BHARAT HEAVY ELECTRICALS LIMITED
TRANSMISSION BUSINESS ENGINEERING MANAGEMENT
NEW DELHI

DOCUMENT NO.:	TB-393-316-001	REV: 00	Prepared	Checked	Approved
TYPE OF DOC.:	TECHNICAL SPECIFICATION	NAME:	DKS	SKS	RS
TITLE: 500MVA, 400/220/33kV Auto Transformer		SIGN:			
		DATE:	15/02/17	16/02/17	16/02/2017
		GROUP:	TBEM		

CUSTOMER:	Power Grid Corporation of India (POWERGRID)
PROJECT:	Substation Package for Extension of 400kV Tumkur Pooling station (Pavagada) (including transformer & Reactor), Extension of 400/220kV Mysore Substation and Extension of 400/220kV Tumkur (Vasantnarsapur) (Including Transformer) under Transmission System for Ultra Megar Solar Power Park (2000MW) at Tumkur (Pavagada), Karnataka-Phase-II (Part-A)
NOA REF.:	CC-CS/702-SR2/SS-3340/7/G7/NOA-I/7102 Dt. 16.12.2016 (Supply) & CC-CS/702-SR2/SS-3340/7/G7/NOA-II/7103 Dt. 16.12.2016 (Service)

CONTENTS

*Guaranteed Technical Particulars- Not to be submitted with technical bid, however same shall be reviewed and approved during detailed engineering.

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SECTION-1
SCOPE, SPECIFIC TECHNICAL REQUIREMENTS & BILL OF QUANTITIES

1.1 SCOPE

This specification covers design, type testing, engineering, manufacture, testing at factory, delivery at site including all materials, accessories, spares, supervision of unloading, handling, proper storage, erection, testing, and commissioning of 500MVA, 400/220/33kV Auto Transformer.

The scope shall encompass and include all the activities listed above.

This section covers the specific technical requirements, scope and quantities. The specific technical requirements for the above item as specified by the POWERGRID are given in Section-2A & 2B. The offered equipment shall also comply with the general technical requirements for the project as detailed under section-3 of this specification.

500MVA, 400/220/33kV Auto Transformer is required for the following project:

Name of the Customer: **Power Grid Corporation of India (POWERGRID)**

Name of the Project: **400/220kV Tumkur (Pavagada), 400kV Mysore & 400/220kV Tumkur (Vasantnarsapur) Substation Package**

This specification comprises of following sections:
Section-1: Scope, Specific Technical Requirements & Bill of Quantities
Section-2A: Applicable Standards & References
Section-2B: Equipment Specification under Scope of Supplies-Technical Specification **(section–Transformer up to 400kV Class Rev10)**
Section-3: Project Details & General Technical Requirements
Section-4: Guaranteed Technical Particulars
Section-5: Technical Checklist
Section-6: Schedule of Technical Deviations

In case of any conflict between various sections, order of precedence shall be in the same order as listed above.

The scope of supplies shall be as per commercial terms and conditions enclosed separately with the enquiry.

1.2 SPECIFIC TECHNICAL REQUIREMENTS

1.2.1 Specific Technical Requirements for Auto Transformer

For 500MVA, 400/220/33 kV Auto Transformer				
A.	Voltage ratio (kV)	400/220/33		
B.	Rated frequency (Hz)	50		
C.	Max. Design Ambient Temp. (°C)			
D.	Windings	HV	IV	LV
	(i) System Fault level (KA)	63	40	25
	(ii) 1.2/50 micro sec. impulse withstand voltage (kVp)	1300	950	250
	(iii) 20/200/500 micro second switching surge withstand voltage (kVp)	1050	--	--
	(iv) One minute power frequency voltage kV (rms)	--	--	95
	(v) Winding connection	Star	Star	Delta
	(vi) Neutral	Solidly grounded		
	(vii) Insulation	Solidly grounded		
	(viii) Vector Group	YN a0 d11		

Notes:

1. For parallel operation with existing transformer, the impedance, OLTC connection & range 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.
3. Tan delta of Winding & Bushing shall be measured at ambient temperature. No temperature correction factor shall be applied.
4. The criteria for Transformer losses shall be **"Copper Loss (Load Loss) > Iron Loss (No Load Loss) > Cooler Loss (Auxiliary Loss)".**

1.2.2 Maximum Permissible Losses for Auto Transformer

Transformer Rating	Max. No Load Loss/ Iron Loss at rated voltage and frequency (kW)	Max. Load Loss/ Copper Loss at rated current and at 75°C (kW)	Max. Auxiliary Loss/ Cooler Loss at rated voltage and frequency (kW)
500MVA, 400/220/33kV, 3-Ph Auto Transformer	90	500	15

Note:

Bidder is required to offer the Transformer with above specified losses.

1.2.2.1 Guaranteed Losses and Liquidated Damage due to higher loss: The maximum loss at rated condition (voltage, current and frequency, as applicable) for Auto Transformer shall be corrected in accordance with IEC-60076 for the purpose of comparison of maximum losses with measured losses for levy of liquidated damages. If during factory tests, measured loss (es) are found to be more than the specified maximum value(s) (specified in clause 1.2.2 above), BHEL/POWERGRID at his discretion may accept or reject Auto Transformer after assessing the liquidated damages (LD) against the contract as per rates given in clause 1.2.2.3 below and such amount shall be deducted from the contract price or otherwise recovered from Bidder. No cost benefit shall be considered in case measured losses are less than the specified maximum losses.

1.2.2.2 Criterion for calculating Liquidated damage:

Differential losses = Losses measured at the time of testing - corresponding losses (specified in clause 1.2.2 above) (corrected in accordance with IEC-60076)

1.2.2.4 Liquidated Damage due to differential losses on pro-rata basis:
If measured losses are exceeding maximum specified guaranteed losses (specified in clause 1.2.2 above), value by 0 to +5%, the details for liquidated damages on pro-rata basis for the performance of Auto Transformer shall be as follows,

Sl. No.	Equipment Category	Parameter	Value of Liquidated Damages in Indian Rupees per unit of parameter differential with respect to maximum losses
1.	500 MVA, 400/220/33 kV, 3-ph Auto Transformer	Differential Load Loss/ Copper loss (kW)	INR 167,715/- (Indian Rupees One Hundred Sixty Seven Thousand Seven Hundred and Fifteen only) per KW.
		Differential No Load Loss/ Iron loss (kW)	INR 369,960/- (Indian Rupees Three Hundred Sixty Nine Thousand Nine Hundred and Sixty only)
		Auxiliary Loss/ Cooler Loss (kW)	INR 246,640/- (Indian Rupees Two Hundred Forty Six Thousand Six Hundred and Forty only) per KW.

Liquidated damages shall be applied in the following manner depending on the variation of losses with respect to the maximum values:

a) Measured losses exceeding Maximum value by 0 to +5%: Rates of LD mentioned above
b) Measured losses exceeding Maximum value by > +5% to +10%: Twice the rates of LD mentioned above
c) Measured losses exceeding Maximum value by > +10% to +15%: Four times the rates of LD mentioned above

However, the equipment under no circumstances shall be accepted if the measured losses in each category exceed by more than +15 percent of the Maximum losses (as specified in clause 1.2.2 above) at rated conditions.

Please refer **Section-2A & 2B** for detailed specific Technical requirements and Parameters.

1.3 GENERAL TECHNICAL REQUIREMENTS

1.3.1 Paint System and Procedure

Bidder to follow paint system and procure as per **Clause 7.0** and **Annexure-F of Section-2B.**

1.3.2 Grounding/ Earthing work

Supply of grounding/ earthing material (except 40mm Dia MS rod and/or GI Flat) and supervision of erection/fixing of grounding/ earthing of Auto Transformer and its accessories shall be under

bidder's scope, based on their design philosophy.

1.3.3 Cabling work

Cabling from Marshalling Box to Auto Transformer and its Cooling Bank is under scope of supply including glands, lugs, tags and ferruling etc. Termination schedule shall be submitted along with drawings.

1.3.4 Auxiliary Supply

Terminals in marshalling box for external power supply coming into marshalling box shall be suitable to requirement.

1.4 BILL OF QUANTITIES

Sr. No.	Description of Item	Unit	Quantity	
			Pavagada	Vasantnar sapur)
A	**Main Supply Items for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer**			
1	500 MVA, 400/220/33kV, 3-Ph Auto Transformer excluding insulating oil	No	2	1
2	Insulating Oil for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer (including 10% extra oil as per note1 for each Auto Transformer)	Set	2	1
3	On line dissolved gas (multi gas) & moisture analyser) (As per technical specification)	No	2	1
4	On line insulating oil drying system (cartridge type) (As per technical specification)	No	2	1
5	Digital RTCC panel consist of digital RTCC relays as per technical specification	Set	--	1
~~6~~	~~Recommended spare parts and maintenance equipment necessary for three (3) years of successful operation of Auto Transformer~~	~~Set~~	~~2~~	~~1~~
B	**Mandatory Spares Items for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer**			
1	Oil cooler pump with motor for 400kV Transformer	Set	1	1
2	Buchholz relay (Main Tank) complete with float and contacts for Transformer	Set	1	1
3	Local winding temperature indicator (WTI) with contact	No	1	1
4	Remote winding temperature indicator (WTI) with sensing device and matching unit	No	1	1
5	Magnetic oil level gauge	No	1	1
6	Cooler fan with motor for 400kV Transformer	No	1	1
7	Remote tap position indicator for 400kV Transformer	No	1	1
8	Oil flow indicator for 400kV Transformer	Set	1	1
9	245kV, 2000A RIP Bushing with metal parts and gaskets	No	1	1
10	52kV, 3150A Bushing with metal parts and gaskets	No	1	1
11	Spares insulating oil to be handed over to POWERGRID after commissioning	KL	10	10

Remark: (A.5) Digital RTCC panel consist of 3 number digital RTCC relays as per technical specification

12	36kV, 2000A Bushing with metal parts and gaskets for Transformer	No	1	1
13	Starters, contactors, switches & relays for electrical control panels of 400kV Transformer (one set of each type)	Set	1	1
14	420kV, 1250A RIP Bushing with metal parts and gaskets	No	1	1
C	**Service Items for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer**			
1	Supervision of unloading for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer at site	No	2	1
2	Supervision of erection for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer at site	No	2	1
3	Supervision of testing for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer at site	No	2	1
4	Supervision of commissioning for 500 MVA, 400/220/33kV, 3-Ph Auto Transformer at site	No	2	1
5	Submission of final documentation after handing over to BHEL/POWERGRID	No	2	1

Note:

1. Ten percent (10%) extra oil shall also be supplied for topping up, in non-returnable containers suitable for outdoor storage. The cost of the same should be included in the quoted price and no price implication will be accepted at later stage.

1.5 TECHNICAL QUALIFYING REQUIREMENT

Bidder should have successfully carried out **Dynamic Short Circuit test on 315MVA, 400/220/33kV Auto Transformer** as on the originally scheduled date of bid opening **i.e. 08.08.2016** and shall enclose the relevant Test Report/ Certificate along with bid. In case bidder has not successfully tested 315MVA, 400/220/33kV Auto Transformer for Dynamic Short Circuit test, their bid shall not be considered. Further, design review of offered 400 kV Class Auto transformer shall be carried out based on the design of short circuit tested 315MVA Auto transformer.

1.6 TYPE TESTING

The reports for all type tests as per technical specification shall be furnished by the Bidder along with equipment / material drawings.

The validity of Type Tests **(except dynamic short circuit test)** of Transformer shall be **5 years** as on the originally scheduled date of bid opening **i.e. 08.08.2016**, provided that offered transformer design is identical to the type tested transformer and same active materials (CRGO, Conductor and Insulation) of same grade & from the same sub-vendors are used. In case of any change of either active materials or sub-vendors, the type tests shall be carried out by the Bidder at no extra cost to BHEL. Transformer type test report from the same manufacturing plant shall only be acceptable. With regards to validity of dynamic short circuit test once conducted shall be applicable.

Bidder should have successfully carried out **Dynamic Short Circuit test on 315MVA, 400/220/33kV Auto Transformer** as on the originally scheduled date of bid opening **i.e. 08.08.2016** and shall enclose the relevant Test Report/ Certificate along with bid. In case bidder has not successfully tested 315MVA, 400/220/33kV Auto Transformer for Dynamic Short Circuit test, their bid shall be considered technically non responsive. Further, design review of offered 400 kV Class Auto Transformer shall be carried out based on the design of short circuit tested

315MVA Auto Transformer.

Type Tests on Transformer fittings: The test reports submitted, shall be of the tests conducted within last **10 (ten) years** prior to the originally scheduled date of bid opening **i.e. 08.08.2016.** In case the test reports are of the test conducted earlier than 10 (ten) years prior to the originally scheduled date of bid opening **i.e. 08.08.2016.**, the Bidder shall repeat these test(s) at no extra cost to the BHEL/POWERGRID. The type tests conducted earlier should have either been conducted in accredited laboratory **(accredited based on ISO / IEC Guide 25 / 17025 or EN 45001 by the national accreditation body of the country where laboratory is located)** or witnessed by BHEL/POWERGRID or representative authorized by POWERGRID or Utility or representative of accredited test lab or reputed consultant. Further, in the event of any discrepancy in the test reports i.e. any test report not acceptable due to any design/manufacturing changes (including substitution of components) or due to non-compliance with the requirement stipulated in the Technical Specification or any/all type tests not carried out, same shall be carried out without any additional cost implication to the BHEL/POWERGRID.

The BIDDER shall intimate the BHEL/POWERGRID the detailed program about the tests at least two (2) weeks in advance in case of domestic supplies & six (6) weeks in advance in case of foreign supplies. Further, in case type tests are required to be conducted / repeated and the deputation of Inspector/Purchaser's representative is required, then all the expenses shall be borne by the Bidder.

In addition to this, Bidder shall submit valid type test reports (as per relevant IEC/IS Standard) for approval in line with clause **5.2 & 3.13.1 of section-2B** and **clause 9.0 of Section-3.** In case type test reports are found to be technically unacceptable to BHEL/POWERGRID, the type test shall be conducted without cost and delivery implication to BHEL/POWERGRID.

1.7 INSPECTION AND TESTING AT WORKS

The Bidder shall carry out a comprehensive inspection and testing programme during manufacture of the equipment as detailed in **section-2B** and **section3**.

1.8 QUALITY PLAN

The Bidder to follow valid and approved POWERGRD Quality Plan as per POWERGRID procedure. In case the bidder does not have POWERGRID approved Quality Plan, it will be the bidder's responsibility to get its Quality plan approved directly from POWERGRID.

1.9 ERECTION, TESTING AND COMMISISONING AT SITE

The Bidder shall supervise a comprehensive erection, testing and commissioning programme at site duly POWERGRID approved as detailed in **section-2B** and **section3.**

1.10 INFORMATION TO BE FURNISHED BY THE CONTRACTOR

Information/ documents to be furnished at the TENDER STAGE shall be as per **Section-2B** and **Section-3**.

1.11 DRAWINGS/ DATA SHEETS

Bidder shall submit POWERGRID approved/Standard drawings wherever available for extension of approval.

1.12 STANDARDS

The equipment to be furnished under this specification shall conform to latest issue with all amendments (as on the originally scheduled date of bid opening i.e.**08.08.2016**) of standard specified under **Section-2A,** unless specifically mentioned in the specification.

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SECTION-2A
APPLICATION STANDARDS AND REFERENCES

STANDARDS

a. The Indian Electricity Act 2003

b. Indian Electricity Rules

c. Indian Factories Act

d. Normative References

IEC 60076	Power transformers
IEC 60076-1	Part 1: General
IEC 60076-2	Part 2: Temperature rise
IEC 60076-3	Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-4	Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors
IEC 60076-3-1	Part 3-1: Insulation Levels and Dielectric Tests –External Clearances in Air
IEC 60076-5	Part 5: Ability to withstand short circuit
IEC 60076-6	Part 6: Reactors
IEC 60076-7	Part 7: Loading guide for oil-immersed power transformers
IEC 60076-8	Part 8: Application guide
IEC 60076-10	Part 10: Determination of sound levels
IEC 60076-10-1	Part 10-1: Determination of sound levels - Application guide
IEC 60076-11	Part 11: Dry-type transformers
IEC 60076-12	Part 12: Loading guide for dry-type power transformers
IEC 60076-13	Part 13: Self-protected liquid-filled transformers
IEC 60076-14	Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials
IEC 60076-15	Part 15: Gas-filled power transformers
IEC 60076-16	Part 16: Transformers for wind turbine applications
IEC 60076-18	Part 18: Measurement of frequency response
IEC 60076-19	Part 19: Rules for the determination of uncertainties in the measurement of losses in power transformers and reactors
IEC 60076-21	Part 21: Standard requirements, terminology, and test code for step-voltage regulators
IEC 60044	Current transformers

BS 3938	
IEC 60050	International Electrotechnical Vocabulary
IEC 60050(421)	International Electrotechnical vocabulary- Chapter 421 : Power Transformers and Reactors
IEC 60060	High Voltage test techniques
IEC 60060-1	General definitions and test requirements
IEC 60060-2	Measuring systems
IEC 60071	Insulation co-ordination
IEC 60071-1	Part 1: Definitions, principles and rules
IEC 60071-2	Part 2 : Application guide
IEC 60137	Bushing for alternating voltage above 1000V
IEC 60214	On-Load Tap changers
IEC 255-21-3	Relays vibration
IEC 60270	Partial discharge measurements
IEC 60296	Specification for Unused Mineral Oil for Transformers and Switchgear
IEC 60422	Supervision and Maintenance guide for Mineral Insulating Oil in Electrical Equipment
IEC 60475	Method of Sampling Liquid dielectrics
IEC 60529	Classification of Degrees of Protection provided by Enclosures
IEC 60542	Application Guide for On-Load Tap-Changers
IEC 60567	Guide for the Sampling of Gases and of Oil from Oil-filled Electrical Equipment for the Analysis of Free and Dissolved Gases
IEC 60651	Sound Level Meters
IEC 61083	Digital Recorders and Software for High Voltage Impulse testing
IEC 61083-1	Part 1: Requirements for digital recorders in high voltage impulse tests
IEC 61083-2	Part 2: Evaluation of software used for the determination of the parameters of impulse waveforms
CISPR 16	Specification for radio disturbance and immunity measuring apparatus
CISPR 16-1	Radio disturbance and immunity measuring apparatus
CISPR-18	Radio Interference Characteristics of Power Lines and High Voltage Equipment
ISO 9001	Quality system-Model for Quality Assurance in Design /development
Cigre Publication 202	Guidelines for conducting design reviews for transformers 100 MVA and 123 kV and above. August 2002-Cigre Working

	Group 12.22
WG 12-15	Guide for Customers Specifications for Transformers 100 MVA and 123 kV and above
WG 12 19	Short Circuit Performance of Transformers.
BS-4360	Specification for weldable structural steel
BS-5135	Specification for arc welding of carbon and carbon manganese steels
BS-5500	Specification for unfired fusion welded pressure vessels
IS-3618	Specification for phosphate treatment of iron & steel for protection against corrosion
IS-6005	Code of practice for phosphating of Iron and Steel
ISO-8501	Preparation of steel surface before application of Paints and related product
IEC-60599	Mineral oil impregnated electrical equipment in service – guide to the interpretation of dissolved and free gases analysis
IS-10593	Method of evaluating the analysis of gases in oil filled electrical equipment in service
IS-2099	Bushings for alternating voltages above 1000 volts
IS-3347 Part I to 8	Dimension for porcelain transformer bushing
DIN-42530	Bushing up to 1000kV from 250A-5000A for liquid filled Transformer
IS-2026 Part 1 to 5	Power transformer
IS-4691	Degrees of protection provided by enclosure for rotating electrical machinery
IEC-60034-5	Degrees of protection provided by integral design of rotating electrical machines(IP Code) classification
IS:325 / IEC -60034	Performance of cooling fan / oil pump motor
IS-13947 part 1 to 5	Specification for low voltage switchgear and control gear
IS:3400	Methods of test for vulcanised rubber
IS:7016 part 1 to 14	Methods of test for coated and treated fabrics
IS:803	Code of practice for design, fabrication and erection of vertical mild steel cylindrical welded oil storage tanks.
IS:3637	Gas operated Relays
IS:335	New Insulating oils – Specification
IEC-62271-203	Gas insulated metal enclosed switchgear for rated voltage above 52kV
IEC-61639	Direct connection between power transformers and gas-insulated metal enclosed switchgear for rated voltages of 52.5 kV and above.
IS:3400 / BS 903 / IS:7016	Air cell (Flexible Air Separator)

IEC 60529 / IP : 55	Degree of protection for cooler control cabinet , MOLG ,Cooling fan , oil pump, Buchholz Relay
IEC 60529 / IP : 56	Degree of protection for Pressure Relief Device
IEC 60529 / IP : 43	Degree of protection for Remote tap Changer cubicle (RTCC)

IS-5,	-	Colors for Ready Mixed Paints and Enamels.
IS-335,	-	New Insulating Oils.
IS-617,	-	Aluminium and Aluminium Alloy Ingots and Castings for General Engineering Purposes
IS-1448 (P1 to P 145)	-	Methods of Test for Petroleum and its Products.
IS-2071 (P1 to P3)	-	Methods of High Voltage Testing.
IS-12063	-	Classification of degrees of protection provided by enclosures of electrical equipment.
IS-2165 P1:1997 P2:1983	-	Insulation Coordination.
IS-3043	-	Code of Practice for Earthing
IS-6103	-	Method of Test for Specific Resistance (Resistivity) of Electrical Insulating Liquids
IS-6104	-	Method of Test for Interfacial Tension of Oil against Water by the Ring Method
IS-6262	-	Method of test for Power factor & Dielectric Constant of Electrical Insulating Liquids.
IS-6792	-	Method for determination of electric strength of insulating oils.
IS-5578	-	Guide for marking of insulated conductors.
IS-11353	-	Guide for uniform system of marking & identification of conductors & apparatus terminals.
IS-8263	-	Methods for Radio Interference Test on High voltage Insulators.
IS-9224 (Part 1,2&4)	-	Low Voltage Fuses
IEC-60 (Part 1 to P4)	-	High Voltage Test Techniques
IEC 66	-	Environmental Test
IEC-117	-	Graphical Symbols
IEC-156,	-	Method for the Determination of the Electrical Strength of Insulation Oils.
IEC-270,	-	Partial Discharge Measurements.
IEC-376	-	Specification and Acceptance of New Sulphur Hexafluoride
IEC-437	-	Radio Interference Test on High Voltage Insulators.
IEC-506,	-	Switching Impulse Tests on High Voltage Insulators.
IEC-507	-	Artificial Pollution Tests on High Voltage Insulators to be used on AC Systems.
IEC-6094	-	Common Specification for High Voltage Switchgear & Control gear Standards.
IEC-815	-	Guide for the Selection of Insulators in respect of Polluted Conditions.
IEC-865 (P1 & P2)	-	Short Circuit Current - Calculation of effects.
ANSI-C.1/NFPA.70	-	National Electrical Code
ANSI-C37.90A	-	Guide for Surge Withstand Capability (SWC) Tests

ANSI-C63.21,	-	Specification for Electromagnetic Noise and
C63.3	-	Field Strength Instrumentation 10 KHz to 1 GHZ
C36.4ANSI-C68.1	-	Techniques for Dielectric Tests
ANSI-C76.1/EEE21	-	Standard General Requirements and Test Procedure for Outdoor Apparatus Bushings.
ANSI-SI-4	-	Specification for Sound Level Meters
ANSI-Y32-2/C337.2	-	Drawing Symbols
ANSI-Z55.11	-	Gray Finishes for Industrial Apparatus and Equipment No. 61 Light Gray
NEMA-107T	-	Methods of Measurements of RIV of High Voltage Apparatus
NEMA-ICS-II	-	General Standards for Industrial Control and Systems Part ICSI-109
CISPR-1	-	Specification for CISPR Radio Interference Measuring Apparatus for the frequency range 0.15 MHz to 30 MHz
CSA-Z299.1-1978h	-	Quality Assurance Program Requirements
CSA-Z299.2-1979h	-	Quality Control Program Requirements
CSA-Z299.3-1979h	-	Quality Verification Program Requirements
CSA-Z299.4-1979h	-	Inspection Program Requirements

CURRENT TRANSFORMERS, VOLTAGE TRANSFORMERS AND COUPLING CAPACITOR VOLTAGE TRANSFORMERS

IS-2705- (P1 to P4)	-	Current Transformers.
IS:3156- (P1 to P4)	-	Voltage Transformers.
IS-4379	-	Identification of the Contents of Industrial Gas Cylinders
IEC-44-1	-	Current transformers.
IEC-44-2	-	Voltage Transformers.
IEC-358	-	Coupling capacitors and capacitor dividers.
IEC-44-4	-	Instrument Transformes: Measurement of Partial Discharges
IEC-481	-	Coupling Devices for power Line Carrier Systems.
ANSI-C5713	-	Requirements for Instrument transformers
ANSIC92.2	-	Power Line Coupling voltage Transformers
ANSI-C93.1	-	Requirements for Power Line Carrier Coupling Capacitors

BUSHING

IS-2099	-	Bushings for Alternating Voltages above 1000V
IEC-137	-	Insulated Bushings for Alternating Voltages above 1000V

SURGE ARRESTERS

IS-3070 (PART2)	-	Lightning arresters for alternating current systems : Metal oxide lightning arrestors without gaps.
IEC-99-4	-	Metal oxide surge arrestors without gaps
IEC-99-5	-	Selection and application recommendation
ANSI-C62.1	-	IEE Standards for S A for AC Power Circuits
NEMA-LA 1	-	Surge Arresters

CUBICLES AND PANELS & OTHER RELATED EQUIPMENT

IS-722, IS-1248, IS-3231, 3231 (P-3)-Electrical relays for power system protection

IS:5039	-	Distributed pillars for Voltages not Exceeding 1000 Volts.
IEC-68.2.2	-	Basic environmental testing procedures Part 2: Test B: Dry heat
IEC-529	-	Degree of Protection provided by enclosures.
IEC-158(upto P3-1985)	-	Low Voltage Control Gear: Contactors.
IEC-439 (P1 & 2)	-	Low Voltage Switchgear and control gear assemblies
ANSI-C37.20	-	Switchgear Assemblies, including metal enclosed bus.
ANSI-C37.50	-	Test Procedures for Low Voltage Alternating Current Power Circuit Breakers
ANSI-C39	-	Electric Measuring instrument
ANSI-C83	-	Components for Electric Equipment
IS: 8623: (Part 1 to 3)	-	Specification for Switchgear & Control Assemblies.
NEMA-AB	-	Moulded Case Circuit and Systems
NEMA-CS	-	Industrial Controls and Systems
NEMA-PB-1	-	Panel Boards
NEMA-SG-5	-	Low voltage Power Circuit breakers
NEMA-SG-3	-	Power Switchgear Assemblies
NEMA-SG-6	-	Power switching Equipment
NEMA-5E-3	-	Motor Control Centers
1248 (P1 to P9)	-	Direct acting indicating analogue electrical measuring instruments & their accessories.

Protection and control equipment

IEC-51 : (P1 to P9)	-	Recommendations for Direct Acting indicating analogue electrical measuring instruments and their accessories.
IEC-255 (Part 1 to part 23)	-	Electrical relays.
IEC-297 (P1 to P4)	-	Dimensions of mechanical structures of the 482.6mm (19 inches) series.
IEC-359	-	Expression of the performance of electrical & electronic measuring equipment.
IEC-387	-	Symbols for Alternating-Current Electricity meters.
IEC-447	-	Man machine interface (MMI) - Actuating principles.
IEC-521	-	Class 0.5, 1 and 2 alternating current watt hour meters
IEC-547	-	Modular plug-in Unit and standard 19-inch rack mounting unit based on NIM Standard (for electronic nuclear instruments)
ANSI-81	-	Screw threads
ANSI-B18	-	Bolts and Nuts
ANSI-C37.1	-	Relays, Station Controls etc.
ANSI-C37.2	-	Manual and automatic station control, supervisory and associated telemetering equipment
ANSI-C37.2	-	Relays and relay systems associated with electric power apparatus
ANSI-C39.1	-	Requirements for electrical analog indicating instruments

MOTORS

IS-325	-	Three phase induction motors.
IS-4691	-	Degree of protection provided by enclosure for rotating electrical machinery.

IEC-34 (P1 to P19:)	-	Rotating electrical machines
IEC-Document 2	-	Three phase induction motors
(Central Office) NEMA-MG1		Motors and Generators

Electronic equipment and components

MIL-21B, MIL-833 & MIL-2750		
IEC-68 (P1 to P5)		Environmental testing
IEC-326 (P1 to P2) :		Printed boards
		Material and workmanship standards
IS-1363 (P1 to P3)	-	Hexagon head bolts, screws and nuts of product grade C.
IS-1364 (P1 to P5)	-	Hexagon head bolts, screws and nuts of products grades A and B.
IS-3138	-	Hexagonal Bolts and Nuts (M42 to M150)
ISO-898	-	Fasteners: Bolts, screws and studs
ASTM		- Specification and tests for materials

Clamps & connectors

IS-5561	-	Electric power connectors.
NEMA-CC1	-	Electric Power connectors for sub station
NEMA-CC 3	-	Connectors for Use between aluminium or aluminum-Copper Overhead Conductors

Bus hardware and insulators

IS: 2121	-	Fittings for Aluminum and steel cored Al conductors for overhead power lines.
IS-731	-	Porcelain insulators for overhead power lines with a nominal voltage greater than 1000 V.
IS-2486 (P1 to P4)	-	Insulator fittings for overhead power lines with a nominal voltage greater than 1000 V.
IEC-120	-	Dimensions of Ball and Socket Couplings of string insulator units.
IEC-137	-	Insulated bushings for alternating voltages above 1000 V.
IEC-168	-	Tests on indoor and outdoor post insulators of ceramic material or glass for Systems with Nominal Voltages Greater than 1000 V.
IEC-233	-	Tests on Hollow Insulators for use in electrical equipment.
IEC-273	-	Characteristics of indoor and outdoor post insulators for systems with nominal voltages greater than 1000V.
IEC-305	-	Insulators for overhead lines with nominal voltage above 1000V-ceramic or glass insulator units for a.c. systems Characteristics of String Insulator Units of the cap and pin type.
IEC-372 (1984)	-	Locking devices for ball and socket couplings of string insulator units : dimensions and tests.
IEC-383 (P1 and P2)	-	Insulators for overhead lines with a nominal voltage above 1000 V.
IEC-433	-	Characteristics of string insulator units of the long rod type.
IEC-471	-	Dimensions of Clevis and tongue couplings of string insulator units.
ANSI-C29	-	Wet process porcelain insulators
ANSI-C29.1	-	Test methods for electrical power insulators

ANSI-C92.2	-	For insulators, wet-process porcelain and toughened glass suspension type
ANSI-C29.8	-	For wet-process porcelain insulators apparatus, post-type
ANSI-G.8	-	Iron and steel hardware
CISPR-7B	-	Recommendations of the CISPR, tolerances of form and of Position, Part 1
ASTM A-153	-	Zinc Coating (Hot-Dip) on iron and steel hardware

Strain and rigid bus-conductor

IS-2678	-	Dimensions & tolerances for Wrought Aluminum and Aluminum Alloys drawn round tube.
IS-5082	-	Wrought Aluminum and Aluminum Alloy Bars. Rods,Tubes and Sections for Electrical purposes.
ASTM-B 230-82	-	Aluminum 1350 H19 Wire for electrical purposes
ASTM-B 231-81	-	Concentric - lay - stranded, aluminum 1350 conductors
ASTM-B 221	-	Aluminum - Alloy extruded bar, road, wire, shape
ASTM-B 236-83	-	Aluminum bars for electrical purpose (Bus-bars)
ASTM-B 317-83	-	Aluminum-Alloy extruded bar, rod, pipe and structural shapes for electrical purposes (Bus Conductors)

Wires and cables

ASTMD-2863	-	Measuring the minimum oxygen concentration to support candle like combustion of plastics (oxygen index)
IS-694	-	PVC insulated cables for working voltages upto and including 1100 Volts.
IS-1255	-	Code of practice for installation and maintenance of power cables, upto and including 33 kV rating
IS-1554 (P1 and P2)	-	PVC insulated (heavy duty) electric cables (part 1) for working voltage upto and including 1100 V.
	-	Part (2) for working voltage from 3.3 kV upto and including 11kV.
IS:1753	-	Aluminium conductor for insulated cables
IS:2982	-	Copper Conductor in insulated cables.
IS-3961 (P1 to P5)	-	Recommended current ratings for cables.
IS-3975	-	Mild steel wires, formed wires and tapes for armouring of cables.
IS-5831	-	PVC insulating and sheath of electric cables.
IS-6380	-	Elastometric insulating and sheath of electric cables.
IS-7098	-	Cross linked polyethylene insulated PVC sheathed cables for working voltage upto and including 1100 volts.
IS-7098	-	Cross-linked polyethyle insulated PVC sheathed cables for working voltage from 3.3kV upto and including 33 kV.
IS-8130	-	Conductors for insulated electrical cables and flexible cords.
IS-1753	-	Aluminum Conductors for insulated cables.
IS-10418	-	Specification for drums for electric cables.
IEC-96 (part 0 to p4)	-	Radio Frequency cables.
IEC-183	-	Guide to the Selection of High Voltage Cables.
IEC-189 (P1 to P7)	-	Low frequency cables and wires with PVC insulation and PVC sheath.
IEC-227 (P1 to P7)	-	Polyvinyl Chloride insulated cables of rated voltages up to and including 450/750V.
IEC-228	-	Conductors of insulated cables
IEC-230	-	Impulse tests on cables and their accessories.

IEC-287 (P1 to P3)	-	Calculation of the continuous current rating of cables (100% load factor).
IEC-304	-	Standard colours for insulation for low-frequency cables and wires.
IEC-331	-	Fire resisting characteristics of Electric cables.
IEC-332 (P1 to P3)	-	Tests on electric cables under fire conditions.
IEC-502	-	Extruded solid dielectric insulated power cables for rated voltages from 1 kV upto to 30 kV
IEC-754 (P1 and P2)	-	Tests on gases evolved during combustion of electric cables.

Galvanizing

IS-209	-	Zinc Ingot
IS-2629	-	Recommended Practice for Hot-Dip galvanizing on iron and steel.
IS-2633	-	Methods for testing uniformity of coating of zinc coated articles.
ASTM-A-123	-	Specification for zinc (Hot Galvanizing) Coatings, on products Fabricated from rolled, pressed and forged steel shapes, plates, bars and strips.
ASTM-A-121-77	-	Zinc-coated (Galvanized) steel barbed wire

Painting

IS-6005	-	Code of practice for phosphating of iron and steel.
ANSI-Z551	-	Gray finishes for industrial apparatus and equipment
SSPEC	-	Steel structure painting council

Fire protection system

Fire protection manual issued by tariff advisory committee (TAC) of India

HORIZONTAL CENTRIFUGAL PUMPS

IS:1520	-	Horizontal centrifugal pumps for clear, cold and fresh water
IS:9137	-	Code for acceptance test for centrifugal & axial pumps
IS:5120	-	Technical requirement - Rotodynamic special purpose pumps
API-610	-	Centrifugal pumps for general services
	-	Hydraulic Institutes Standards
BS:599	-	Methods of testing pumps
PTC-8.2	-	Power Test Codes - Centrifugal pumps

Other civil works standards

IS-269	-	33 grade ordinary portland cement.
IS2721	-	Galvanized steel chain link fence fabric
IS-278	-	Galvanized steel barbed wire for fencing.
IS-383	-	Coarse and fine aggregates from natural sources for concrete.
IS-432 (P1 and P2)	-	Mild steel and medium tensile steel bars and hard-dawn steel wire for concrete reinforcement.
IS-456	-	Code of practice for plain and reinforced concrete.
IS-516	-	Method of test for strength of concrete.
IS-800	-	Code of practice for general construction in steel.
IS-806	-	Steel tubes for structural purposes.
IS-1172	-	Basic requirements for water supply, drainage and sanitation.

IS-1199	-	Methods of sampling and analysis of concrete.
IS-1566	-	Hard-dawn steel wire fabric for concrete reinforcement.
IS-1742	-	Code of Practice for Building drainage.
IS-1785	-	Plain hard-drawn steel wire for prestressed concrete.
IS-1786	-	High strength deformed Steel Bars and wires for concrete reinforcement.
IS-1811	-	Methods of sampling Foundry sands.
IS-1893	-	Criteria for earthquake resistant design of structures.
IS-2062	-	Steel for general structural purposes.
IS-2064	-	Selection, installation and maintenance of sanitary appliances-code of practices.
IS-2065	-	Code of practice for water supply in buildings.
IS-2090	-	High tension steel bars used in prestressed concrete.
IS-2140	-	Standard Galvanized steel wire for fencing.
IS-2470 (P1 & P2)	-	Code of practice for installation of septic tanks.
IS-2514	-	Concrete vibrating tables.
IS-2645	-	Integral cement waterproofing compounds.
IS-3025 (Part 1 to Part 48)	-	Methods of sampling and test (Physical and chemical) for water and waste water.
IS-4091	-	Code of practice for design and construction of foundations for transmission line towers and poles.
IS-4111 (Part 1 to P5)	-	Code of practice for ancillary structures in sewerage system.
IS-4990	-	Plywood for concrete shuttering work.
IS-5600	-	Sewage and drainage pumps.

National building code of India 1970

USBR E12	-	Earth Manual by United States Department of the interior Bureau of Reclamation
ASTM-A392-81	-	Zinc/Coated steel chain link fence fabric
ASTM-D1557-80	-	test for moisture-density relation of soils using 10-lb (4.5 kg) rame land 18-in. (457 mm) Drop.
ASTM-D1586	-	Penetration Test and Split-Barrel
(1967)	-	Sampling of Soils
ASTM-D2049-69	-	Test Method for Relative Density of Cohesionless Soils
ASTM-D2435	-	Test method for Unconsolidated, (1982)
	-	Undrained Strengths of Cohesive Soils in Triaxial Compression.
BS-5075	-	Specification for accelerating Part I Admixtures, Retarding Admixtures and Water Reducing Admixtures.
CPWD	-	Latest CPWD specifications

ACSR MOOSE CONDUCTOR

IS:6745		Methods for Determination of Mass of zinc coating on zinc coated Iron and Steel Articles	BS:443-1969
IS:8263		Methods for Radio Interference	
IEC:437	-	1973Test on High Voltage Insulators	NEMA:107-1964
		CISPR	
IS:209		Zinc Ingot	BS:3436-1961

IS:398 Part - V	Aluminum Conductors for IEC:209-1966 Overhead Transmission Purposes
BS:215(Part-II)	Aluminium Conductors galvanized IEC:209-1966steel reinforced extra high
BS:215(Part-II)	voltage (400 kV and above)
IS:1778	Reels and Drums forBS:1559-1949 Bare Conductors
IS:1521	Method for Tensile Testing ISO/R89-1959of steel wire
IS:2629	Recommended practice for Hot dip Galvanising on Iron and Steel.
IS:2633	Method for Testing Uniformity of coating of zinc Coated Articles.
IS:4826	Hot dip galvanised coatings on round steel wires ASTMA-472-729

GALVANISED STEEL EARTHWIRE

IS:1521	Method for Tensile Testing ISO/R:89-1959 of Steel Wire
IS:1778	Reels and Drums for Bare Conductors
IS:2629	Recommended practice forHot Dip Galvanising on Ironand Steel.
IS:2633	Methods for testing Uniformityof Coating of Zinc Coated Articles.
IS:4826	Hot dip Galvanised Coatings ASTM:A 475-72a on Round Steel Wires BS:443-1969
IS:6745	Method for Determination BS:443-1969of mass of Zinc Coating on Zinc coated Iron and Steel Articles.
IS:209	Zinc ingot BS:3463-1961
IS:398 (Pt. I to P5:1992)	Aluminum Conductors for BS:215 (Part-II) overhead transmission purposes.

Lighting Fixtures and Accessories

(i)	IS:1913	General and safety requirements for electric lighting fittings.
(ii)	IS:3528	Water proof electric lighting fittings.
(iii)	IS:4012	Dust proof electric lighting fittings.
(iv)	IS:4013	Dust tight proof electric lighting fittings.
(v)	IS:10322	Industrial lighting fittings with metal reflectors.
(vi)	IS:10322	Industrial lighting fittings with plastic reflectors.
(vii)	IS:2206	Well glass lighting fittings for use under ground in mines (non-flameproof type).
(viii)	IS:10322	Specification for flood light.
(ix)	IS:10322	Specification for decorative lighting outfits.
(x)	IS:10322	Lumanaries for street lighting
(xi)	IS:2418	Tubular flourescent lamps
(xii)	IS:9900	High pressure mercury vapour lamps.
(xiii)	IS:1258	Specification for Bayonet lamp flourescent lamp.
(xiv)	IS:3323	Bi-pin lamp holder tubular flourescent lamps.
(xv)	IS:1534	Ballasts for use in flourescent lighting fittings. (Part-I)
(xvi)	IS:1569	Capacitors for use in flourescent lighting fittings.

(xvii)	IS:2215	Starters for flourescent lamps.
(xviii)	IS:3324	Holders for starters for tubular flourescent lamps
(xix)	IS:418	GLS lamps
(xx)	IS:3553	Water tight electric fittings
(xxi)	IS:2713	Tubular steel poles
(xxii)	IS:280	MS wire for general engg. Purposes

Conduits, Accessories and Junction Boxes

(1)	IS:9537	Rigid steel conduits for electrical wiring
(2)	IS:3480	Flexible steel conduits for electrical wiring
(3)	IS:2667	Fittings for rigid steel conduits for electrical wiring
(4)	IS:3837	Accessories for rigid steel conduits for electrical wiring
(5)	IS:4649	Adaptors for flexible steel conduits.
(6)	IS:5133	Steel and Cast Iron Boxes
(7)	IS:2629	Hot dip galvanising of Iron & Steel.
(4)	IS:2551	Danger notice plates
(5)	IS:2705	Current transformers
(6)	IS:9224	HRC Cartridge fuse links for voltage above 650V(Part-2)
(7)	IS:5082	Wrought aluminium and Al. alloys, bars, rods, tubes and sections for electrical purposes.
(8)	IS:8623	Factory built Assemblies of Switchgear and Control Gear for voltages upto and including 1000V AC and 1200V DC.
(9)	IS:1248	Direct Acting electrical indicating instruments

Electrical Installation

(1)	IS:1293	3 pin plug
(2)	IS:371	Two to three ceiling roses
(3)	IS:3854	Switches for domestic and similar purposes
(4)	IS:5216	Guide for safety procedures and practices in electrical work.
(5)	IS:732	Code of practice for electrical wiring installation (system voltage not exceeding 650 Volts.)
(6)	IS:3043	Code of practice for earthing.
(7)	IS:3646	Code of practice of interior illumination part II & III.
(8)	IS:1944	Code of practice for lighting of public through fares.
(9)	IS:5571	Guide for selection of electrical equipment for hazardous areas.
(10)	IS:800	Code of practice for use of structural steel in general building construction.
(11)	IS:2633	Methods of Testing uniformity of coating on zinc coated articles.
(12)	IS:6005	Code of practice for phosphating iron and steel.

(13) INDIAN ELECTRICITY ACT
(14) INDIAN ELECTRICITY RULES

SECTION- TRANSFORMER
(UPTO 400 KV CLASS)

REV 10

CONTENTS
SECTION- TRANSFORMER (UPTO 400 KV CLASS)

TECHNICAL SPECIFICATION
SECTION: TRANSFORMER (UPTO 400kV CLASS)

1. General

1.1. This specification covers design, engineering, manufacture, testing, delivery at site including all materials, accessories, spares, unloading, handling, proper storage at site, erection, testing and commissioning of the equipment specified.

1.2. The transformers shall in general have constant ohmic impedance between HV and IV on all taps. However, in case of parallel operation with the existing transformer,

i) The percentage impedance, vector group, OLTC connection & range etc. of the transformer is to be matched with that of the existing transformer.

ii) Necessary provision is to be kept in the transformer control scheme for parallel operation with the existing OLTC control scheme having provision of Master/Follower/Independent /Off operation etc.

1.3. External or internal reactors shall not be used to achieve the specified HV/LV and IV/LV impedances. Further, matching of physical orientation, mounting rail gauge etc. shall be done to facilitate inter-changeability.

2. Transportation

2.1. The Contractor 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 will comply with the requirements of loading and clearance restrictions for the selected route. It shall be the responsibility of the contractor to coordinate the arrangement for transportation of the transformer for all the stages from the manufacturer's work to site.

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

2.3. The main tank of the transformer shall be inland transported on trailers equipped with GPS system for tracking the location of transformer at all times during transportation from manufacturer works to designated site. The contractor shall intimate to Employer about the details of transporter engaged for transportation of the Transformer for tracking the Transformer during transit. Requirement of **Hydraulic trailer** is envisaged for 400kV class transformers.

2.4. All metal blanking plates and covers which are specifically required to transport and storage of the transformer shall be considered part of the transformer 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.

2.5. The Contractor shall despatch the transformer filled with dry air at positive pressure. The necessary arrangement shall be ensured by the contractor to take care of pressure drop of dry air during transit and storage till completion of oil filling during erection. The total duration of storage at site with dry gas shall preferably be limited to three (3)

months after which the Transformer shall be processed and filled with oil. The dry air cylinder(s) provided to maintain positive pressure can be taken back by the contractor after oil filling. A gas pressure testing valve with necessary pressure gauge and adaptor valve shall be provided.

In case, turrets are having insulation assembly and is transported separately then the same shall also be filled with dry air.

2.6. Transformer shall also be fitted with sufficient number of Electronic impact recorders (on returnable basis) during transportation to measure the magnitude and duration of the impact in all three directions. 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 50mSec (20Hz) as per EMPLOYER pre-commissioning document mentioned at Annexure-D or as per contractor standard, whichever is lower.

3. Performance

3.1. The transformers shall be used for bi-directional flow of rated power. The major technical parameters of single phase and three phase transformer units are defined at **Annexure - A**

3.2. 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. 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. Transformers fitted with two coolers, each capable of dissipating 50 per cent of the loss at continuous maximum rating, 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 140deg C at continuous max rating. The contractor shall submit supporting calculations for the above and the same shall be reviewed during design review.

3.3. The transformer shall be free from any electrostatic charging tendency (ECT) under all operating conditions when all oil circulation systems are in operation. In general, oil flow speed shall not exceed 1.0 m/sec within winding in the oil flow system of the transformers. The manufacturer shall ensure that there is no electrostatic charging tendency in the design.

3.4. 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.

3.5. 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.

3.5.1. Tank hotspot shall not exceed 130 Deg. Celsius. Maximum ambient temperature shall be considered as 50 Deg. C.

3.6. 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 for a period of 2 secs. The short circuit level of the HV & IV System to which the transformers will be connected is as follows:

400kV system	- 63kA for 1 sec (sym, rms, 3 phase fault)
220kV system	- 40 kA for 1 sec (sym, rms, 3 phase fault)
132kV system	- 31.5 kA for 1 sec (sym, rms, 3 phase fault)
66kV system	- 31.5 kA for 1 sec (sym, rms, 3 phase fault)
33kV system	- 25 kA for 1 sec (sym, rms, 3 phase fault)

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

3.7. 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.

The transformer shall be designed to withstand for short circuit duration of 2 seconds for Thermal stress and the same shall be verified during design review.

3.8. 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.

3.9. 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

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

3.11. **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.

3.12. **Radio Interference and Noise Level**

The transformers 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.

3.13. **Dynamic Short Circuit Test requirement**

3.13.1. **For 400 kV Class Auto transformer**

Bidder / Manufacturer should have successfully carried out Dynamic Short Circuit test on 315MVA, 400/220/33kV Auto transformer as on the originally scheduled date of bid opening and shall enclose the relevant Test Report/certificate along with bid. In case bidder has not successfully tested 315MVA, 400/220/33kV Auto transformer for Dynamic Short Circuit test, their bid shall be considered technically non responsive. Further, design review of offered 400 kV Class Auto transformer shall be carried out based on the design of short circuit tested 315MVA Auto transformer.

3.13.2. **For 220 kV Class Transformer:**

Bidder / Manufacturer should have successfully carried out Dynamic Short Circuit Test on any rating of 220 kV or above voltage class transformer as on the originally scheduled date of bid opening and shall enclose the relevant Test Report / Certificate along with bid. In case bidder has not successfully tested 220 kV or above voltage class transformer for Dynamic Short Circuit Test, their bid shall be considered technically non-responsive. Further design review of offered 220 kV class transformers shall be carried out based on design of short circuit tested 220 kV or above voltage class transformer.

3.13.3. **For 132 kV Class Transformer:**

Bidder / Manufacturer should have successfully carried out Dynamic Short Circuit Test on any rating of 132 kV or above voltage class transformer as on the originally scheduled date of bid opening and shall enclose the relevant Test Report / Certificate along with bid. In case bidder has not successfully tested 132 kV or above voltage class transformer for Dynamic Short Circuit Test, their bid shall be considered technically non-responsive. Further design review of offered 132 kV class transformers shall be carried out based on design of short circuit tested 132 kV or above voltage class transformer.

4. **Measurable Defects**

The following shall constitute as Measureable Defects for the purpose of Defect Liabilities as per relevant clauses of GCC / SCC of the bidding document:

a) Repair, inside the Transformer 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.

H2	CH4	C2H2	C2H4	C2H6	CO	CO2	TDCG
100	120	1	50	65	350	2500	720

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

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

5. Design review

5.1. The transformer 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. The manufacturer will be required to demonstrate the 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 with least maintenance and 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 – E.**

5.2. Raw material and sub-vendors used by transformer manufacturer shall be declared before commencement of manufacturing. **The validity of Type tests (except dynamic short circuit test) of Transformer shall be 5 years as on the originally scheduled date of bid opening,** provided that offered transformer design is identical to the type tested transformer and same active materials (CRGO, Conductor and Insulation) of same grade & from the same sub-vendors are used. In case of any change of either active materials or sub-vendors, the type tests shall be carried out by the contractor at no extra cost to Employer. Transformer type test report from the same manufacturing plant shall only be acceptable.

With regard to Validity of Dynamic short circuit test, refer clause 3.13 above.

5.3. Design reviews shall be conducted by Purchaser or an appointed consultant during the procurement process for transformers; however the entire responsibility of design shall be with the manufacturer. Purchaser may also visit the manufacturer's works to inspect design, manufacturing and test facilities at any time.

5.4. The design review will commence after placement of award with the successful bidder and shall be finalised before commencement of manufacturing activity. These design reviews shall be carried out in detail to the specific design with reference of the transformer under the scope of this specification. It shall be conducted generally following the "Guidelines for conducting design reviews for transformers - 100 MVA and 123 kV and above" prepared by CIGRE SC 12 Working Group 12.22.

5.5. The manufacturer shall provide all necessary information and calculations to demonstrate that the transformer meets the requirements for short circuit strength and

durability. The latest recommendations of IEC and Cigre SC 12 shall be applied for short circuit withstand evaluation.

6. Construction Details

The construction details and features of transformer shall be in accordance with the requirement stated hereunder. The components and fitting associated with transformers are subject to Purchaser's approval.

6.1. Tank

6.1.1. Tank shall be of welded/bolted construction and 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. Material Samples, technical literature, drawings, test reports and list of the names of the principal users with experience gained shall be supplied on request.

6.1.2. 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. After fabrication of tank and before painting, dye penetration test shall be carried out on welded parts of jacking bosses, lifting lugs and all load bearing members. 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.

6.1.3. Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water.

6.1.4. The tank shall be of proven design either bell type with bolted /welded joint or conventional type with welded / bolted top cover. Bell type tank shall be provided with joint at about 500 mm above the bottom of the tank. 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.

6.1.5. Tank shall be provided with:

a. Lifting lugs: Four symmetrically placed lifting lugs shall be provided so that it will be possible to lift the complete transformer when filled with oil without structural damage to any part of the transformer. The factor of safety at any one point 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.

c. 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.

d. Suitable haulage holes shall be provided.

e. Provision of 04 nos. of Gate valves for UHF sensors for PD Measurements at various locations. Location of valves shall be finalized during detailed engineering.

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

6.1.6. The tank shall be designed in such a way that it can be mounted either on the plinth directly or on rollers, as per manufacturer's standard practice.

6.1.7. The base of each tank shall be so designed that it shall be possible to move the complete transformer unit by skidding in any direction without damage when using plates or rails.

6.2. **Tank Cover**

6.2.1. The tank cover shall be designed to prevent retention of water and shall not distort when lifted. The internal surface of the top cover shall be shaped to ensure efficient collection and direction of free gas to the buchholz relay.

6.2.2. 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. The inspection covers shall not weigh more than 25 kg. Handles shall be provided on the inspection cover to facilitate lifting.

6.2.3. 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.

6.2.4. 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.

6.2.5. 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 in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.

6.2.6. The transformer 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.

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

6.3. **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. The Gaskets / O-Ring in contact with oil shall be Nitrile rubber or any other better approved quality.

All bolted connections shall be fitted with weather proof, hot oil resistant, resilient gasket in between for complete oil tightness. If gasket 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.

6.4. **Roller Assembly and Anti Earthquake Clamping Device**

The roller mounted transformers are to be provided with flanged bi-directional wheels and axles. This set of wheels and axles shall be suitable for fixing to the under carriage of transformer to facilitate its movement on rail track. Suitable locking arrangement along with foundation bolts shall be provided for the wheels to prevent accidental movement of transformer. The rail track gauge shall be 1676 mm.

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

6.5. **Conservator**

6.5.1. 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.

6.5.2. 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.

6.5.3. 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.

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

6.5.5. 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 is fully installed. To prevent oil filling into the air cell, the oil filling aperture shall be clearly marked. The transformer rating and diagram plate shall bear a warning statement that the **"Main conservator is fitted with an air cell".**

6.5.6. 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 $110^{O}C$ during operation. As such air cell used shall be suitable for operating continuously at this temperature.

6.5.7. The transformer 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.

6.5.8. 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.

6.5.9. 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.

6.5.10. 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.

6.6. **Piping works for conservator**

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

6.6.2. The feed pipe to the transformer tank shall enter the transformer cover plate at its highest point and shall be straight for a distance not less than five times its internal diameter on the transformer side of the Buchholz relay, and straight for not less than three times that diameter on the conservator side of the relay. Gas-venting pipes shall be connected to the final rising pipe between the transformer and Buchholz relay as near as possible in an axial direction and preferably not less than five times pipe diameters from the Buchholz relay.

6.6.3. This pipe shall rise towards the oil conservator, through the Buchholz relay, at an angle of not less than 5 degrees.

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

6.6.5. The feed pipe diameter for the main conservator shall be not less than 80mm.

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

6.7. **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, or other structure supplied by the contractor, 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) shall be connected in series for main tank conservator. Contractor 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. Contractor shall provide flexible connection pipes to be used during replacement of any silicagel breather.

6.8. **Pressure Relief Device**

Adequate number of pressure relief devices (at least 2 numbers) shall be provided at suitable locations preferably close to bushing turret/ cover. These shall have opening diameter of at least 100 mm for rapid release of any pressure that may be generated in the tank and which may result in damage to equipment. The device shall maintain its oil tightness under static oil pressure equal to the static operating head of oil plus 20 kPa. The device shall operate and attain its full opening in not more than 2.5 ms when subject to an internal pressure impulse equal to static operating head of oil plus 50 kPa. It shall be capable of withstanding full internal vacuum at mean sea level. It shall be mounted directly on the tank. One set of potential free contacts (**with plug & socket type arrangement suitable for 2.5sq.mm control cable)** 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

6.9. **Sudden Pressure Relay**

Adequate number of Sudden Pressure relay with alarm/trip contacts **(Plug & socket type arrangement suitable for 2.5sq.mm control cable)** shall be provided on tank of Transformer. Operating features, size and quantity shall be reviewed during design review. Pressurised water ingress test for Terminal Box (routine tests) shall be conducted on Sudden Pressure Relay.

6.10. **Buchholz Relay**

Two numbers double float, reed type Buchholz relay shall be provided in series of the connecting pipe between the oil conservator and the Transformer tank with minimum distance of five times pipe diameters between them. Any gas evolved in the Transformer shall be collected in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation and taking gas sample. A copper tube shall be connected from the gas collector to a valve located about 1200 mm above ground level to facilitate sampling while the Transformer in service. Each device shall be provided with two potential free contacts **(Plug & socket type arrangement suitable for 2.5sq.mm control cable),** one for alarm / trip on gas accumulation and the other for tripping on sudden rise of pressure.

The Buchholz relay shall not operate during starting/ stopping of the transformer oil circulation under any oil temperature conditions. The pipe or relay aperture baffles shall not be used to decrease the sensitivity of the relay. The relay shall not mal-operate

for through fault conditions or be influenced by the magnetic fields around the transformer during the external fault conditions. Pressurised water ingress test for Terminal Box (routine tests) shall be conducted on Buchholz relay.

6.11. **Oil Temperature Indicator (OTI)**

All transformers shall be provided with a dial type thermometer of around 150 mm diameter for top oil temperature indication. It shall have adjustable, potential free alarm and trip contacts **(Plug & socket type arrangement suitable for 2.5sq.mm control cable)** besides that required for control of cooling equipment if any. A temperature sensing element suitably located in a pocket on top oil shall be provided. This shall be connected to the OTI by means of capillary tubing. Temperature indicator dials shall have linear gradations to clearly read at least every 2 deg C. Accuracy of OTI shall be ± 3.0 deg C or better or better for a temperature of 100 deg C.

The setting of alarm and tripping contacts shall be adjustable at site. For alarm & trip settings refer EMPLOYER Pre-Commissioning Procedures and formats for switchyard equipment (enclosed at Annexure-D).

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

a) 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 provide dual output 4-20mA for remote OTI and SCADA system individually. 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 Contractor.

b) Remote oil temperature indicator

It shall be suitable for flush mounting on Employer's control panel/ digital RTCC panel and shall operate on 4-20mA input available from the above transducer. Any special cable required for shielding purpose, for connection among Individual Marshalling Box, Common Marshalling Box/Cooler control cabinet and remote OTI control circuit, shall be in the scope of Contractor.

6.12. **Winding Temperature Indicator (WTI)**

All Transformers shall be provided with a device for measuring the hot spot temperature of each winding (HV, IV and LV) with dial type thermometer of 150 mm diameter for winding temperature indication and shall have adjustable potential free alarm and trip contacts **(Plug & socket type arrangement suitable for 2.5sq.mm control cable**) besides that required for control of cooling equipment if any. WTI shall have Temperature sensing element, Image coil and Auxiliary CTs, if required to match the image coil, shall be mounted in the cooler control cabinet. Temperature indicator

dials shall have linear gradations to clearly read at least every 2 deg C. Accuracy of WTI shall be ± 3.0 deg C or better for a temperature of 100 deg C.

The setting of alarm and tripping contacts shall be adjustable at site. For alarm & trip settings refer EMPLOYER Pre-Commissioning Procedures and formats for switchyard equipment (enclosed at **Annexure-D**).

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

a) 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, Auxiliary CT 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 Contractor.

b) Remote winding temperature indicator (RWTI)

It shall be suitable for flush mounting on Employer's control panel/ digital RTCC panel and shall operate on 4-20mA input available from the above transducer. Any special cable required for shielding purpose, for connection among Individual Marshalling Box / Cooler control cabinet, Common Marshalling Box and remote WTI control circuit, shall be in the scope of Contractor.

Only one RWTI with suitable selector switches or separate individual RWI shall be provided for display of temperature of all the three windings (HV, IV and LV as applicable).

6.13. 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.

6.14. **Optical sensors & temperature measuring unit (for 400kV Class Transformer)**

Each Transformer unit shall be fitted with at least **16 numbers** optical temperature sensors. The optical sensors based temperature measuring system shall be of direct measurement non calibrating type. All the sensors shall be brought out to separate optical sensor box mounted on transformer tank to facilitate measurement of temperature during service life on each unit.

In order to facilitate measurement of temperature from the optical sensors, temperature measuring unit/system having at least 16 channels shall be mounted in above optical sensor box (stainless steel, IP 55 Protection) for each transformer 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 housed in above box shall be suitable for satisfactory operation with ambient conditions and IEC 61850 compliant to interface with Employer's SCADA system.

Location of optical temperature sensors inside the transformer shall be decided during design review. Manufacturers are advised to provide few more optical temperature sensors (probes) to take care of any damage during handling.

6.15. **Earthing Terminals**

6.15.1. 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.

6.15.2. 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.

6.15.3. 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.

6.16. **Core**

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

6.16.2. 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.

6.16.3. 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.

6.16.4. 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.

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

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

6.16.7. 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.

6.16.8. Adequate lifting lugs will be provided to enable the core and windings to be lifted.

6.16.9. The core shall be earthed to the core clamping structure at one point only, through a removable external link of minimum size of 80 sq. mm copper suitably located and protected to facilitate testing after installation of the transformer. 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' on the outside of tank cover.

6.16.10. 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.

6.17. **Windings**

6.17.1. The Contractor shall ensure that windings of all transformers are made in dust proof and conditioned atmosphere.

6.17.2. The conductors shall be of electrolytic grade copper free from scales and burrs.

6.17.3. 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.

6.17.4. 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.

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

6.17.6. 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.

6.17.7. 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.

6.17.8. The barrier insulation including spacers shall be made from high- density pre-compressed pressboard (1.1 gm/cc minimum for load bearing and 1 to 1.3 gm/cc minimum for non-load bearing) to minimize dimensional changes.

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

6.17.10. 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.

6.17.11. 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.

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

6.17.13. The bracing of the windings and connections shall be such that these parts shall safely withstand the cumulative effects of stresses which may occur during handling, transportation, installation and service including line-to–line and line-to–ground faults.

6.18. **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.

6.19. **Winding terminations into bushings**

6.19.1. 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 in service.

6.19.2. 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.

6.19.3. 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.

6.19.4. 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.

6.19.5. 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.

7. Paint system and procedures

The typical painting details for transformer main tank, pipes, conservator tank, radiator, control cabinet/ marshalling box / oil storage tank etc. shall be as given in **Annexure – F**. 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.

8. Inhibited Insulating Oil

The insulating oil shall be virgin high grade inhibited, conforming to IEC-60296 & all parameters specified at **Annexure – G**, while tested at oil supplier's premises. The contractor shall furnish test certificates from the supplier against the acceptance norms as mentioned at **Annexure – G**, 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 – G**. 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 (in line with IEC 60076-3) which shall be supplied at site and shall meet parameters as per specification.

8.1. Particles in the oil

The particle analysis shall be carried out in an oil sample taken 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".

8.2. Moisture content in the solid insulation

Dummy insulation test block shall be inserted in the active part of Transformer at factory and same shall be used to detect the volume moisture content. Before application of vacuum and oil filling in the Transformer, it will be ensured that moisture content in the dummy insulation test block is less than 0.5%.Measurement shall be carried out as per IEC.

8.3. Oil filling

8.3.1. Procedures for site drying, oil purification, oil filling etc. shall be done as per EMPLOYER Field Quality Plan (FQP).

8.3.2. The duration of the vacuum treatment shall be demonstrated as adequate by means of water / dew point measurement with a cold trap or other suitable method. The vacuum shall be measured on the top of the transformer tank and should be less than 1mbar.

8.3.3. Oil filling under vacuum at site shall be done with transformer oil at a temperature not exceeding 65°C. Vacuum shall not be broken until the Transformer is oil filled up to the Buchholz relay.

8.3.4. The minimum safe level of oil filling (if different from the Buchholz level) to which the Transformer shall be oil filled under vacuum, shall be indicated in the manual.

8.3.5. The Ultra High Vacuum type oil treatment plant of suitable capacity (**minimum 6000** litres per hour) suitable for treatment of oil in EHV class Transformer shall be used in order to achieve properties of treated oil. The plant shall be capable of treatment of new oil (as per IEC 60296 and reconditioning of used oil (as per IS: 1866/IEC: 60422 for oil in service) at rated capacity on single pass basis as follow:

i) Removal of moisture from 100 ppm to 3 ppm (max.)
ii) Removal of dissolved gas content from 10% by Vol. to 0.1% by vol.
iii) Improvement of dielectric strength break down voltage from 20 to 70 KV
iv) Vacuum level of degassing chamber not more than 0.15 torr/0.2 mbar at rated flow and at final stage. Machine shall have minimum of two degassing chambers and these should have sufficient surface areas to achieve the final parameters.
v) Filter shall be capable of removing particle size more than 0.5 micron in the filtered oil.
vi) Processing temperature shall be automatically controlled and have an adjustable range from 40°C to 80°C.

The above oil treatment plant (Filtration unit) shall be arranged by the bidder at his own cost.

8.3.6. **Transportation of Oil**

The insulating oil for the transformer shall be delivered at site generally not before 90 days from the date of commissioning, with prior information to the Employer.

Insulating oil shall be delivered to the site in returnable oil drums / flexi bag / tanker. The oil drums / flexi bag / tanker shall be taken back without any extra cost to Employer within generally 45 days after utilisation of oil but in any case before contract closing. However, the spare oil shall be delivered in non-returnable drums.

9. Preparation of spare unit

9.1. **Unit in service:** In case, purchaser intends to replace any of the 1-phase Transformer units by spare 1-phase unit through isolator switching arrangement i.e. without physically shifting of the Transformers, the spare Transformer shall be completely erected, oil filled and commissioned similar to the other Transformers.

9.2. **Unit for long term storage:** In case, due to space limitation, Isolator based switching arrangement is not possible, the faulty unit shall be replaced with spare unit by physical shifting. The spare unit shall be completely erected at the identified location/foundation in the substation, oil filled and commissioned similar to the other Transformers with all accessories (except cooler/radiator bank) for long-term storage. The contractor shall carry out all pre-commissioning tests on the spare Transformer similar to the unit kept in service. After completion of pre-commissioning tests, bushings may be dismantled and re-packed or erected condition as advised by Employer. If the conservator is mounted on cooler bank, suitable arrangement shall be made for the conservator to be mounted on tank top during long-term storage of Transformer. Radiators shall be kept in original packing and shall be stored as per the direction of site Engineer in charge or in erected condition wherever storage space not available.

All other accessories/fittings etc. shall be suitably packed in reusable boxes in line with standard drawings/documents. Instructions for dismantling, installation and safe storage shall be provided with every packing box. Arrangement shall be made to minimize moisture ingress inside the boxes. All pipes and radiators shall be provided with blanking plates during storage to prevent entry of foreign material/ water.

In addition to the blanking plates & covers provided during transportation, one complete set of all metal blanking plates and covers, which are specifically required during transport and storage at site shall be considered as integral part of each Transformer and handed over to the site packed in a separate box. Bill of quantity and relevant drawings of these items shall also be provided to enable the Purchaser to re-fabricated, if required.

In case spare Transformer needs to be commissioned similar to the unit in service, as advised by Employer, the same shall be erected, tested and commissioned as per standard procedures. However, other accessories/fittings/packing materials etc. As required for long-term storage shall be considered include in the scope of bidder.

Any special maintenance procedure required during long-term storage shall be clearly brought out in the instruction manual.

10. Bushings

10.1. Bushings shall be robust and designed for adequate cantilever strength to meet the requirement of seismic condition, substation layout and movement along with the spare Transformer with bushing erected and provided with proper support from one foundation to another foundation within the substation area. The electrical and mechanical characteristics of bushings shall be in accordance with IEC: 60137/DIN 42530. All details of the bushing shall be submitted for approval and design review.

10.2. Bushing for voltage of 52 kV and above shall be RIP bushing with composite insulator. 36 kV bushing shall be solid porcelain or oil communicating type.

10.3. 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.

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

10.5. 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 – D**.

10.6. 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.

10.7. 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.

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 IEC60587. 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.

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

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

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

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

10.10. No arcing horns shall be provided on the bushings.

10.11. Spare 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. In case of RIP bushing with polymer housing, 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.

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

11. Neutral Formation and Earthing Arrangement

11.1. For 3-Phase Unit

The neutral of the transformer shall be brought out through bushing. The neutral terminal of 3-phase transformer 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) 75 x 12 mm galvanised steel flats connected to Employer's grounding mat.

11.2. **For 1-Phase Unit**

The neutral of the transformer shall be brought out through bushing. The contractor shall connect the neutrals of 1-phase transformers 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. All material like Bus post insulator, Aluminium tube, conductor, clamps & connectors, earthing materials, support structure, hardware etc required for neutral formation and connection with neutral CT and earthing of neutral shall be provided by contractor. 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.

12. 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. The minimum phase to phase horizontal spacing for delta formation shall be 1.5 meter. All associated materials like bus post insulators, Aluminium tube, clamps & connectors, support structures, hardware etc. required for tertiary delta formation shall be provided by the contractor.

13. Spare Unit connection arrangement (as applicable for 1-Phase Transformer)

Connection arrangement of spare unit of transformer with other units shall be made by isolator switching (Isolators are not part of this specification). Tertiary delta and neutral formation for spare unit of transformer shall be done by manual connection. The contractor shall make connection arrangement as well as control scheme of OLTC and Cooler in such a way that spare unit of transformer can be connected in place of faulty unit without physically shifting it from its location. For this purpose, HV, IV, Tertiary and Neutral Connections of spare unit are to be extended upto the other unit by forming auxiliary buses with tertiary connection insulated with heat shrinkage insulating sleeve of suitable voltage class and adequate thickness and shall be supported by structure mounted bus post insulators at suitable intervals to enable spare unit connection through flexible/rigid conductor and suitable connector in place of existing unit to be replaced. A typical sketch of connection arrangement is shown in the drawing enclosed at **Annexure-D**. However, the detail configuration and actual sizes of various items shall be finalised during detailed engineering and shall be subject to Employer's approval. All associated materials like Bus post insulators, Aluminium tube, conductors, clamps & connectors, insulator strings, hardware, cables, support structures, required for the above-mentioned arrangement shall be provided by the contractor.

14. Cooling Equipment and its Control

14.1. Cooling Equipment for Radiator Bank

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

14.1.2. 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 without the need of any extra member/pipe maintaining the electrical clearances.

14.1.3. 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

14.1.4. 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.

14.1.5. Required number of standby fans of approximately 20% capacity shall also be provided with each radiator bank.

14.1.6. Cooling fans shall not be directly mounted on radiator bank which 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.

14.1.7. Two (2), 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.

14.1.8. An oil flow indicator shall be provided for the confirmation of the oil pump operating in a normal state. An indication in the flow indicator and potential free contacts for remote alarm shall be provided.

14.1.9. 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.

14.1.10. 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. 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.

14.1.11. 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.

14.1.12. 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.

14.2. **Cooling Equipment Control for Radiator banks**

14.2.1. Automatic operation control of fans/pumps shall be provided (with temperature change) from contacts of winding temperature indicator. The Contractor 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.

14.2.2. 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.

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

14.2.4. In addition to the traditional starting of fan and pump by oil temperature, the starting of forced cooling shall be done if the load exceeds a current setting of 0.6 p.u. for 5 seconds. Furthermore, a one-week timer is required to check the healthiness of the cooling system on a routine basis for one hour at a time.

14.2.5. 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 ph. unit connection shall be extended further to CMB.

14.2.6. 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 upto 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.

14.2.7. All the necessary terminations for remote connection to Purchaser's panel shall be wired upto the Common Marshalling box.

14.2.8. The Contractor shall derive AC power for Cooler Control Circuitry 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 by the Contractor. Details of station auxiliary power supply are mentioned in GTR.

14.3. **Unit cooler arrangement for transformer (if applicable)**

14.3.1. The cooler shall be designed using Unit Cooler arrangement with capacity as specified in Annexure-A. Design of cooling system shall satisfy the performance requirements.

14.3.2. Each Unit Cooler shall have its own cooling fans, oil pumps, oil flow indicator, shut off valves at the top and bottom of at least 80 mm size, 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.

14.3.3. 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.

14.3.4. 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.

14.3.5. 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

14.3.6. 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.

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

14.3.8. 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.

14.4. **Cooling Equipment Control (OFAF or ODAF) for Unit Coolers**

i) Suitable manual control facility for unit cooler shall be provided.

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

iii) 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.

iv) 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.

v) 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

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

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

viii) 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.

14.5. **Auxiliary Power Supply for OLTC, Cooler Control and Power Circuit**

14.5.1. **For Single Phase unit**

14.5.1.1. Two auxiliary power supplies, 415 volt, three phase four (4) wire shall be provided at common marshalling box. 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 Common Marshalling Box for each circuit.

14.5.1.2. For each circuit, suitably rated MCBs/MCCBs as required for further distribution of auxiliary power supply 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 individual marshalling boxes /cooler control boxes.

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

14.5.1.4. Supply and laying of Power, Control and special cables from common marshalling box to individual MB/Cooler Control Cubicle (including spare unit) & further distribution from IMB/CCC to all accessories is in the scope of the contractor. Further any special cable (if required) from CMB to Owner's Control Panels/Digital RTCC panels is also in the scope of the contractor.

14.5.1.5. Connection arrangement for spare unit shall be in such a way that spare unit of transformer can be connected in place of faulty unit without physically shifting and all the control, protection, indication signals of spare unit shall also be brought in common marshalling box of all the banks. Necessary arrangement in schematic of Common marshalling box is required to facilitate change over of all the signals of faulty units to spare unit of Transformer, to ensure flow of control, protection and indication signals between Purchaser's Control panels / Digital RTCC Panel /SCADA and individual units under operation (i.e. any designated unit for bank or spare unit, if it replace any designated unit). To facilitate change-over of spare unit signals with faulty unit in CMB, male-female plug-in connector or better arrangement shall be provided to reduce the outage time.

14.5.2. **For Three Phase Transformer**

14.5.2.1. Two auxiliary power supplies, 415 volt, three phase four (4) wire shall be provided by the Purchaser at cooler control cabinet. All loads shall be fed by one of the two sources through an electrically interlocked automatic transfer scheme housed in the cooler control cabinet.

14.5.2.2. 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.

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

14.5.3. **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.

14.6. **Valves**

14.6.1. All valves upto and including 100 mm shall be of gun metal or of cast steel/cast iron. 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. All hardware used shall be hot dip galvanised / stainless steel.

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

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

14.6.4. All valves flanges shall have machined faces.

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

14.6.6. 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.

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

14.6.8. **Flow sensitive conservator Isolation valve**

a) In order to restrict the supply of oil in case of a fire in transformer, 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.

d) A suitable platform / ladder shall be provided to approach the valve for manual reset.

14.6.9. All valves shall be painted with a shade (preferably red or yellow) distinct and different from of main tank surface and as per the painting system and procedure specified.

15. Cabling

All interconnecting control and power cables between various parts of Transformers 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. Typical Technical specification for cables is attached at **Annexure-I**. Contractor shall provide type tested cables from approved sources. No type testing for cables is envisaged. 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