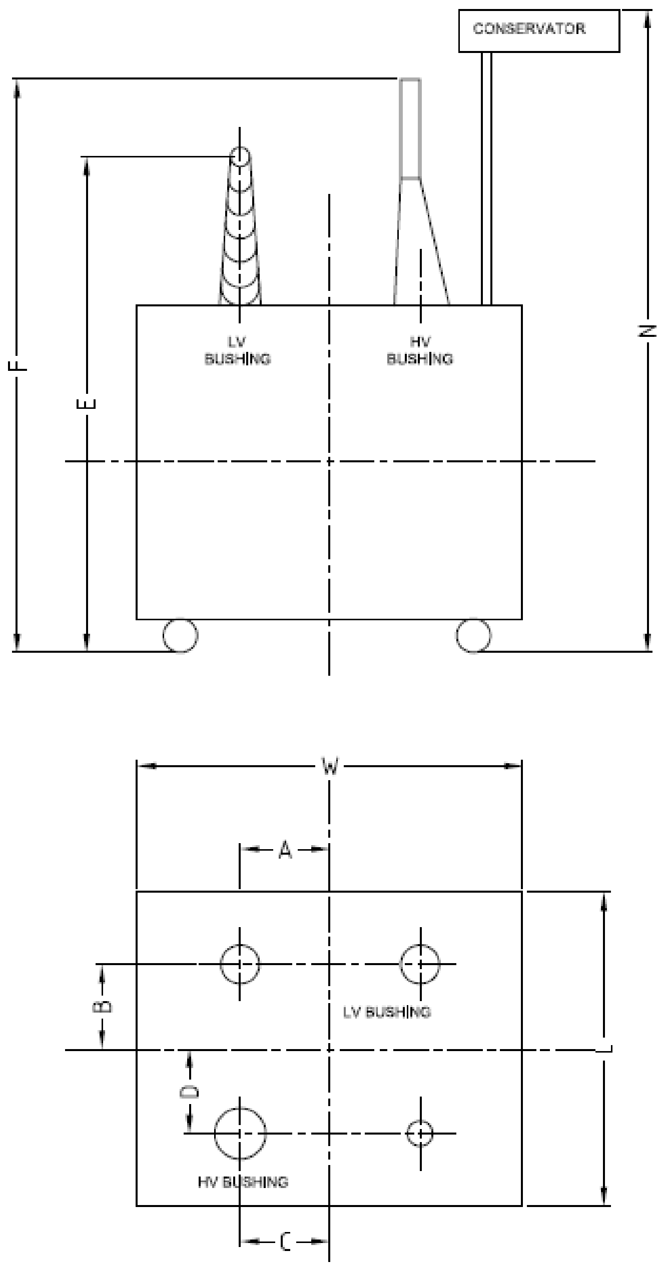


Foundation Plan of Three Phase 420 kV Shunt Reactor



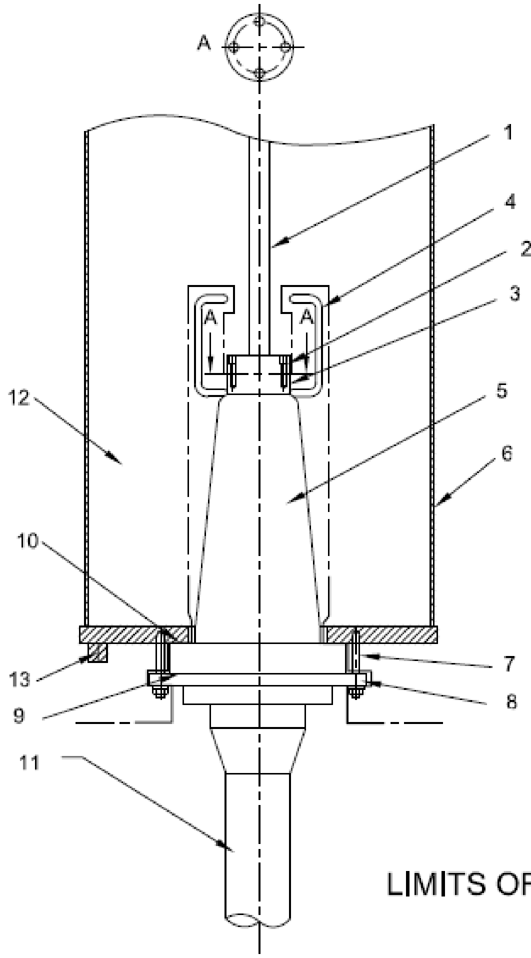
Annexure –Q

STANDARD GA DRAWINGS 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

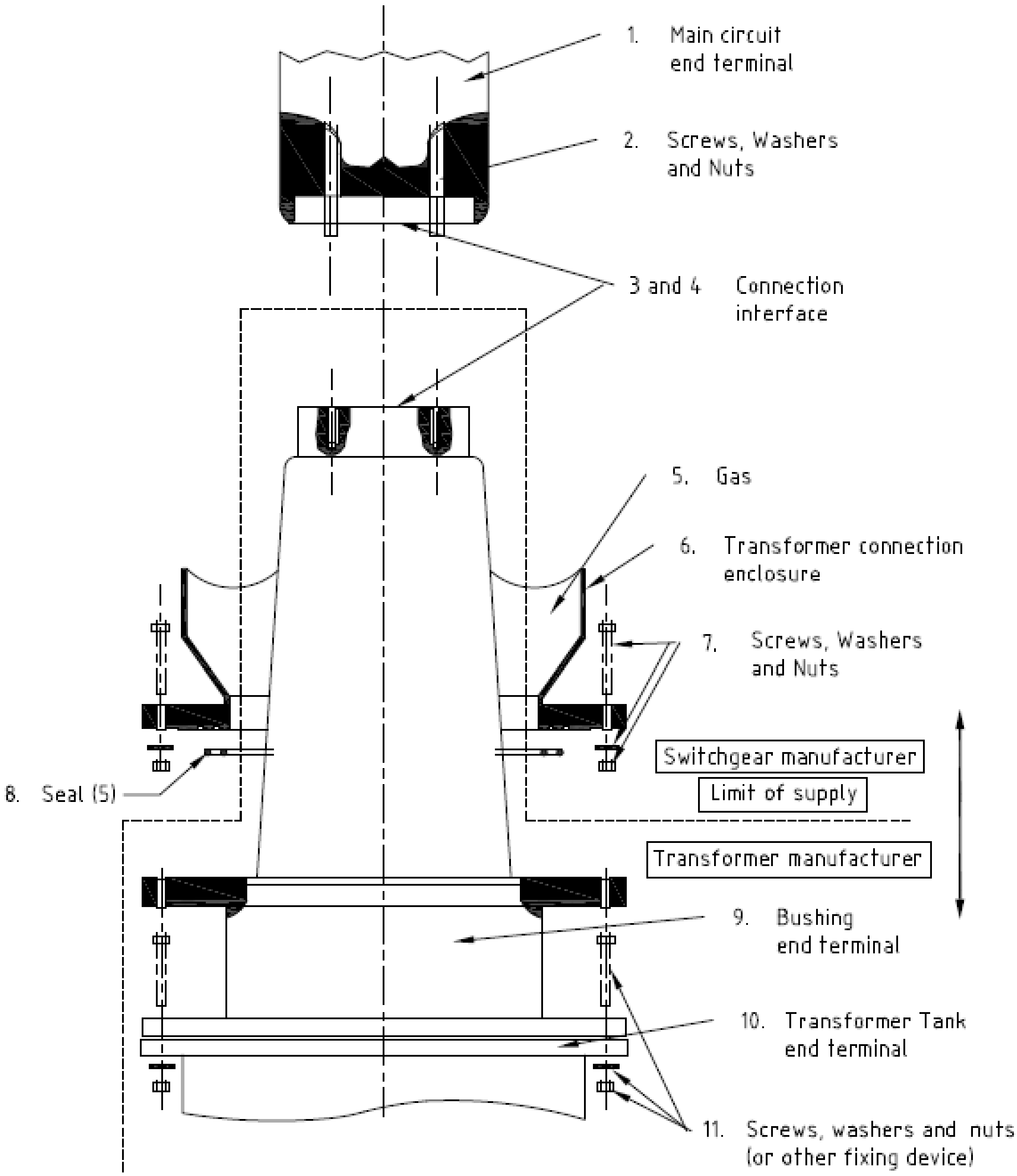


Description	Item	Supplier	
		Trans-former	Dry-type cable termination
Conductor current terminal with removable link	1	X	
connection interface including fixing elements	2	X	
connection interface	3		X
Shielding electrode [a]	4		X
Socket	5		X
Cable connection box	6	X	
Bolts, washers, nuts	7	X	
Clamping flange [b]	8		X
Intermediate gasket [b]	9		X
O-ring seal	10	X	
Cable gland	11		X
Insulating liquid	12	X	
Earthing terminal	13	X	

a divided or removable because of mountin.

b If needed.

LIMITS OF SUPPLY BETWEEN TRANSFORMER AND DRY-TYPE CABLE TERMINATION



Typical direct connection between power Transformer and gas-insulated metal-enclosed switchgear

SOURCE – IEC 62271-211

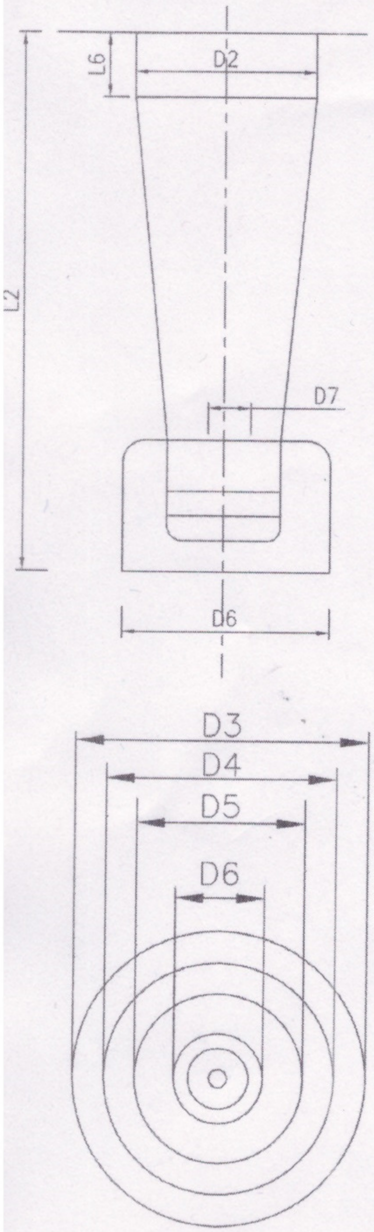
Limits of Supply
(Refer typical connection between Power Transformer and Gas Insulated Switchgear)

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

STANDARD DIMENSION FOR CONDENSER BUSHINGS (LOWER PORTION)

A. For 400 kV and below voltage class transformer/reactor



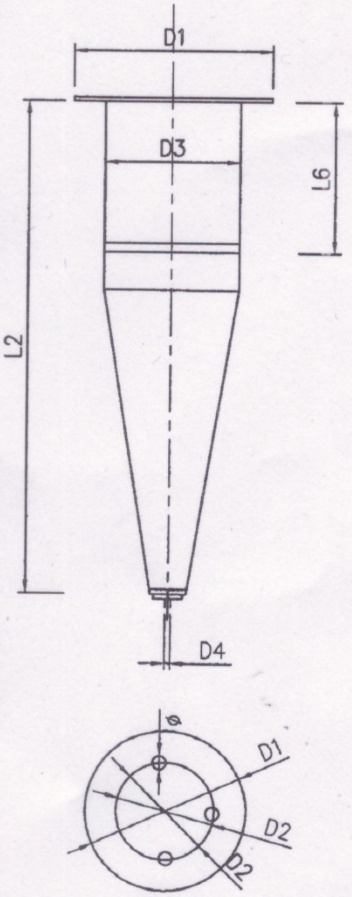
<table>
<tr><td>VOLTAGE RATING KV</td><td colspan="2">420</td><td colspan="2">245</td><td>145</td><td>72.5</td><td>52</td></tr>
<tr><td>BIL (kVp)</td><td colspan="2">1425</td><td colspan="2">1050</td><td>650</td><td>325</td><td>250</td></tr>
<tr><td>CREEPAGE (MM) (Min.)</td><td colspan="2">10500</td><td colspan="2">6125</td><td>3625</td><td>1810</td><td>1300</td></tr>
<tr><td>CURRENT RATING (A) (Min.)</td><td>800</td><td>1250</td><td>1250</td><td>2000</td><td>800</td><td>800</td><td>3150</td></tr>
<tr><td>L2±5
(FOR DIFF. VALUES OF L6)</td><td colspan="2">1640</td><td>1130</td><td>1230</td><td>600#/800</td><td>695</td><td>475</td></tr>
<tr><td>L6 (MIN.)</td><td colspan="2">400</td><td colspan="2">300</td><td>100#/300</td><td>300</td><td>100</td></tr>
<tr><td>D2 (Max.)</td><td colspan="2">350</td><td colspan="2">270</td><td>165</td><td>115</td><td>165</td></tr>
<tr><td>D3±2</td><td colspan="2">720</td><td colspan="2">450</td><td>335</td><td>225</td><td>335</td></tr>
<tr><td>D4±1</td><td colspan="2">660</td><td colspan="2">400</td><td>290</td><td>185</td><td>290</td></tr>
<tr><td>D5xN</td><td colspan="2">24x12</td><td colspan="2">20x12</td><td>15x12</td><td>15x6</td><td>15x12</td></tr>
<tr><td>D6 (MAX)</td><td colspan="2">350</td><td colspan="2">270</td><td>165</td><td>115</td><td>115</td></tr>
<tr><td>D7 (Min)</td><td colspan="2">60</td><td>48</td><td>–</td><td>38</td><td>—</td><td>—</td></tr>
</table>

NOTE:

1. ALL DIMENSIONS ARE IN MM
2. NO POSITIVE TOL. WHERE MAX. DIMENSION SPECIFIED AND NO NEG. TOL. WHERE MIN. DIMENSION IS SPECIFIED

APPLICABLE FOR SHUNT REACTOR

B. For 765 kV transformer/reactor



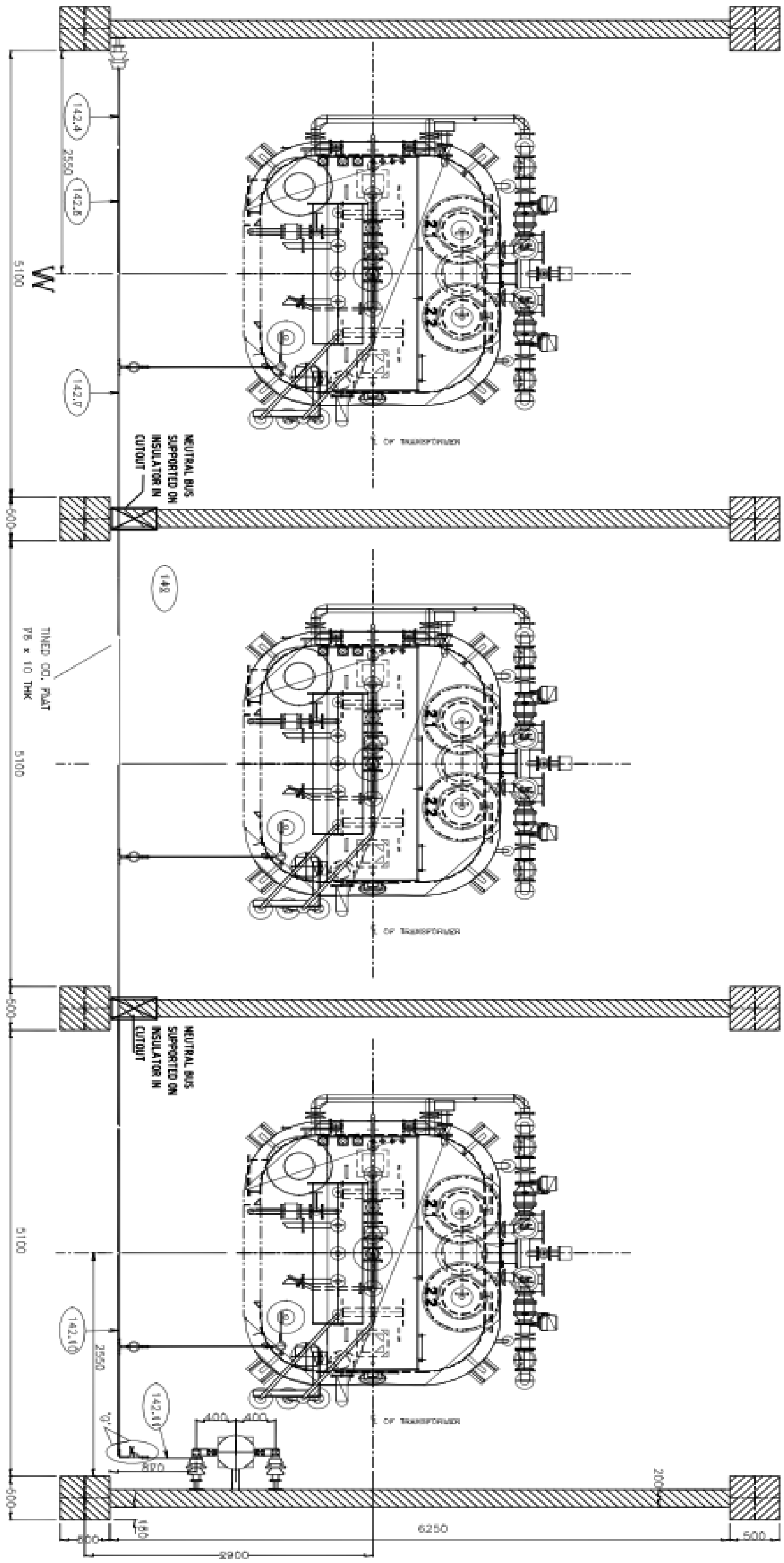
VOLTAGE RATING KV	800	420	145	52
TYPE	OIP	OIP	RIP	RIP
BIL (kVp)	2550	1425	650	250
CREEPAGE(MM)(MIN.)	20000	10500	3625	1300
CURRENT RATING(A)(Min.)	2500	2500	1250	3150
L2±5 (FOR DIFF.VALUES OF ℓ)	1955	1335	1100	685
L6 (MIN.)	600	600	500	300
(D1+2)	780	480	400	350
(D2+1)	711	430	350	300
D3 (Max.)	528	330	220	224
(Ø X N)	32x12	20x8	24x6	20x6
D4 (Min.)	48	48	34	48
TAN DELTA(Max.) (AT AMBIENT TEMPERATURE)	0.004	0.004	0.004	0.004

NOTE:

1. ALL DIMENSIONS ARE IN MM
2. NO POSITIVE TOL. WHERE MAX. DIMN.SPECIFIED NO NEG. TOL. WHERE MIN.DIM.. SPECIFIED
3. APPLICABLE FOR 765kV CLASS TRANSFORMER/REACTOR ONLY

Annexure-S

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-T

TECHNICAL SPECIFICATION OF OIL BDV TEST SET (if applicable)

Item	**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	Inbuilt/External
Measurement Programmes	Fully Automatic Pre-programmed/User programmed Test Sequences including 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 S/S. Additionally, all the required accessories, tools, drawing, documents should be provided for the smooth functioning of kit. Further hard carrying case (which should be robust/ rugged enough) for ensuring proper safety of the kit during transportation shall have to be provided.
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 ±10 %, f: 50 Hz ±5 % on standard sockets.
Operating Temperature	0 to +50 deg C
Relative humidity	Max. 90% non-condensing.
Protection/ Control	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.

Guarantee	Warranty/Guarantee Period: Min 05 year from the date of successful & complete commissioning at the purchaser's sub-station. All the materials, including accessories, cables, laptops etc. are to be covered under warranty/guaranty period. If the kit needs to be shifted to supplier's works for repairs within warranty/guaranty period, suppliers will have to bear the cost of spares, software, transportation of kit for repair at test lab / works.
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 made 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 services.

Technical Specification of Portable Dissolved Gas Analysis of Oil (if applicable)

S.No.	Particulars	Specification
01	Functional Requirement	The Portable DGA equipment to extract, detect, analyze and display the dissolved gases in insulating oil as specified in IEEE C 57-104-2008 and IEC 60599-2007.
02	Detection of Gases	All the fault gases i.e. H2, CH4, C2H2, C2H4, C2H6, CO & CO2 concentrations shall be individually measured and displayed. The minimum detection limits of the instrument for the above gases shall strictly be met the requirement of IEC-60567-2011-Page No. 47-clause 9.2, table-5.
03	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.
05	Instrument control and	a) Instrument shall be having in-built control for all the functions (data acquisitions and data storage), it shall

	Data handling, Internal Memory	have a facility for communication with computer for downloading the data from instrument via USB port. b) Laptop shall be provided for communication with the instrument. it shall be of latest specification along with licensed preloaded OS and software as well as software for interpreting DGA results accordance with IEEE C 57-104-1991 and IEC 60559-1999. Laptop carrying case shall also be provided. c) Internal Memory can capable of store at least 15000 records
06	General Conditions	a) Performance Parameters like - Minimum Detection Limits, Working Range, Accuracy, repeatability etc. shall be finalized during detailed engineering. b) The portable DGA equipment supplier shall demonstrate during commissioning of the kit that the results shown by the kit are within the specified accuracy and repeatability range and EMPLOYER 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 that are essential to understand and operate the instrument shall be supplied at no extra cost.
07	Operating Temperature, Relative humidity & Dimensions	01. Temperature 0-50 Deg. C 02. 85% non-condensing 03. Portable
08	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 needs to be shifted to suppliers works for repairs, supplier will have to bear the

		cost of, spares, software, transportation etc. of kit for repair at test lab/works.
09	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.
10	Training	The supplier shall provide adequate training for a period of two working days pertaining to the operation and troubleshooting to site personnel.

Annexure-U

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 rating 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 LPM).

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 automation system.

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

Annexure-V

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. 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.

5. The scope of oil sampling bottles shall be included in the bid price as per the quantity indicated in the bid price schedule.

OIL SYRINGE

1. If specified by the utility, the glass syringe of capacity 50ml (approx) and three way stop cock valve shall be supplied. The syringe shall be made from Heat resistant borosilicate Glass. 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

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. 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. 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 form the tank.

5. The following accessories shall also form part of supply along with each Oil storage tank.

5.1 Four numbers of 50NB suitable rubber hoses for Transformer oil application up to temperature of 100°C, full vacuum and pressure up to 2.5 Kg/ cm2 with couplers and unions each not less than 10 metre long shall be provided.

5.2 Two numbers of 100NB suitable for full vacuum without collapsing and kinking vacuum hoses with couplers and unions each not less than 10 metre long shall also be provided.

5.3 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.

5.4 The painting of oil storage tank and its control panel shall be as per technical specification.

5.5 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.