CHAPTER – 8: POWER TRANSFORMERS

SCOPE

These specifications are intended to cover design, engineering, manufacture, inspection and testing at manufacturer's works before dispatch, supply, transportation, insurance, dispatch & delivery at project sites at Quileva & Quito in Angola , handling, storage & preservation at site, complete work of site assembly, erection, dehydration, testing and commissioning & remedial action, if any, up to defect liability period of following type of oil immersed core type transformers complete with RTCC and OLTC panels, all accessories and fittings, erection & maintenance tools & tackles, mandatory spares as detailed in this specifications:

b) 1 Nos. of 80/100 MVA (ONAN/ONAF), 220/60/30 kV Power Transformer, YNyn0d11, oil immersed with OLTC, RTCC & NIFPS outdoor type Power Transformer with all accessories and fittings, mandatory spares.

c) 2 Nos. of 50/60 MVA (ONAN/ONAF), 220/60/15 kV Power Transformer, YNyn0d11, oil immersed with OLTC, RTCC & NIFPS outdoor type Power Transformer with all accessories and fittings, mandatory spares.

The scope of supply shall include all parts, accessories, auxiliaries, mountings, etc. including insulating oil required for first filling plus 10% extra, which are necessary for satisfactory operation of the Transformers even though not individually or specifically stated or enumerated. The Transformer shall be transported filled with Nitrogen gas along with gas pressure monitoring device and gas replenishing arrangement.

Corresponding parts of the Transformers, accessories, spares, etc. shall be of the same materials, dimensions and workmanship and shall be interchangeable.

Necessary shock absorbing device shall be provided on the Transformers to absorb the, intensity of jerks during transportation to site.

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

Power cables, control cables & special cables, supports, cable racks, cable glands, lugs, terminals, connectors, etc. for cabling between equipment & devices covered in this section and up to UCB, Protection Panels shall be under scope of supply.

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

Components having identical rating shall be interchangeable.

The bidder has to furnish the testing facilities available at the manufacturer's works.

The Technical Specification for Power Transformers are given below:

INTRODUCTION

SPECIFIC TECHNICAL REQUIREMENTS

TABLE: 8.0

A. SPECIFIC TECHNICAL REQUIREMENTS FOR 220/60/30kV 80/100MVA, 220/60/15kV 50/60MVA (ONAN/ONAF) POWER TRANSFORMER

(i) Description	**220/60/30kV**	**220/60/15 kV**
(ii) Rated MVA of the Transformer HV LV TV	80/100 MVA (ONAN/ONAF) 100 MVA 100 MVA 30 MVA	50/60 MVA (ONAN/ONAF) 60 MVA 60 MVA 05 MVA
(iii) Nos. Required	1 at Quileva Substation	2 at Quito Substation
(iv) Type of installation	Outdoor	
(v) Frequency	50 Hz ± 3 %	
(vi) Cooling medium	Mineral oil	
(vii) Rated Voltage/highest system voltage		
a) High voltage side (HV)	220/ 245 kV	220/ 245 kV
b) Low Voltage (LV) c) Tertiary Voltage (TV)	60/72.5 kV 30/36 kV	60/72.5 kV 15/17.5 kV
(viii) Method of system earthing:		
a) High Winding (HV)	Neutral terminal- Solidly earthed	
b) Low Winding (LV)	Neutral terminal- Solidly earthed	
c) Tertiary Voltage (TV)	Earthed through station-cum-grounding transformer with Suitable NGR (Grounding Resistor)	
(ix) Type of tap changer (HV-LV)	OLTC in tank	
(x) Range of tapping for HV-LV	Plus 10% to minus 10 % in sixteen (16) equal steps of 1.25%	

(xi) Impedance at rated MVA Base on different Taps a. HV-LV b. HV-TV c. LV-TV	 12.45% 40.71% 57.87%	 12.50% 45.00% 30.00%
(xii) Type of insulation & insulation level for winding: HV LV TV	220 kV 60 kV 30 kV	220 kV 60 kV 15 kV
a) Type of insulation: HV LV TV Neutral	 Graded Graded Uniform	 Graded Graded Uniform
b) Type of Bushing HV LV TV Neutral	RIP	OIP
c) One-minute power frequency withstand test voltage (kV RMS) HV LV TV Neutral	 460 kV 140 kV 95 kV 70 kV	 460 kV 140 kV 50 kV 70 kV
d) Impulse withstand test voltage (kVp): HV LV TV Neutral	 1050 kV 325 kV 250 kV 170 kV	 1050 kV 325 kV 125 kV 170 kV
e) Rated current (A) HV LV	 1250 2000	 1250 2000

TV Neutral (HV &LV)	2000 2000	2000 2000
f) Creepage	31 mm/ kV	31 mm/ kV
(xiii) Winding connection	Star – Star-Delta (HV- LV-TV)	Star – Star-Delta (HV- LV-TV)
(xiv) Material	Copper	Copper
(xv) Vector group:	YNyn0d11	YNyn0d11
(xvi) Tan Delta	Less than 0.004 at 20^0 C	
(xvii)Maximum Flux Density (B_m) in core & yoke at normal voltage & frequency	1.6 wb/m^2	
(xviii) Short circuit level of the system to which Transformer is to be connected	40 kA for 1 sec.	40 kA for 1 sec.
(xix) Short circuit withstand capacity for transformer	40 kA for 2 sec.	40 kA for 2 sec.
(xx) Terminal details		
a. HV Termination	AAAC Twin Yew.	AAAC Twin Yew.
b. LV Termination	Aluminium Tube of suitable size	ACSR Twin Zebra conductor for connecting to bushing terminals
(xxi) Rail a. Shorter Axis: b. Longer Axis:	1676 mm 1676 mm	1676 mm 1676 mm
(xxii)Tan delta of winding	Less than 0.005 at 20^oC	
(xxiii)	Maximum Temperature Rise for various types of cooling over an Max ambient of 42 deg C	

a) Temperature rise of top oil (Measured by Thermometer) b) Temperature rise of winding Measured by resistance)	50^0 C 55^0 C	50^0 C 55^0 C
(xxiv) Losses		
a. Maximum No Load Loss on principal tap at Rated Voltage and frequency, in kW	To be specified by the bidder	To be specified by the bidder
b. Maximum Load Losses (Copper + stray loss)at rated current on principal tap at 75 oC HV-LV combination for Two winding Transformer, in kW	To be specified by the bidder	To be specified by the bidder
c. Max. I2R Loss at rated current and frequency and at 75°C at principal tap between HV & LV	To be specified by the bidder	To be specified by the bidder
d. Maximum Auxiliary/Cooler Loss in kW	To be specified by the bidder	To be specified by the bidder
(xxv) Bushing CT (As per SLD)	300-600/5-5	200-400/5-5
(xxvi) Overload Capacity	As per IEC 60354	
(xxvii) Noise Level at Rated Voltage & Frequency	Less than 75db for ONAN Less than 80db at full load	
(xxviii)Transformer Oil	As per IEC 60296, IEC 60156 & IEC 60814 (latest edition) PCB is Prohibited in Transformer Oil.	

PERFORMANCE

The Transformers shall be capable of operating at full load for at least ten (10) minutes during total failure of auxiliary power supply to cooling fans and pumps without exceeding winding hot spot temperature exceeding 140°C. It should also be capable of operating for 20 minutes in the event of failure of blowers associated with all unit coolers except one unit cooler without exceeding winding hot spot temperature exceeding 140°C. Necessary calculations in this regard shall be submitted during design stage.

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

The maximum flux density in any part of the core and yoke at normal voltage and Frequency shall be such that the flux density under 10% over voltage condition shall not exceed 1.76 Tesla.

The maximum flux density in any part of the core and yoke at rated MVA, voltage and frequency shall not exceed 1. 6 wb/square meter at the lowest tap position under 10% continuous over voltage & frequency condition.

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

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

Withstanding time for 150% & 170% over-fluxing conditions shall be indicated. Over fluxing characteristics, up to 170 % shall be submitted.

The air core reactance of HV winding of the transformer shall not be less than 20%. External or internal reactors shall not be used to achieve the specified HV/LV impedances.

The temperature of any part of the core or its support structure in contact with oil shall not exceed 120°C under normal operating condition and 130°C under most extreme operating condition.

The insulation of core to bolts and core to clamp plates shall withstand a voltage of 2kV (RMS) for 1minute.

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

The transformer shall be free from any Electrostatic Charging Tendency (ECT) under all operating conditions and maximum oil velocity shall be such that it does not lead to static discharges inside the transformer while all coolers are in operation.

Transformers shall be designed to achieve suppression of harmonic voltage especially the third & fifth so as to eliminate wave form distortion and any possibility of high frequency disturbances,

inductive effects or circulating currents between neutral points of different Transformers reaching such a magnitude as to cause interference with communication circuits.

It shall be capable of being loaded up to 150% of rated load as per IEC 60076-7. There shall be no limitation for overloading imposed by bushing, tap changer etc. or any other associated equipment.

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

Transformer shall under exceptional circumstances due to sudden disconnection of the load, be capable of operating at the voltage approximately 25% above normal rated voltage for a period of not exceeding one minute and 40% above normal for a period of 5 seconds.

The transformer may be operated continuously without danger on any particular tapping at the rated MVA ±10% of the voltage corresponding to the tapping.

The thermal ability withstand short circuit shall be demonstrated by calculation and simulations.

Transformers shall be suitable for continuous operation at rated output with a frequency variation of up to ± 3% from normal frequency of 50 Hz without exceeding the specified temperature rise.

The transformer shall be so designed that the current density of all the windings and the regulating winding at the lowest tap should not exceed 250 A/sq.cm.

The thermal ability of the Transformer to withstand the short circuit shall be demonstrated by calculations. The duration of the symmetrical short circuit current to be used for the calculation of the thermal ability to withstand short circuit shall be 2 seconds.

AUXILIARY POWER SUPPLIES

The following Auxiliary power supplies shall be available at site:

i) AC, 3 phase 400 Volts 50 Hz. earthed
ii) AC, 1 phase 230 Volts 50 Hz. earthed
iii) 110V DC ungrounded.

DRAWINGS INCORPORATING THE FOLLOWING PARTICULARS SHALL BE SUBMITTED WITH THE BID

i. General outline drawing showing shipping dimensions and overall dimensions, net weights and shipping weights, quality of insulating oil, spacing of wheels in either direction of motion, location of coolers, marshalling box and tap changers etc.
ii. Height of centre line of HV, LV and TV connectors of transformers from the rail top level.
iii. Dimensions of the largest part to be transported.

iv. GA drawings/details of various types of bushing.

v. Type test certificates of Identical design transformers.

vi. Illustrative & descriptive literature of the Transformer.

vii. Maintenance and Operating Instructions.

MISCELLANEOUS

Padlocks along with duplicate keys as asked for various valves, marshalling box etc., shall be supplied by the contractor, wherever applicable.

Foundation bolts for wheel locking devices of Transformer shall be supplied by the Contractor.

NAME/RATING PLATE

Transformer rating plate shall contain the information as given in IEC 60076/ Equivalent international standards. The details on rating plate shall be finalized during the detailed engineering. Name/ Rating plate shall be in English languages.

STANDARDS & CODES

The equipment, materials and service covered by this specification shall conform to the relevant IEC standard / Equivalent international standards:

IEC 60076	Power Transformer
IEC 60354	Loading guide for oil immersed power transformers
IEC 60606	Application Guide for Power Transformers
IEC 60296	Mineral Insulating oils for transformers & switchgear
IEC 60137:2008,	Bushings for alternating voltages above 1 000 V
IEC 60044-1	Current Transformers
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60060-1	High-voltage test techniques. Part 1: General definitions and test requirements
IEC 60270	High-Voltage Test Techniques – Partial Discharge Measurements
BS EN 50216-2:2002	Power transformers and reactor fittings. Gas and oil actuated relay for liquid immersed transformers and reactors with conservator

ANSI/NEMA CC 1-2009 (R2015)	Electric Power Connectors for Substations
IEC 60214	Tap Changers

GENERAL DESIGN CONSTRUCTIONAL FEATURES

All material used shall be of best quality and of the class most suitable for working under the conditions specified and shall withstand the variations in temperature and atmospheric conditions without distortion or deterioration or the setting up of undue stresses which may impair suitability of the various parts for the work which they have to perform.

Similar parts, particularly removable ones, shall be interchangeable.

Pipes and pipe fittings, screws, studs, nuts and bolts used for external connections shall be as per the relevant standards. Steel bolts and nuts exposed to atmosphere shall be galvanized/Stainless steel.

Nuts, bolts and pins used inside the transformers and tap changer compartments shall be provided with lock washers or locknuts.

Exposed parts shall not have pockets where water can collect.

Internal design of transformer shall ensure that air is not trapped in any location.

Material in contact with oil shall be such as not to contribute to the formation of acid in oil. Surface in contact with oil shall not be galvanized or cadmium plated.

Labels, indelibly marked, shall be provided for all identifiable accessories like relays, switches, current transformers etc. All label plates shall be of non-corrodible material.

All internal connections and fastenings shall be capable of operating under overloads and over-excitation, allowed as per specified standards without injury.

Transformer and accessories shall be designed to facilitate proper operation, inspection, maintenance and repairs.

No patching, plugging, shimming or other such means of overcoming defects; discrepancies or errors will be accepted.

Schematic Drawing of the wiring, including external cables shall be put under the prospane sheet on the inside door of the transformer marshalling box.

PAINTING

The interior of all transformer tanks and other oil filled chambers and internal structural steel work shall be cleaned of all scale and rust by shot blasting. These surfaces shall be painted with not less than two coats of heat resistant, oil insoluble and insulating varnish. Steel surfaces exposed to the

weather shall be thoroughly cleaned and have a priming coat of zinc chromate applied. The second coat shall be of glossy oil and weather resisting non fading paint. Painting shade shall be approved by employer during detailed design engineering stage.

Metal parts not accessible for painting shall be made of corrosion resistant material.

Interior surfaces of mechanism chambers and marshalling kiosks shall receive three coats of paint after proper cleaning. The final coat shall be of a light colored anti-corrosion paint.

All paints shall be carefully selected to withstand heat, rain and extremes of weather. The paint shall not scale off or crinkle or be removed by abrasion due to normal handling.

In case finish paint chips off or crinkle during transit or installation, the contractor shall arrange for repainting transformer at site at his cost. The paint for repainting shall be supplied by the contractor.

DETAILED DESCRIPTION

The detailed description of various parts of the Transformer is as follows:

TANK

The Transformer tank and cover shall be fabricated from high grade low carbon plate steel of adequate thickness and tested quality. The tank and the cover shall be of welded construction.

Lifting lugs or eyes shall be provided on the Transformer tank for handling during assembly or dismantling. These lugs or eyes shall also be used for lifting of the complete Transformer with the help of crane during handling. A minimum of four jacking pads shall be provided in accessible position in tank to enable raising or lowering of complete Transformer (with oil) and changing the plane of rotation of wheels using hydraulic jacks.

Tank shall be designed to permit lifting (without any distortion) by crane or jacks of the complete transformer assembly filled with oil. Suitable lugs and bosses shall be provided for this purpose. The Transformer design shall be such that the tank will not be split between lower and upper connections for untanking.

All beams, flanges, lifting lugs, braces and permanent parts attached to the tank, shall be welded and where practicable, they shall be double welded.

The tank shall have sufficient strength to withstand without distortion, filling under vacuum and continuous internal gas pressure of minimum 0.35 Kg/cm2 with oil at operating level. The main tank body of the transformer, excluding tap changing compartments and radiators, shall be capable of withstanding pressure of 760 mm of Hg.

Inspection hole(s) with welded flange(s) and bolted cover(s) shall be provided on the tank cover. The inspection hole(s) shall be of sufficient size to afford easy access to the lower ends of the bushings, testing of earth connection, terminals etc. The design should be such that water shall not collect near the gasketed joints. At least two openings, one at each end of the tank shall be provided.

The tank cover shall be fitted with pockets for a thermometer and for the bulbs of oil. & winding temperature indicator. The thermometer pockets shall be fitted with a captive screwed top to prevent ingress of water. The pockets for the oil temperature indicator shall be located in the zone of maximum oil temperature and it shall be possible to remove the instrument bulbs without lowering the oil in the tank.

All bolted connections to the tank shall be fitted with suitable oil-tight gaskets which shall give satisfactory service under the operating conditions. Special attention shall be given to the methods of making the hot oil-tight joints between the tank and the cover as also between the tank cover and the bushings and all outlets to ensure that the joint can be remade satisfactorily and with ease, with the help of semi-skilled labor. Where compressible gaskets are used, steps shall be provided to prevent over-compression.

All tank gaskets used shall be of NBR (Acrylonitrile Butadiene Rubber) suitable for above temperature conditions, expected to be encountered during operation. The gasket material and additives should be fully compatible with transformer insulating fluid/oil. The gasket should not contain oil soluble Sulphur compounds. The properties of all the above gaskets/O-Rings shall comply with the requirements of type-IV rubber of IS-11149. Gaskets and O-rings shall be replaced every time whenever the joints are opened.

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

TANK COVER

The transformer top shall be provided with a detachable tank cover with bolted flanged gasket joint. Lifting lugs shall be provided for removing the cover. The surface of the cover shall be suitably sloped so that it does not retain rainwater.

CONSERVATOR TANK

The conservator tank shall have an adequate capacity between the highest and lowest visible levels to meet the requirement of expansion of the total cold oil volume in the transformer & cooling equipment from the minimum ambient temperature to 90°C.

A conservator complete with sump and drain valve (so placed as to drain the conservator completely) shall be provided in such a position of the Transformer so as not to obstruct the electrical

connections to the Transformer and bolted so appropriately that it can be easily removed for clearing purpose.

One prismatic oil level gauge & one magnetic oil level gauge, the latter with low level electrically insulated alarm contacts and a dial showing minimum, maximum, and normal oil levels shall be fitted at a height readable from the Transformer base level. Taps or valves shall not be fitted to the oil gauges.

The conservator tank shall be fitted with flexible diaphragm.

Transformer shall be provided with thermo siphon fitters to prolong the life of transformer.

The oil pipe from the base of the conservator tank shall project into the conservator for a distance of not less than 50 mm so as to form a water trap.

The oil connection from the Transformer tank to the conservator vessel up to the Buchholz relay shall be arranged, at a rising angle of 3 to 7 degrees to the horizontal & shall consist of 80 mm inside diameter pipe.

The conservator shall be provided with a valve to cut off the oil supply to the Transformer after providing a straight run of pipe for at least a length of 5 times the internal diameter of the pipe on the tank side and at least 3 times the internal diameter of the pipe on the conservator side of the Gas & Oil actuated (Buchholz) relay. Isolating valve shall be provided on both sides of the Buchholz relay.

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

The conservator should preferably be on the left side of the tank while viewing from HV side.

The MOG and prismatic oil level gauge should not be obstructed with radiator bank, and it should be clearly visible from ground.

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

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

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 stenciled 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".

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

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 be saturated with oxygen. Air cells with well proven long-life characteristics shall be preferred.

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

The conservator vessel shall be fitted with a breather in which silica gel is the dehydrating agent and designed in such a way as to ensure the following: -

a) The passage of air is through the silica gel.

b) The external atmosphere is not continuously in contact with the silica gel.

c) The moisture absorption indicated by a change in color of the tinted crystals can be easily observed from distance.

d) The breather shall be mounted approximately 1400 mm above ground level. In addition to the silica gel breather, an oil-resistant synthetic diaphragm seal/bag/air cell shall be installed on the conservator to prevent direct contact between oil & air. The magnetic oil level gauge provided with the conservator should have contacts for giving alarm when the air cell gets damaged or sinks. Instead of silica gel breather as specified, the Supplier may furnish the details of other alternative method considered to be more efficient & effective for breathing for consideration of the Employer along with relative merits of the offered method.

To minimize the ingress of moisture three breathers (of identical size) for 220kV and above voltage class transformer/ and two breathers (of identical size) for below 220kV class transformer/ shall be connected in series for main tank conservator. Manufacturer shall provide flexible connection pipes to be used during replacement of any silica gel breather.

Regenerative maintenance free breather may also be used if mutually agreed with the employer.

UNDER CARRIAGE

The transformer tank shall be supported on steel structure with detachable forged steel flanged bidirectional wheels suitable for moving the transformer completely filled with oil. A 1676 mm

convenient track gauge for motion in both longitudinal and transverse directions shall be installed by the Employer for which necessary drawing indicating rail size, track gauge dimension, embedment details showing fixing of rails in concrete shall be provided by the supplier. Means shall be provided for locking the swivel movements in positions, parallel to and at right angles to the longitudinal axis of the tank. Suitable stoppers for the track wheels shall also be supplied. Flanged wheels shall be spaced accordingly. Wheels shall be provided with suitable bearings which will resist rust and corrosion and shall be equipped with fittings for lubrication.

The necessary arrangement for clamping of the wheels with the rails, capable of being put on and off easily, shall also be provided by the supplier.

Jacking pads shall be provided on the transformer. It shall be possible to change the direction of the wheels through 90 degrees when the transformer is lifted on jacks to permit movement of the transformer both in longitudinal and transverse directions.

A set of hydraulic jacks (4 Nos.) for lifting the transformer shall be supplied by the supplier, for each transformer.

Pulling eyes along with adequate capacity equipment for haulage & turning of Transformers by 90 degrees shall be provided by the supplier to facilitate haulage of the Transformers and these shall be suitably braced in vertical direction so that bending does not occur when the pull has vertical components.

CORE

The magnetic circuit shall be constructed from high grade cold rolled non-ageing grain-oriented silicon steel lamination known as Hi-B Grade or superior grade.

The laminations shall be free of all burst and sharp projections. Each sheet shall have an insulating coating resistant to the action of hot oil.

The core shall be clamped by epoxy resin clamps having sufficient strength and rigidity to withstand the short circuit forces, if the core bolts are used to clamp the core. The insulation for the core to bolts and core to clamp plates shall be designed to withstand a voltage of 2 kV AC for one minute. The framework and clamping arrangements shall be earthed in accordance with relevant IEC.

The completed core and coil shall be so assembled that the axis and the plane of the outer surface of the core stack shall not deviate from the vertical plane by more than 25 mm.

All steel sections used for supporting the core shall be thoroughly shot or sand blasted, after cutting, drilling and welding. Adequate care shall be exercised in the selection, treatment and handling of core steel to ensure that the laminations are flat, and the finally assembled core is free from

distortion. Laminations shall be coated with a durable baked enamel/fiber glass insulation coating which shall be inert to the action of hot Transformer oil.

The finally assembled core with all the clamping structures shall be free from deformation and shall not vibrate during operation.

The core clamping structure shall be designed to minimize eddy current loss.

The framework and clamping arrangements shall be securely earthed.

The core shall be carefully assembled and rigidly clamped to ensure adequate mechanical strength.

Oil ducts shall be provided where necessary to ensure adequate cooling. The welding structure and major insulation shall not obstruct the free flow of oil through such ducts.

The design of magnetic circuit should 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 angle to the plane of the lamination which may cause local heating. The supporting framework of the cores shall be so designed as to avoid the presence of pockets which would prevent complete emptying of the tank through the drain valve or cause trapping of air during filling.

The construction is to be of `core' type. The core shall be provided with lugs suitable for lifting the complete core and coil assembly. The core and coil assembly shall be so fixed in the tank that shifting will not occur during transport or short circuits. All parts of the cores shall be of robust design capable of withstanding any shocks to which they may be subjected during lifting, transport, installation and worst forces during service.

The magnetization characteristics of the Transformer for impressed voltage up to 1.8 p.u. shall be furnished during design stage.

Adequate lifting lugs shall be provided to enable the core and winding to be lifted. The method of supporting the core structure in the tank and method of lifting weight of core and coil assembly shall be subject to Employer's approval. When lifted, the weight shall be carried from the base so that it does not subject core structure to undue stress. The drawing showing the arrangement of supporting the core and coil including their lifting arrangement shall be furnished for approval during design stage.

INTERNAL EARTHING

All internal metal parts of the transformer, with the exception of individual laminations, core bolts and their individual clamping plates shall be maintained at same fixed potential.

The top clamping structure shall be connected to the tank by a copper strap. The bottom clamping structure shall be earthed by one or more of the following methods:

By connection through vertical tie-rods to the top structure.

By direct metal to metal contact with the tank base.

By a connection to the top structure on the same side of the core as the main earth connection to the tank.

Earthing of core clamping structure

It shall be ensured that all the laminations of the core shall be at earth potential. Shorting bridge piece shall be provided at core duct location. One point shall be taken out from the core at the top and shall be shorted to the tank at the tank cover. The core and clamp earthing shall be done outside the tank and no internal earthing arrangement shall be provided.

The magnetic circuit shall be connected to the clamping structure at one point only and this shall be brought out of the top cover of the transformer tank through a suitably rated insulator. A disconnecting link shall be provided on transformer tank to facilitate disconnections from ground for IR measurement purpose. The connection to the link from the core shall be on the same side of the core as the main earth connection. Magnetic circuits having an insulated sectional construction shall be provided with a separate link for each individual section.

Earthing of coils clamping rings

Where coil clamping rings are of metal, each ring shall be connected to the adjacent core clamping structure on the same side of Transformer as the main earth connections.

All earthing connections with the exception of those from the individual coil clamping rings shall have a cross-sectional area of not less than 0.8sq cm. Connections inserted between laminations of different sections of core shall have a cross-sectional area of not less than 0.2 Sq cm.

WINDING

Winding shall be subjected to a shrinking and seasoning process, so that no further shrinkage occurs during service. Adjustable devices shall be provided for taking up possible shrinkage in service.

All low voltage windings for use in the circular coil concentric winding shall be wound on a performed insulating cylinder for mechanical protection of the winding in handling and placing around the core.

Winding shall not contain sharp bends which might damage the insulation or produce high dielectric stresses. The conductors shall be transposed at sufficient intervals in order to minimize eddy currents and equalize the distribution of currents & temperatures along the windings. No strip conductor wound on edge shall have a width exceeding six times its thickness.

Materials used in the insulation and assembly of the windings shall be insoluble, non-catalytic and chemically inactive in the hot transformer oil and shall not liable to soften, ooze out, shrink or collapse or the otherwise affected under the operating conditions.

Varnish application on coil windings may be given only for mechanical protection and not for improvement in dielectric properties. In no case varnish or other adhesive, be used which will seal the coil and prevent evacuation of air and moisture and impregnation by oil.

Winding and connections shall be braced to withstand shocks during transport or short circuit.

Permanent current carrying joints in the windings and leads shall be welded or brazed. Clamping bolts for current carrying parts inside oil shall be made of oil-resistant material which shall not be affected by acidity in the oil. Steel bolts, if used, shall be suitably treated.

Terminals of all windings shall be brought out of the tank through bushings for external connections.

The completed core and coil assembly shall be dried in vacuum at not more than 0.5mm of mercury absolute pressure and shall be immediately impregnated with oil after the drying process to ensure the elimination of air and moisture within the insulation. Vacuum may be applied in either vacuum over or in the transformer tank.

The winding shall be so designed that all coil assemblies of identical voltage ratings shall be interchangeable and field repairs to the winding can be made readily without special equipment. The coils shall have high dielectric strength.

Coils shall be made of continuous smooth high grade electrolytic copper conductor, shaped and braced to provide for expansion and contraction due to temperature changes. Excessive current densities shall be avoided.

Adequate barriers shall be provided between coils and core and between high and low voltage coil. End turns shall have additional protection against abnormal line disturbances.

The insulation of winding shall be designed to withstand voltage stress arising from surge in transmission lines due to atmospheric or transient conditions caused by switching etc.

Tapping's shall not be brought out from inside the coil or from intermediate turns and shall be so arranged as to preserve as far as possible magnetic balance of the transformer at all voltage ratios.

INSULATING OIL

The insulating oil for the transformers shall be of EHV grade, generally conforming IEC 60296 /Equivalent international standards. No inhibitor shall be used in oil.

The quantity of oil required for the first filling of the transformer shall be stated in the bid. The bidder shall quote the price of transformer complete with first filling of oil plus 10% extra. The transformer oil shall be supplied in non-returnable containers/drums.

The design and materials used in the construction of the transformer should be such as to reduce the risk of the development of acidity in the oil.

PCB type insulating oil is prohibited.

The contractor shall dispatch the transformer filled with oil or in an atmosphere of Nitrogen. In the former case, the contractor shall take care of the weight limitation on transport and handling facility at site. In the later case necessary arrangement shall be ensured by the contractor to take care of pressure drop of Nitrogen during transit and storage. A gas pressure valve with necessary pressure gauge and adopter valve shall be provided.

VALVES

Valves shall be of forged carbon steel up to 50 mm size and of gun metal or of cast iron bodies with gun metal fittings for sizes above 50 mm. They shall be of full way type with screwed ends and shall be opened by turning counterclockwise when facing the hand wheel. There shall be no oil leakage when the valves are in closed position.

Each valve shall be provided with an indicator to show the open and closed positions and shall be provided with facility for padlocking in either open or closed position. All screwed valves shall be furnished with pipe plugs for protection. Padlocks with duplicate keys shall be supplied along with the valves.

All valves except screwed valves shall be provided with flanges having machined faced drilled to suit the applicable requirements. Oil tight blanking plates shall be provided for each connection for use when any radiator is detached and for all valves opening to atmosphere. If any special radiator valve tools are required, the Contractor shall supply the same.

Each transformer shall be provided with following valves on the tank:

a) Drain valve so located as to completely drain the tank.
b) Two filter valves on diagonally opposite corners, of 50 mm size.
c) Oil sampling valves not less than 8 mm at top and bottom of main tank.
d) One 15 mm air release plug.
e) Valves between radiators and tank.
f) Drain and filter valves shall be suitable for applying vacuum as specified in the specifications.

BUSHINGS

All porcelain used in bushings shall be homogeneous, anti-fog, non-porous, uniformly glazed to brown colour and free from blisters, burns and other defects.

Stress due to expansion and contraction in any part of the bushing shall not lead to deterioration.

Bushings shall be designed and tested to comply with the latest edition of applicable standards IEC 60137-2008 & 60518 and to operate in foggy conditions.

Liquid/oil-filled bushings shall be equipped with liquid level indicators and means for sampling and draining the liquid. The angle of inclination to vertical shall not exceed 30 degrees. Tap for capacitance test shall be provided for condensers.

The bushings shall have puncture strength greater than the dry flash over value. Further, the spacing between the bushing shall be adequate to prevent flash over under all conditions of operation.

Bushing flanges shall not be of re-entrant shape which may trap air. Bushing turrets shall be provided with vent pipes which shall be connected to route any gas collection through the Buchholz relay.

Bushings for 72.5 kV voltages and above shall be condenser type.

Bushings rated for 600A and above shall have non-ferrous flanges and hardware.

Clamps and fittings made of steel or malleable iron shall be galvanized. All bolt threads shall be greased before erection.

Bushing shall be so located on the transformers that full flashover strength will be utilized. Minimum clearances as required for the BIL shall be realized between live parts and live parts to earthed structures.

All applicable routine and type tests certificates of the bushings shall be furnished for approval.

Bushing shall be supplied with bimetallic/terminal connector/clamp suitable for fixing to bushing terminals.

The connector/clamp shall be rated to carry the bushing rated current without exceeding a temperature rise of 55+°Cover a max ambient of 42 °C. The connector/clamp shall be designed to be corona free at the maximum rated line to ground voltage.

Weatherproof outdoor type class porcelain bushings shall be provided for HV, LV & TV side neutral terminal of Transformer. The neutral terminals of the Transformer bank shall be suitable for connection to station ground mat through bimetallic connector. Bushing of identical voltage rating shall be interchangeable.

The insulation class of high voltage neutral bushing shall be properly coordinated with the insulation class of the neutral of the low voltage winding.

Each bushing shall be so coordinated with the transformer insulation that all flashover will occur outside the tank.

COOLING ARRANGEMENTS

2x50% unit coolers shall be provided. Relevant calculations in this regard shall be submitted by the contractor at the time of detailed design engineering. Each unit cooler shall be provided with its own cooling fans, oil pumps and other accessories.

Cooling Fans: The motor blowers shall be direct driven suitable for continuous outdoor operation and complete with necessary air dusting. These shall be mounted independently from the radiator and in the case, these are radiator mounting type, use shall be made of some anti vibration means. Care shall be taken that the blower unit is capable of being removed without disturbing the radiator structure. The blades shall be suitably painted and shall not be of hollow sections. Suitably painted wire mesh guards with mesh not greater than 25mm shall be provided to prevent accidental contact with the blades.

MOTORS

The motor shall be squirrel cage totally enclosed weatherproof type suitable for direct starting and for continuous running from 400/230 Volts, three phase/single phase 50 Hz supply. The motors shall comply IEC as applicable for continuous rated machine.

All motors shall be capable of continuous operation at frequency 50Hz with variation of ±5 % and 400/230 V AC ± 10 % variation of the normal voltage without injurious overheating.

All motors shall have ball or roller bearing with hexagonal nipples for greasing. In case of vertical spindle, motor shall have bearing capable of withstanding thrust, due to weight of the moving parts.

Varnished cambric or glass insulator shall be used for connections from stator winding to the terminal suitable for external wiring. The motor terminals shall be of stud type and totally enclosed.

Each motor shall be provided with a three-pole electrically operated contactor and with control gear of suitable design for both manual and automatic starting and stopping. Additional terminals for remote control of motors should be provided. Over-load and single phasing protection shall be provided. MCCBs shall be provided for the main supply. The equipment shall be mounted in the marshaling box.

COOLER CONTROL

All connection shall be so arranged as to allow either individual or collective operation of the motors, Alarm indication (audio and visual) for failure of fans and to indicate failure of power supply shall be provided.

The control equipment shall be installed in the marshaling box in readily accessible position.

The alarm indication for failure of power supply and failure of individual fans be provided through independent non trip alarm scheme conforming to the following:-

a. The closing of an initiating contact shall actuate a buzzer and will be accompanied by a flag indication on the concerned auxiliary relay.
b. The closing of an initiating contact shall glow a lamp, which will not be reset until the fault has cleared.
c. It shall be possible to silence the buzzer by pressing 'Accept' push button. If after canceling the alarm but before resetting the visual signal, the same fault persists the buzzer shall be suppressed.
d. If after canceling the alarm but before resetting the visual signal, some other fault takes place, the alarm accompanied by flag indication on appropriate auxiliary relay shall take place.
e. If after canceling the alarm and after resetting the visual signal, the same fault appears or some other fault take place, the alarm, flag indication and non-trip lamp indication shall reappear as usual.
f. The non-trip alarm acceptance shall be by means of push button and resetting of visual signal may also preferably be done through a push button.
g. Means shall be provided for test checking the lamp and alarm circuit at frequent intervals.
h. The equipment shall be suitable for 110 Volts DC operations.

Static facia annunciator conforming to the foregoing requirements of non-trip alarm scheme too would be acceptable.

MARSHALLING BOX AND MAIN CONTROL PANEL

Sheet stainless steel (minimum 3 mm thick), vermin proof, well-ventilated and weatherproof marshalling box with water-tight hinged and padlocked door of a suitable construction shall be provided for the transformer ancillary apparatus. The box shall have slopping roof and the interior and exterior painting shall be in accordance with the specification. Padlock along with duplicate keys shall be supplied for marshalling box. The degree of protection should be IP-55. The offered box shall be type tested for IP55.

The schematic diagram of the circuitry inside the marshalling box be prepared and fixed inside the door under a prospane sheet.

To prevent internal condensation, an approved type of metal clad heater controlled by a thermostat and watertight, single pole, iron-clad rotary switch mounted on the outside of the box, shall be provided.

The marshalling box shall accommodate the following equipment along with their completely wired repeat contacts:

Protection and control equipment for the cooling system.

Oil & Winding Temperature indicators of each phase of HV, LV & IV windings mounted at the height of not more than 1600 mm from the ground level.

Terminal boards & ground plates for incoming & outgoing cables and for Current Transformer secondary's and control equipment.

Illumination lamp and 5/15 Amp, 240 V, 3 pin socket with switch.

All incoming cables shall enter the marshalling box from the bottom and the gland plate shall not be less than 450 mm from the base of the box. The gland plates & associated compartment shall be sealed in a suitable manner to prevent the ingress of moisture from the cable trench.

Temperature Indicating devices

All transformers shall be provided with a dial type thermometer for indicating oil temperature. The indicator shall be fitted with a pointer to register maximum temp recorded and adjustable set of mercury contact for alarm and trip.

In addition, all the transformers shall be provided with a dial type Hot Spot winding temperature indicator for all the windings. The indicator shall have a pointer to register maximum temperature reached and four sets of adjustable mercury contacts for alarm, trip, automatic control of fans & remote indication. The static remote repeater (for winding temperature indicator) suitable for flush mounting shall be installed on remote tap changer control cubicle.

The temperature indicators shall be housed in marshaling box.

The alarm (mercury) and trip (mercury) contact of WTI & OTI shall be adjustable between 40 °C to 100 °C. The temperature difference between opening & closing of these mercury contacts shall not be more than 10 °C.

The mercury contacts used for controlling cooling plant motors shall be adjustable to close between 40 °C and 100 °C. The temperature differential between opening & closing of this mercury contact shall be between 10 °C to 15 °C.

All contacts should be accessible on removal of the cover adjustable to scale. It shall also be possible to move the pointers by hand for checking the operation of contacts and associated equipment.

In addition, each transformer shall be provided with a dial type thermometer for indicating the ambient temperature.

ON LOAD TAP CHANGER (OLTC)

Each transformer shall be provided with an on-load tap changer for varying its effective transformation ratio while the transformer is ON Load and without providing phase displacement. The salient features of the OLTC shall be as under:

1. The tap changing mechanism should be suitable for remote control operation from remote control panel in the control room in addition to being capable of local manual as well as local electrical operation.
2. Tap Changing Switch shall be provided on HV side in sixteen (16) equal steps of 1.25% for variation of voltage as per provided in table 6.0.
3. The on-circuit switch handle shall be so located as to be easily operated by a man standing on the Transformer floor and shall be provided with a locking arrangement along with tap position indicator.

The On Load Tap Changer (OLTC) shall be of high-speed resistor type principle, MR Germany or ABB Switzerland make. The on-load changer shall be vacuum technology including the following:

1. An oil immersed tap selector and arcing switch or arc suppressing tap selector, provided with reactor or resistor for reduction of make and breaks arcing voltages, overloads and short circuits.
2. OLTC in addition to the requirement of 8.3 of IEC 60214 for on-load tap changers, tap-changing equipment shall be capable of carrying the same currents, due to external short-circuit, as the transformer windings with they are associated.
3. The contract life of the moving and fixed contacts of the on-load tap selector switch shall be 600,000 operations minimum. The mechanical life shall be more than 800,000 operations. The number of operations between each maintenance period shall be 300,000 operations. The type test reports to support these figures shall be attached to the bid.
4. Motor driven mechanism.
5. Control and Protection devices.
6. Local tap changer position indicator.
7. Manual operation device.

The on-load tap changer shall be designed so that the contacts do not interrupt arc within the main tank of transformer. The tap changer selector and arcing switch or arc suppressing tap selector switch shall be located in one or more oil filled compartments. The diverter switch should be provided with gas vent and Buchholz relay. It should be designed so as to prevent the oil in tap selector and diverter switch compartments from mixing with the oil in transformer tank. The tap changer shall be capable of permitting parallel operation with other transformer of the same type.

The transformer shall give full load output on all taps without exceeding the limit of permissible temperature rise in oil and winding. The manual operating device shall be so located on the transformer that it can be operated by a man standing at the level of transformer track. It should be strong and robust in construction and shall be capable of giving satisfactory service under site

conditions including frequent operations. It shall not be possible to operate the electric drive when the manual operating gear is in use.

Necessary interlocks blocking independent control when the units are in parallel shall be provided.

The controls shall be so arranged as to ensure that when a tap change operation has commenced, it shall be completed independently of the operation of control relays or switches. Local or remote-control switch shall cause one tap movement only until, the control switch is returned to the off position between successive operations. Under abnormal conditions such as may occur when the contactor controlling one tap change sticks, the arrangement must be such as to switch off supply to the motor so that an out of step condition is limited to one tap difference between the units. Limit switches shall be provided to prevent over running of mechanism.

The transformer and the tap changing equipment shall be designed to permit full rated operation with tap changing equipment temporarily installed in any intermediate position. Details of out-of-step protection provided for the taps should be furnished in the tender.

The control scheme for the tap changer shall be provided for independent auto/ non-auto control of the tap changer when the transformers are in independent service.

In addition, provisions shall be made to enable parallel control also so that the tap changers of two or more transformers will be operated simultaneously when one unit is in parallel with another so that under normal conditions the tap changer will not become out of step and this will eliminate circulating current. Additional features like “Master / Follower” and visual indication, during the operation of motor shall also be incorporated.

A mechanical tap position indicator shall be provided on the tap changer in addition to remote indication equipment in the control room on remote control cubicle of OLTC. Necessary interlocks, for independent control when the units are in parallel, shall be provided.

The whole motor drive unit comprising the motor and its control gear including contactors, indicator, local electrical push buttons, five-digit operation counters, handle for manual control etc. as well as terminals for the control and indication wiring shall be housed in a dust proof kiosk mounted on a tap changer. A heating element with thermostat and switch shall also be provided in kiosk, for ensuring trouble free operation of the drive in cold weather. Arrangement shall be made for padlocking the kiosk. Tap position indication shall be visible by number appearing in a small glass window on the front of the kiosk. For remote indication an instrument type indication of digital type shall be provided, on a panel.

Any enclosed compartment not oil filled shall be adequately ventilated. All contactors, relay coils or other parts shall be suitably protected against corrosion or deterioration due to condensation, fungi etc.

The oil in the compartments of the main tap changing apparatus which do not contain contacts used for making or breaking current shall be maintained under conservator head by means of a pipe connection from the highest point of the chamber to the conservator. This connection shall be controlled by a suitable valve and shall be arranged so that any gas leaving the chamber will pass into the gas and oil actuated relay. A separate Buchholz relay with trip contacts shall be provided for the On-Load Tap Changer chamber.

Each compartment in which the oil is not maintained under conservator head shall be provided with a suitable direct reading oil level gauge.

A permanently legible lubrication chart shall be fitted with the driving mechanism chamber.

Local electrical control switches and the local operating gear shall be clearly labeled in suitable manner to indicate the direction of operation of tap changer.

The prices shall include necessary indoor and outdoor equipment except for power and control cables (between the tap changer and control room). Complete particulars of the on-load tap changer gear including, the capacity of the motor shall be stated in the tender.

The remote-control panel of OLTC gear to be installed in the control room should match in colour and dimensions with the Employer's transformer control panel for which details would be furnished to the successful bidder.

In addition to the fittings, auxiliaries and accessories considered necessary by the Employer the following items shall be provided.

For Local Electrical Control

1. Raise/ lower selector switch with a intermediate `OFF' position.
2. Auxiliary transformer (if necessary) along with MCB's and links.
3. Step by step contactor
4. Thermal over-load relay for the motor
5. Reversing contactor
6. ON/OFF automatic trip air circuit breaker for motor supply
7. Local /remote change-over selector switch.
8.

For Remote Electrical Independent Control

1. All equipment listed above.
2. Tap position indicator for mounting on control panel in the control room.
3. Signal lamp and buzzer, for indicating "Tap Change in Progress".

4. Raise lower switch push button type with intermediate off/position for remote control.
5. Emergency stop button (push button type) with visual indication.
6. Visual and alarm indication for non-completion of operation within pre-set time.
7. Provision of interlocking system for blocking independent control when the units are to run in parallel by providing inter lockable phase sequence selector switch.
8. All audio-visual indications should be brought to the Remote Tap Changer Cubicle (RTCC) panel.
9. A voltage chart along with HV, LV & IV and tap position.
10. Space Heater with thermostat & switch to avoid condensation of moisture.
11. Suitable 11 W, LED along with switch and 3 pin socket.

Note: - All equipment and their connections in RTCC panel should be properly marked. The buzzer/bell (Industrial type) should be provided.

For Simultaneous Parallel Operation of Transformers

1. All equipment listed above.
2. Out of step relay along with auxiliary relays, contactors and other equipment including a buzzer and signal lamp to indicate the out of step indication when transformers in one of pair of groups of rating in parallel are one tap out of step and also to trip the circuit breaker.
3. Control selector switches to enable to run a transformer as Master/Follower or independent in a group.
4. Selection switches for individual/parallel operation.
5. DC supply, Isolators, DC supply, ON' indication & DC failure, booster along with cancellation.

AUTOMATIC VOLTAGE CONTROL

Following methods of control shall be provided:

1. Automatic Independent – It shall be possible to select automatic independent control for each transformer irrespective of the method of control selected for any other of the associated transformers.
2. Automatic parallel- It shall be possible to select any transformer for master or follower control.
3. Interlocking shall be provided to not operate any tap changer by supervisory, remote or local electrical hand control while the equipment is switched for automatic operation.

VOLTAGE REGULATING RELAYS

Automatic voltage control shall be initiated by a voltage regulating relay of an approved type and suitable for flush mounting. The relay shall operate from the nominal reference voltage stated in the

schedule of requirement derived from a circuit mounted LV voltage transformer having Class 1.0 or 0.5 accuracy to IEC 60186 and the relay voltage reference balance point shall be adjustable.

The relay bandwidth shall preferably be adjustable to any value between 1.5 times and 2.5 times the transformer tap step percentage, the nominal setting being twice the transformer tap step percentage.

The relay shall be insensitive to frequency variation between the limits of 47 Hz and 51 Hz. The relay shall be complete with a time delay element adjustable between 10 to 120 seconds. The relay shall also incorporate an under voltage blocking facility which renders the control inoperative if the reference voltage falls below 80% of the nominal value with automatic restoration of control when the reference voltage rises to 85% of nominal value.

On each transformer the voltage transformer supply to the voltage regulating relay shall be mounted for partial or complete failure. The specified indicating lamp and alarm will be inoperative when the circuit breaker controlling the lower voltage side of the transformer is open and also that when the tap changer is on control other than automatic control.

The voltage regulating relays shall be equipped with in line compensation facility for impedance or load current based compensation.

The voltage regulating relays AVRs shall be suitable for parallel, slave/follower and independent mode of operation and shall communicate with the other relays fitted with the transformer to operate in parallel.

ANTI-EARTHQUAKE CLAMPING DEVICE

To prevent transformer movement during earthquake, a clamping device shall be provided for fixing the transformer to the foundation. The contractor shall supply necessary bolts for embedding in the concrete after transformer is placed on foundation. The arrangement shall be such that the transformer can be fixed to or unfastened from these bolts as desired.

FITTINGS

The following fittings shall be provided on the transformers:

1. Conservator with isolating valves, oil filling hole with cap and drain valve. The drain valve of 15 mm size for conservator vessels of dia. Up to 650 mm and of 25 mm size for conservator vessel dia. above 650 mm. The conservator vessel shall be fitted with constant oil pressure diaphragm oil sealing system to prevent oxidation and contamination of oil due to contact with air. The requirement of the system are as given below:
   a. Contact of the oil with atmosphere shall be prevented by using a flexible oil-resistant nitrile rubber air cell.
   b. Diaphragm of conservator shall be able to withstand the vacuum during installation/maintenance periods. Otherwise, provision shall be kept to isolate the

conservator from the main tank when the latter is under vacuum by providing a vacuum sealing valve in the pipe connecting main tank with the conservator.

c. The connection of the air cell to the top reservoir is by an airproof seal preventing entrance of air into the conservator.

d. The magnetic oil level gauge provided with the conservator shall have contacts for giving alarm when the air cell gets damaged or sinks.

2. Magnetic type oil level gauge (150 mm dia.) with low oil level alarm contacts. Prismatic/toughened glass oil level gauge.

3. Maintenance-free Dehydrating breather shall be provided at a level of 1300 mm above ground level & Each silica gel breather shall be equipped with a condition based self-learning microprocessor control unit for optimal maximization-controlled regeneration on the silica gel during phase when the transformer exhaling and LED status condition. The function should be tested via a test button or silica gel free breather is also accepted.

4. A double float type Buchholz relay with isolating valve, bleeding pipe and a testing cock, the test cock shall be suitable for a flexible (pipe connection for checking its operation). A 5 mm dia. Copper pipe shall be connected from the relay test cock to a valve located about 1.25 meters above ground level to facilitate sampling of gas with the transformer in service. Interconnection between gas collection box and relay should also be provided. The device shall be provided with two electrically independent ungrounded contacts, one for alarm on gas accumulation and the other for tripping on sudden oil surge. These contacts shall be wired up to transformer marshalling box. The relay shall be provided with shut off valve on the conservator side as well as on the tank side.

5. **Pressure relief device**

   A pressure relief device of sufficient size capable of resealing shall be provided for rapid release of any pressure that may be generated within the tank, and which may result in damage to the equipment. The device shall be spring loaded and shall be calibrated to operate at a set pressure of oil. The device shall be capable of resetting itself automatically to its original condition after release of excess pressure. The device shall be designed to eliminate any chattering of the valve during operation. The device shall be provided with suitable alarm & trip contacts. The device shall operate at a static pressure of less than the hydraulic test Pressure for the Transformer tank.

   A necessary air equalizer connection through a pipe connecting the pressure relief device to the conservator along with necessary alarm contacts shall be provided for relieving or equalizing the pressure in the pressure relief device. A suitable pipe shall be provided for draining the oil from the pressure relief device down to the oil pit.

6. Air release plugs in the top cover.

7. Inspection cover, access holes with bolted covers for access to inner ends of bushing, etc.
8. Winding temperature (hot spot) indicating device for local mounting complete in all respects. Winding temperature indicator shall have three sets of contacts to operate at different settings.
9. To provide winding temperature `high alarm'.
10. To provide temperature too high `trip'.
11. Dial thermometer with pocket for oil temperature indicator with one set of alarm and one set of trip contacts and maximum reading pointer.
12. Lifting eyes or lugs for the top cover, core and coils and for the complete transformer.
13. Jacking pads.
14. Haulage lugs.
15. Protected type mercury/alcohol in glass thermometer and a pocket to house the same.
16. Top and bottom filter valves on diagonally opposite ends with pad locking arrangement on both valves.
17. Top and bottom sampling valves.
18. Drain valve with pad locking arrangement.
19. Rating and connection diagram plate.
20. Two earthing terminals, each capable of carrying short circuit current of the Transformer for 4 seconds shall be provided at bottom at two corners of the Transformer tank. The earthing terminals shall be suitable for bolted connection and connection to the earth mat risers.
21. Bi-directional flagged rollers with locking and bolting device.
22. Marshalling Box (MB)
23. Shut off valve on both sides of flexible pipe connections between radiator bank and transformer tank.
24. Cooling Accessories:
25. Requisite number of radiators provided with necessary valves
26. One shut off valve on top
27. One shut off valve at bottom
28. Air release device on top
29. Drain and sampling device at bottom
30. Lifting lugs.
31. Air release device and oil drain plug on oil pipe connectors.
32. Terminal marking plates for Current Transformers and Main Transformer.
33. On Load tap changer as per arrangement of similar equipment for main transformer.
34. Buchholz Relay.
35. Pressure Relief Valve with trip contacts.
36. Remote Tap changer Control Panel.
37. Any other equipment recommended or suggested by the manufacturer of OLTC.
38. One number ladder with provision for anti-climbing device.

Note:

i. The fittings listed above are indicative and any other fittings which are generally required for satisfactory operation of the transformer are deemed to be included in the quoted price of the transformer.

ii. The contacts of various devices required for alarm and trip shall be potentially free and shall be adequately rated for continuous, making and breaking current duties at 110 Volts D.C. (nominal).

CONTROL CONNECTIONS, ALARMS AND WIRING TERMINAL, BOARD AND FUSES

The Transformer manufacturer shall supply complete control equipment for the Transformers and sufficient contacts for its auxiliaries including cooling fans and various annunciations/alarms shall be provided. The control equipment for the Transformers shall be housed in the respective marshalling boxes of weatherproof construction. The supplier shall take care the provision of Auxiliary supplies to marshalling box by providing necessary MCCB and cables etc. The Transformer supplier shall make provision for repeat indications of winding temperature of all the phases of HV & LV windings, oil temperature, Buchholz relay status, pressure relief device status, AC/DC supply status etc.

The control equipment to be provided with the Transformer shall also include (but not limited to) necessary supply distribution arrangement consisting of switch fuse units contactors, overload relays, remote/local control switch, start/ stop push buttons etc.

Provision should be made in the Transformer control panels for annunciation alarms & trips for the following (but not limited to) abnormal conditions for which sufficient number of contacts shall be provided on the initiating relays/devices:

Alarms

1. H. V. Winding temperature 'High'
2. L. V. Winding temperature 'High'
3. T. V. Winding temperature 'High' (if applicable)
4. Oil temperature 'High'
5. Buchholz relay 'Alarm'
6. Oil level 'Low'
7. Differential pressure 'Low'
8. Power supply "Failure"

Trips

1. H. V. Winding temperature 'Very High'

2. L. V. Winding temperature 'Very High'

3. T. V. Winding temperature 'Very High' (if applicable)

4. Oil temperature 'Very High'

5. Buchholz relay 'Trip'

6. Pressure relief device operated

Normally no fuses shall be used anywhere. Instead of fuse, MCBs (both in AC & DC circuits) shall be used. Only in cases where a MCB cannot replace a fuse due to system requirements, a HRC fuse can be accepted.

All wiring connections, terminal boards, fuses MCB's and links shall be suitable for tropical atmosphere. Any wiring liable to be in contact with oil shall have oil resisting insulation and the bare ends of stranded wire shall be sweated together to prevent seepage of oil along the wire.

Panel connections should be neatly and squarely fixed to the panel. All instruments and panel wiring shall be run in PVC or non-rusting metal cleats of the compression type. All wiring to a panel shall be taken from suitable terminal boards.

Where conduits are used, the runs shall be laid with suitable falls, and the lowest parts of the run shall be external to the boxes. All conduit runs shall be adequately drained and ventilated. Conduits shall not be run at or below ground level.

When 400 Volt connections are taken through junction boxes or marshalling boxes, they shall be adequately screened and 400 Volts Danger Notice must be affixed to the outside of the junction boxes or marshalling box. Proper colour code for Red, Yellow, Blue wires shall be followed.

All box wiring shall be in accordance with relevant IEC. All wiring shall be of stranded copper (48 strands) of 1100 Volt grade and size not less than 2.5 sq mm. For CT Circuits 4 Sq.mm cable is to be used.

All wires on panels and all multicore cables shall have ferrules which bear the same number at both ends, as indicated in the relevant drawing.

At those points of interconnection between the wiring carried out by separate contractors, where a change of number cannot be avoided double ferrules shall be provided on each wire. The change of numbering shall be shown on the appropriate diagram of the equipment.

The same ferrule number shall not be used on wires in different circuits on the same panels.

Ferrules shall be of white insulating material and shall be provided with glossy finish to prevent the adhesion of dirt. They shall be clearly and durably marked in black and shall not be affected by dampness or oil.

Stranded wires shall be terminated with tinned Ross Courtney terminals, claw washers or crimped tubular lugs. Separate washers shall be suited to the size of the wire terminated. Wiring shall, in

general, be accommodated on the sides of the box and the wires for each circuit shall be separately grouped. Back of panel wiring shall be arranged so that access to the connecting items of relays and other apparatus is not impeded.

All circuits, in which the voltage exceeds 110 Volts, shall be kept physically separated from the remaining wiring. The function of each circuit shall be marked on the associated terminal boards.

Where apparatus is mounted on panels, all metal cases shall be separately earthed by means of stranded copper wire or strip having a cross section of not less than 2 sq. mm where strip is used, the joints shall be sweated. The copper wire shall have green colored insulation for earth connections.

All wiring diagram for control and relay panel shall preferably be drawn as viewed from the back and shall show the terminal boards arranged as in services.

Terminal board rows should be spaced adequately not less than 100 mm apart to permit convenient access to external cables and terminations.

Terminal boards shall be placed with respect to the cable gland (at a minimum distance of 200 mm) as to permit satisfactory arrangement of multicore cable tails.

Terminal boards shall have pairs of terminals for incoming and outgoing wires. Insulating barriers shall be provided between adjacent connections. The height of the barriers and the spacing between terminals shall be such as to give adequate protection while allowing easy access to terminals. The terminals shall be adequately protected with insulating dust proof covers. No live metal shall be exposed at the back of the terminal boards. CT terminals shall have shorting facilities. The terminals for CTs should have provision to insert suitable plugs and with isolating links. 20% spare terminals shall be provided.

All fuses shall be of the HRC cartridge type, and these shall be properly labelled, wherever these cannot be replaced by MCB as normally only MCB’s shall be used.

All interconnecting wiring, as per the final approved scheme between accessories of transformer and marshalling box is included in the scope of this specification and shall be done by the Transformer supplier.

The schematic diagram shall be drawn and fixed under a transparent prospane sheet on the inner side of the marshalling box cover.

As a rule, the fuses shall be replaced by Miniature Circuit Breakers
(MCBs) in the control and other supplies.

To avoid condensation in the MB, a space heater shall be provided with an MCB and thermostat.

Suitable 10W (min), LED light should be provided in the Marshalling Box for lightning purpose.

RADIO INTERFERENCE AND NOISE LEVEL

Transformers shall be designed with particular care to suppress at least the third and fifth harmonic voltages so as to minimize interference with communication circuits. Transformer noise level, when energized at normal voltage and frequency shall be as per NEMA stipulations.

NITROGEN INJECTION FIRE PROTECTION CUM EXTINGUISHING SYSTEM (NIFPES) FOR 60 and 100 MVA POWER TRANSFORMERS

The contractor shall provide the nitrogen injection fire protection cum extinguishing system. The fire protection system using nitrogen as fire quenching medium is required for 220/60/30 kV & 220/60/15kV transformer. NIFPES shall act as fire preventer by preventing transformer oil tank explosion and possible fire in case of internal faults. In the event of fire by external causes such as bushing fire, OLTC fires, fire from surrounding equipment etc, it shall act as a fast and effective fire fighter. NIFPES shall accomplish its role as fire preventer and extinguisher without employing water and/or carbon dioxide. Fire shall be put out within max. 3 minutes of system activation and within max. 30 seconds of commencement of nitrogen injection.

Activation of NIFPES

Mal-functioning of fire prevention/extinguishing systems is the major shortcoming which leads to interruption in power supply. The contractor shall ensure that the chances of malfunctioning of NIFPES are practically nil. To achieve this objective, the contractor should work out his scheme of activating signals which, while preventing mal-operation, should not be too rigorous to make the operation of NIFPES impracticable in case of actual need. Transformer isolation shall be the mandatory pre-requisite for activation of the system in automatic mode or remote mode in the control room. In addition, at least following electrical-signals shall be provided in series for activating NIFPES.

Auto Mode

a) For prevention of fire:

(i) Differential relay operation.

(ii) Buchholz relay paralleled with pressure relief valve.

(iii) Tripping of all connected breakers is a pre-requisite for initiation of system activation.

b) For extinguishing fire:

(i) Fire detector.

(ii) Buchholz relay paralleled with pressure relief valve.

(iii) Tripping of all connected breakers is a pre-requisite for initiation of system activation.

Manual Mode (Local/Remote): Tripping of all connected breakers is pre- requisite for initiation of system activation.

Manual Mode (Mechanical): Tripping of all connected breakers is a pre- requisite for initiation of system activation.

General description of NIFPES

Schematic of the system

NIFPES should be a standalone dedicated system for oil filled transformer. It should have a fire extinguishing (F.E.) cubicle placed on a plinth at a distance of 6-10 mtrs from the transformer. The F.E. cubicle may be connected to the transformer oil tank (near its top) and to the oil pit (of capacity approx. equal to 10% of transformer oil tank) from its bottom through oil pipes with gate valves. The F.E. cubicle should house a pressurized nitrogen cylinder connected to the transformer oil tank (near its bottom). Cable connections are to be provided from signal box placed on the transformer to the control box in the control room and from control box to F.E. cubicle. Fire detectors placed at the top of transformer are to be connected in parallel to the signal box. The signal box may be connected to a

Pre-stressed non-return valve fitted between the conservator tank and Buchholz relay. Control box is also to be connected to relay panel in control room for system activation signals.

Operation

On receipt of all activating signals, drain of pre-determined quantity of oil commences thus removing high temp top oil layer. Simultaneously nitrogen is injected under high pressure at a pre-fixed rate, stirring the oil thus bringing the temperature of top oil layer down. Nitrogen occupies the space created by oil drained out and acts as an insulating layer between the tank oil and fire on top cover. Pre-stressed non-return valve blocks oil flow from conservator tank, thus isolating it & preventing aggravation of fire.

System components

Broadly, NIFPES shall consist of the following components. It is emphasized that all components, irrespective of their exclusion in the details given below, necessary for fast reliable and effective working of NIFPES shall be considered within the scope of supply.

Fire extinguishing cubicle

It shall be made of 3 mm thick steel sheet, painted dark red from inside and outside with hinged split doors fitted with high quality tamper proof lock. It shall be complete with the base frame and the following:-

i. Nitrogen gas cylinder with regulator and falling pressure electrical contact manometer.
ii. Oil drain pipe with mechanical quick drain valve.
iii. Electro mechanical control equipment for oil drain and pre-determined regulated nitrogen release.
iv. Pressure monitoring switch for back-up protection for nitrogen release.
v. Limit switches for monitoring of the system.
vi. Flanges on top panel for connecting oil drain and nitrogen injection pipes for transformer.
vii. Panel lighting (LED type)
viii. Oil drain pipe extension of suitable sizes for connecting pipes to oil pit.

Control box

Control box for monitoring system operation, automatic control and remote operation, with following alarms indication, light switches, push buttons, audio signal, line fault detection suitable for tripping and signaling on 110V DC supply and these Signals to be communicated with SCADA System.

i. System on
ii. Pre-stressed non return valve (PNRV)
iii. open
iv. Oil drain valve closed
v. Gas inlet valve closed
vi. PNRV closed
vii. Fire detector trip
viii. Buchholz relay trip
ix. Oil drain valve open
x. Extinction in progress
xi. Cylinder pressure low
xii. Differential relay trip
xiii. PRV operated
xiv. Transformer trip
xv. System out of service
xvi. Line fault fire detector
xvii. Line fault differential relay
xviii. Line fault Buchholz relay
xix. Line fault PRV
xx. Line fault transformer trip
xxi. Line fault PNRV

xxii. Auto / Manual/Off
xxiii. Extinction release on
xxiv. Extinction release off
xxv. Lamp test
xxvi. Visual/Audio alarm
xxvii. Visual/Audio alarm
xxviii. Visual/audio alarm for DC supply fail

Pre-stressed non return valve (PNRV)

PNRV is to be fitted in the conservator pipe line between conservator and Buchholz relay. It shall have the proximity switch for remote alarm, indication and with visual position indicator the valve will not isolate conservator during, normal flow of oil during filtration or filling, Locking plates shall be provided with handle for pad locking to ensure no movement for valve position during service and filter position . The PNRV should be of the best quality because malfunction of PNRV shall be of serious consequence as its closing leads to stoppage of breathing of transformer.

Fire detectors

The system shall be complete with adequate number of fire detectors fitted on the top of oil tank, OLTC for heat sensing, each fitted with two no. cable glands (water proof/weather proof).

Signal box

It shall be fitted on the transformer for terminating cable connections from PNRV and fire detectors and for further connection to the control box.

Cables

Fire survival copper cables, able to withstand 75ºC, Fire retardant low smoke (FRLS) cable 12 core x 2.5 mm sq. for connection between transformer signal box/marshalling box to control box and control box to fire extinguishing cubicle shall be used. Fire retardant low smoke cable 4 core x 2.5mm sq. for connection between control box to DC supply source and fire extinguishing cubicle to AC supply source, signal Box/marshalling box to pre-stressed non return valve connection on transformer shall be used.

Pipes

Pipes, complete with connections, flanges, bends tees etc. shall be supplied along with the system.

Other items

A. Oil drain and nitrogen injection openings with gate valves on transformer tank at suitable locations.

B. Flanges with dummy piece in conservator pipe between Buchholz relay and conservator tank for fixing PNRV.

C. Fire detector brackets on transformer top cover.

D. Spare potential free contacts for system activating signals i.e. differential relay Buchholz relay, pressure relief valve, transformer isolation (master trip relay).

E. Pipe connections between transformer to fire extinguishing cubicle and fire extinguishing cubicle to oil pit.

F. Cabling on transformer top cover for fire detectors to be connected in parallel and inter cabling between signal box to control box and control box to fire extinguishing cubicle.

G. Mild steel oil tank with moisture proof coating and sheet thickness of minimum 5 mm, with watertight cover, to be placed in the oil pit. This tank shall be provided with the manhole, air vent pipe through silica gel breather, drain valve and a spare gate valve at the top.

H. Gate valves on oil drain pipe and nitrogen injection pipe should be able to withstand full vacuum. A non-return valve shall also be fitted on nitrogen injection pipe between transformer and gate valve.

I. The F.E. cubicle shall be painted with post office red color (shade 538 as per IEC). All the exposed parts i.e. pipes, supports, signal box etc shall be painted with enameled paint.

J. Civil works of Fire extinguishing cubicle.

Interlocks

It shall be ensured that once the NIFPES gets activated manually or in auto mode, all the connected breakers shall not close until the system is actually put in OFF mode. Also, PNRV should close only if all the connected breakers are open.

Technical particulars

I. Fire extinction period	
On commencement of nitrogen injection	Max. 30 Seconds
II. From the moment of system activation to	Max. 3 Minutes
III. Complete cooling	14 °C
IV. Fire detectors heat sensing temperature	141 °C
V. Heat sensing area	800mm radius
VI. Pre-stressed non return valve setting	Minimum 40 liter per minute for normal operation and minimum 60 liter per minute for abnormal operation

VII.	Min. Capacity of nitrogen cylinder	$10m^3$ gas at pressure of $150kg/cm^3$upto 60000 liter oil capacity of tank and $20m^3$ gas at pressure of $150kg/cm^2$ above 60000 liters.
VIII.	Power Source (Control Box)	110V DC
IX.	Fire extinguishing cubicle for lighting	230V AC

TESTS

The Transformers shall be completely factory tested before dispatch in accordance with the IEC 60076/ Equivalent international standards and with such other tests as may be necessary to ensure that the equipment is satisfactory and is in accordance with this specification. No equipment shall be dispatched from the manufacturers work before the relevant test reports have been approved by the Employer.

Routine Tests

Routine tests on transformers shall include tests stated in latest issue of IEC 60076. These tests shall also include but shall not be limited to the following:

1. Measurement of winding resistance.
2. Voltage ratio on each tapping and checking of voltage vector relationship.
3. Impedance at principal, minimum & maximum tapping position
4. Magnetic balance test.
5. Load losses.
6. No load losses and no-load current.
7. Insulation resistance for 60 seconds and 15 seconds (R60/R15) and polarization index i.e. Insulation Resistance for 10 minutes and one minute (R10/R1).
8. Induced over voltage withstand test.
9. Separate source voltage withstand test (applied potential).
10. Tan delta measurement and capacitance of each winding to earth (with all other windings earthed) & between all windings connected together to earth.
11. Measurement of acoustic noise level.
12. Measurement of Zero sequence impedance.
13. Lightning Impulse Test
14. **Di-electric Tests:**

    For Transformers

i. Short duration AC
ii. Separate source AC
iii. Long Duration AC

Type Tests

The supplier shall at its own expense carryout at the place of manufacture all such tests and/or inspection of the equipment as per relevant IEC 60076. The employer or their designated representative shall be entitled to attend the aforesaid test and/or inspections.

Type Test:

n) The Bidder shall propose the type tested materials. The successful Bidder shall also submit the type test certificates for each of the above-mentioned items for approval of the Employer before supply. The type tests conducted earlier should have either been conducted in accredited laboratory (accredited based on IEC Guide 25 / 17025 or EN 45001 by the national accreditation body of the country where laboratory is located). The type test reports shall not be earlier than 5 years.

o) In case the type test reports conducted earlier than 5 (five) years prior to the originally Scheduled date of bid opening, the contractor shall repeat these test(s) at no extra cost to the Employer.

p) In case the type test certificates are not as per the requirement, the bidder shall upon the award of the contract undertake to carry out the required type tests from an independent laboratory accredited by reputed accreditation agencies or in a laboratory nominated by the Employer /Employee before the delivery of corresponding equipment at no extra cost to the Employer /Employee including any transportation or costs associated with performing such tests

q) **Routine Test:**

These tests would be conducted or new material and other finished material in accordance with provision of internationally accepted standards. Proper record of all routine tests has to be maintained and made available to the employer on demand.

Acceptance Test:

The manufacturer shall carry out all type & routine tests specified in **"Annexure-P"** during final acceptance test (FAT) as per Quality Assurance Programme approved by the employer on each and every lot of finished material which is ready for dispatch. The tests shall be conducted in presence of employer authorized representatives.

NOTE: For all type, routine and acceptance test, the acceptance value shall be the values guaranteed by the bidder on the guaranteed technical particulars of his proposal or the test value specified in the specification, whichever is more stringent for that particular test.

No material shall be dispatched without the approval of test and inspection report

The transformer shall be subjected to the following type/special tests as per the IEC 60076/ Equivalent international standards in the presence of the Employers representative:

1. **Temperature Rise Test along with Dissolved gas analysis test.**
   The temperature rise test shall be carried out in accordance with IEC 60076/ Equivalent international standards. The Temperature rise shall not exceed the values stated elsewhere in the specification. Test shall be carried out by feeding 1.1 time the total guaranteed losses at 75^0C at highest current tap.
2. Test on OLTC**.**
3. All routine and type test shall be carried out free of cost.

Special Test

Dynamic Short Circuit Test: Short circuit test on one unit of each rating **(Randomly selected from the Lot)** shall be conducted in the presence of employer's representative or if short circuit test on an **identical unit** (Offered) of transformer has already been conducted the same shall be submitted for consideration. However, short circuit calculations/simulation shall be submitted to prove the withstanding capability of transformer for short circuit forces.

TEST WAIVER, PROCEDURES AND COSTS

The Employer, at his discretion, may waive impulse tests provided type test reports of impulse voltage withstand tests carried out on an **identical unit** in any Government approved Laboratory within last 10 years are furnished by the manufacturer.

No load losses and exciting current shall be measured at rated voltage, rated frequency and at 90% and 110% of rated voltage, both before and after the lightning impulse tests.

The method of test loading shall be described in the test report for determination of both average and hottest spot temperature. Where the winding temperature equipment are specified, data shall also be included for calibration of hottest spot temperature indicator.

Resistance of each winding of each phase shall be measured at principal and at all the taps and corrected to 75oC.

Impedance voltage shall be measured at principal and at all taps,

No load Loss Measurement at 400 Volt.

STAGE INSPECTION

The Employer reserves the right for stage inspection at the time of manufacturing of the transformers at various stages, to ensure that internal details are in accordance with specifications approved manufacturer drawings for which the supplier would give 15 days prior notice and the supplier would not go ahead with further production schedule without obtaining concurrence from the Employer.

a) Core:

Bidders will offer the core for inspection and approval by the Employer/Employer during the manufacturing stage.

Following tests shall be carried out:

(i) Measurement of flux density.

(ii) No load loss measurement by providing dummy coils at 90%, 100% and 110% rated voltage and frequency.

(iii) Physical inspection for quality of workmanship.

b) Windings:

(i) Measurement of cross-sectional area for current density.

(ii) Measurement of weight of bare copper/ cover by resistance methods.

(iii) Test may be carried out on sample of copper to assess its quality.

c) Tests on Transformer Tank

(i) **Vacuum Test:** One transformer tank of each size per lot shall be subjected to the vacuum pressure of 760 mm of mercury. The tanks designed for full vacuum shall be tested at an internal pressure of 3.33 kN/m^2 (25 mm of mercury) for one hour. The permanent deflection of flat plates after the vacuum has been released shall not exceed the value specified below on Transformers (or as per IEC/ Equivalent international standard) without affecting the performance of the transformer.

Horizontal length of flat plate (mm)	**Permanent Deflection (mm)**
Up to & including 750	5.0
751-1250	6.5
1251-1750	8.0
1751-2000	9.5
2001-2250	11.0
2251-2500	12.5
2501-3000	16.0
above 3000	19.0

(i) **Pressure Test:** One transformer tank of each size per lot together with its radiators, conservator vessel and other fittings shall be subjected to pressure corresponding to twice the normal head of oil or to the normal pressure plus 35 kN/m^2 square (51b/sq.in) whichever is lower measured at the base of the tank and will be maintained for one hour. The permanent deflection of flat plates after the excess pressure has been released shall not exceed the value specified as above.

(ii) The pressure relief device shall be subjected to increasing oil pressure. It shall operate before reaching the test pressure specified above. The operating pressure shall be recorded. The device shall seal off after the pressure in excess has been relieved (routine test).

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

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

(v) **Oil leakage test:** All tanks and oil filled compartments shall be tested for oil tightness by oil of a viscosity not greater than that of insulating oil to IEC: 60269,701 / Equivalent international standard at the specified ambient temperature and subjected to a pressure equal to the normal pressure plus 35 kN/m^2 square (5 lb/sq.in) measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours, during which time no leakage shall occur.

TESTS ON ASSOCIATED EQUIPMENT

Porcelain bushings, bushing current transformers, wherever provided, winding temperature indicating devices, Pressure Relief Device, Magnetic Oil Level gauge, RTCC Panel, dial thermometers, Cooling fan & motor assembly, Buchholz relays, On Load tap changer, coolers, control devices, insulating oil and other associated equipment shall be tested by the supplier in accordance with relevant IEC. If such equipment is purchased by the supplier from a sub-vendor, he shall have it tested to comply with these requirements.

SEQUENCE OF TESTING ON ASSEMBLED TRANSFORMER

Unless otherwise agreed, the sequence of testing shall be as follows:

1. Ratio and vector group
2. Winding resistance measurement
3. Insulation resistance measurement
4. Separate source voltage withstand test
5. Measurement of Iron losses
6. Load losses and impedance voltage measurement
7. Temperature rise test
8. Induced voltage withstand test

9. Tests on OLTC
10. Magnetic balance test

WITNESSING OF TESTS AND EXCESSIVE LOSSES

The Employer and/or his representative reserve the right to witness any or all tests, or to accord waiver at its sole discretion.

The Employer reserves the right to reject the Transformer if losses exceed the declared losses beyond tolerance limits as per IEC or if temperature rise of oil and winding exceed the values specified elsewhere.

CAPITALISATION OF LOSSES AND LIQUIDATED DAMAGES FOR EXCESSIVE LOSSES

The capitalization of guaranteed losses of the transformer shall be calculated as per the capitalization formula mentioned below and considered while evaluating the bids. The guaranteed values of no-load losses and load losses shall be stated in the bid. Liquidated damages will be applied to successful bidder (as mentioned below) for not achieving the quoted guaranteed figures.

Losses

a. Transformers with lower losses shall be preferred. The bidder shall indicate the values of load, no load losses and auxiliary losses of the transformer in his bid. He shall indicate whether losses are firm or subject to tolerance. If nothing is indicated regarding tolerance on losses, it will be considered that losses are not subject to tolerance. In case no ceiling is specified, these will be taken as per IS and the offer shall be loaded as per Table 7 of latest issue IEC 60076/ Equivalent international standards.

b. The losses are maximum allowable and there would not be any plus tolerance. Transformers with lower losses shall be preferred.

c. The guaranteed values of no-load losses at rated voltage & rated frequency and load losses & Auxiliary losses at rated output, rated voltage & rated frequency will be indicated in the Guaranteed Technical Particulars. The test figures for the no load, load losses& Auxiliary losses will be compared with the corresponding guaranteed values/figures for the purpose of penalty computations.

d. **The penalties shall be separately computed for:**
   i. The excess of test figures of the no load losses over the corresponding guaranteed figures.
   ii. The excess of the test figures for the load losses over the corresponding guaranteed figures.
   iii. The excess of the test figures of the aux. losses over the corresponding guaranteed figures.

e. The penalties per KW for the excess of no-load losses, load losses and auxiliary losses over the guaranteed values will be calculated at the rate mentioned below. The penalties will be applied pro-rata for fraction of a kilowatt.

f. No tolerance shall be permitted over the test figures of the losses, and no bonus shall be paid in case the test figures are less than the guaranteed values.

g. The Employer reserves the right to reject the Transformer(s) if the losses exceed the declared losses or the temperature rise in oil and of winding exceed the values specified in technical particulars or impedance value differs from the guaranteed value by more than the specified value.

Capitalization of losses

a. For the purpose of bid comparison, the transformer unit cost and losses shall be evaluated to get the transformer evaluated cost according to the formula below:

$$A = B+9,461C+5,259(D+G)$$

Where,

A = Evaluated cost of transformer in US Dollars

B=Unit cost of transformer in US Dollars according to the evaluation clause specified in the bid condition.

C= No load loss at room temperature not more than 40^0C in kW.

D=Load loss in kW at 75^0C.

G= Auxiliary losses (Cooling fans and Oil pumps) in kW.

b. The no load loss in kW at the rated voltage and frequency and load loss in kW at rated voltage, rated frequency, rated output and at 75 °C shall be quoted and these figures shall be guaranteed.

Liquidated damages for increase in losses

a. Penalty shall be applied to the successful bidder in case he is unable to achieve the quoted guaranteed figures during test at manufacturer's works as well as after commissioning at site at the following rates:

i.	For each kW of excess of no-load loss	US$ 12,000
ii.	For each kW of excess of load loss	US$ 7,000
iii.	For each kW of Excess of auxiliary loss	US$ 7,000

b. Losses as are subject to IEC 60076/ Equivalent international standards, the component losses shall be increased by 15% tolerance permissible as IEC 60076/ Equivalent international standards. In case firm losses are quoted, the tenders should clearly state that under no circumstances the losses will be more than the quoted firm losses.

c. Please note that the capitalization of losses as are subject to tolerance, the component losses would be increased by 15%. If it is question of acceptance of supplies the tolerance would be limited to

i. Total losses : 10% of total losses

ii. Component losses : 15% of each component losses

iii. Provided that the tolerance for total losses does not exceed by 10%.

d. Total losses comprises of no load, load and auxiliary losses. In case during testing the losses of transformer's are found on higher side then the quoted one than transformer shall be liable to be rejected.

Rejection

The Employer may reject any transformer if during tests or service any of the following conditions arise:

1) No load loss exceeds the guaranteed value by 15% or more.
2) Load loss exceeds the guaranteed value by 15% or more.
3) Impedance value exceeds the guaranteed value by + 10% or more.
4) The difference in impedance values of any two phases during single phase short circuit impedance test exceeds 2% of the average value guaranteed by the vendor.
5) Oil or winding temperature rise exceeds the specified value.
6) Transformer fails on power frequency voltage withstand test.
7) Transformer is proved to have been manufactured not in accordance with the agreed specification.

DRAWINGS & INSTRUCTIONS MANUAL

Drawings

a. The contractor shall furnish, within fifteen days after issuing of Letter of Award, six copies each of the following drawings/documents incorporating name of project and transformer rating for approval.

1. Detailed overall general arrangement drawing showing front and side elevations and plan of the transformer and all accessories including radiators and external features with details of dimensions, spacing of wheels in either direction of motion, net weights and shipping weights, crane lift for untanking, size of lugs and eyes, bushing lifting dimensions, clearances between HV, LV and IV terminals and ground, quantity of insulating oil etc.
2. Foundation plan showing loading on each wheel and jacking points with respect to centre line of transformer.
3. GA drawings/details of bushing and terminal connectors.
4. Name plate drawing with terminal marking and connection diagrams.
5. Wheel locking arrangement drawing.
6. Transportation dimensions drawings.
7. Interconnection diagrams.
8. Over fluxing withstand time characteristic of transformer.
9. GA drawing of marshalling box.

10. Control scheme/wiring diagram of marshalling box, OLTC and interconnection between OLTC, RTCC and marshalling box.
11. Technical leaflets of major components and fittings.
12. As built drawings of schematics, wiring diagram etc.
13. Setting of oil temperature indicator, winding temperature indicator.
14. Completed technical data sheets.
15. Details including write-up of tap changing gear.
16. H.V. cond. bushing.
17. Bushing Assembly.
18. Bi-metallic connectors for connection to (as per site requirement) for conductor for transformers shall be provided.
19. GA of LV cable Box.
20. Radiator type Assembly.
21. Detailed calculations showing short circuit withstand capability due to radial and axial forces during short circuit. Also, calculations for thermal withstand capability during short circuit.

b. All drawings/documents, technical data sheets and test certificates/results/calculations shall be furnished.

c. Detailed calculations showing circuit withstand capability due to radial and axial forces during short circuit. Also, calculations for thermal withstand capability during short circuit.

d. Any approval given to the detailed drawings by the Employer shall not relieve the contractor of responsibility for correctness of the drawing and in the manufacture of the equipment.

Instructions Manual

Six sets of the instruction manuals shall be supplied at least four (4) weeks before the actual dispatch of equipment. The manuals shall be in bound volumes and shall contain all the drawings and information required for erection, operation and maintenance of the transformer.

Completeness of Equipment

a. All fittings and accessories, which may not be specifically mentioned in the specification but which are necessary for the satisfactory operation of the plant, shall be deemed to be included in the specification and shall be furnished by the contractor without extra charges. The equipment shall be complete in all details, whether such details are mentioned in the specification or not, without any financial liability to the Employer under any circumstances.
All deviations from this specification shall be separately listed under the requisite schedules, in the absence of which it will be presumed that all the provisions of the specification are compiled by the bidder.

CENTER OF GRAVITY

The center of gravity of the assembled Transformer shall be low and as near the vertical centre axis as possible. The Transformer shall be stable with or without oil and with or without bushings. If the center of gravity is eccentric relative to track either with or without oil, its location shall be shown in the outline drawing.

TOOLS & TACKLES

Hydraulic jacks of suitable capacity and all the necessary tools and tackles required for normal operation shall be supplied by the Contractor.

GUARANTEED TECHNICAL PARTICULARS

The bidder shall submit the GTPs of transformer along with the tender.

Annexure-P

No.	Test	Um ≤ 170kV	Um > 170kV
1.0	Measurement of winding resistance at all taps	Routine	Routine
2.0	Measurement of voltage ratio at all taps	Routine	Routine
3.0	Check of phase displacement and vector group	Routine	Routine
4.0	Measurement of no-load loss and current measurement at 90%, 100% & 110% of rated voltage and rated frequency	Routine	Routine
5.0	Magnetic balance test (for three phase Transformer only) and measurement of magnetizing current	Routine	Routine
6.0	Short Circuit Impedance and load loss measurement at principal tap and extreme taps	Routine	Routine
7.0	Measurement of insulation resistance & Polarization Index	Routine	Routine
8.0	Measurement of insulation power factor and capacitance between winding to earth and between windings	Routine	Routine
9.0	Measurement of insulation power factor and capacitance of bushings	Routine	Routine
10.0	Tan delta of bushing at variable frequency (Frequency Domain Spectroscopy)	Routine	Routine

11.0	Full wave lightning impulse test for the line terminals (LI)	Type (for Um<= 72.5kV) Routine (for 72.5kV< Um≤170 kV)	-
12.0	Chopped wave lightning impulse test for the line terminals (LIC)	Type	Routine
13.0	Lightning impulse test for the neutral terminals (LIN)	Type	Type
14.0	Switching impulse test for the line terminal (SI) (Not applicable for Um≤72.5 kV)	Type	Routine
15.0	Applied voltage test (AV)	Routine	Routine
16.0	Line terminal AC withstand voltage test (LTAC) (Not applicable for Um≤72.5 kV)	Routine	Type
17.0	Induced voltage withstand test (IVW)	Routine	-
18.0	Induced voltage test with PD measurement (IVPD)	Routine*	Routine
19.0	Measurement of transferred surge on Tertiary due to HV lightning impulse and LV lighting impulse	-	Type
20.0	Measurement of transferred surge on Tertiary due to HV Switching impulse and LV Switching impulse	-	Type
21.0	Test on On-load tap changer (Tap changer fully assembled on the transformer)	Routine	Routine
22.0	Measurement of dissolved gasses in dielectric liquid	Routine	Routine
23.0	Check of core and frame insulation	Routine	Routine
24.0	Leak testing with pressure for liquid immersed transformers (tightness test)	Routine	Routine
25.0	Appearance, construction and dimension check	Routine	Routine
26.0	Measurement of no load current & Short circuit Impedance with 415 V, 50 Hz AC.	Routine	Routine

27.0	Frequency Response analysis (Soft copy of test report to be submitted to site along with test reports)	Routine	Routine
28.0	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine	Routine
29.0	Tank vacuum test	Routine	Routine
30.0	Tank pressure test	Routine	Routine
31.0	Check of the ratio and polarity of built-in current transformers	Routine	Routine
32.0	Temperature rise test	Type	Type
33.0	Overload testing in short-circuit method (applicable for 765 kV transformer only)	-	Type
34.0	Short duration heat run test (Not Applicable for unit on which temperature rise test is performed)	Routine	Routine
35.0	Over excitation test (applicable for 765 kV transformer only)	-	Routine
36.0	Measurement of Zero seq. reactance (for three phase Transformer only)	Type	Type
37.0	Measurement of harmonic level in no load current	Type	Type
38.0	Determination of acoustic sound level	Type	Type
39.0	Measurement of power taken by fans and liquid pump motors (Not applicable for ONAN)	Type	Type
40.0	Dynamic Short circuit withstand test	as specified in the specification	

*The requirements of the IVW test can be incorporated in the IVPD test so that only one test is required.