Islamic Republic of Iran
Vice Presidency for Strategic Planning and Supervision

General Technical Specification and Execution Procedures for Transmission and Subtransmission Networks Power Transformers at HV Substations

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CONNTENTS

DESCRIPTION **PAGE**

Technical Specification of Power Transformers

1- General Requirements

The power transformers shall be designed, manufactured, tested, packed, marked, installed and commissioned according to the applicable requirements of the following standards and this specification.

IEC 60076-1:	General
IEC 60076-2:	Temperature rise
IEC 60076-3:	Insulation levels and dielectric tests
IEC 60076-4:	Guide to the lighting impulse and switching impulse testing of power transformers and reactors.
IEC 60076-5:	Ability to withstand short circuit
IEC 60076-8:	Users Guide
IEC 60076-10:	Determination of transformer and reactor sound level
IEC 60137:	Bushings for alternating voltage above 1000V
IEC 60168:	Tests on insulators
IEC 60185:	Current transformers
IEC 60214:	On load tap changer
IEC 60270:	Partial discharge measurements
IEC 60296:	Specification for unused mineral insulating oils for transformers and switches.
IEC 60354:	Loading guide for oil– immersed power transformers
IEC 60437:	RIV tests on insulators
IEC 60506:	Switching impulse tests on high voltage insulators
IEC 60542:	Application guide for on load tap changer
IEC 60616:	Terminal & tapping marking for power transformer
IEC 60694:	Common clauses for high voltage switchgear and controlgear standard
IEC 60947-1:	Low voltage switchgear- General rules
ANSI C57-1200:	Short circuit dynamic withstand capability of transformers
ISO 1461:	Metallic coating, hot dip galvanized coating on fabricated ferrous products requirements
BS 4232:	Specification for surface finish of blast- cleaned steel for painting

All amendments, supplements and reference publications listed within the above standards shall also apply.

The power transformers shall be complete with the required spare parts and all necessary accessories for proper operation. Basic equipment data and ratings shall be as indicated in schedule TR (I).

The power transformers shall be outdoor, separate winding or auto- transformers, oil-immersed and oil conservator type.

Transformer and their equipments shall deliver its full rate capacity under the specified conditions of ambient air temperatures and elevation.

All current carrying components such as bushings, connections, components and built in current transformers shall have a minimum load carrying capacity equal to 120% of that of the associated windings under all service conditions.

In case of failure of forced cooling, transformers starting from hot condition, shall be capable of remaining in operation without injurious heating for the following periods:

- At full load for not, less than 10 minutes after outage of all forced cooling.
- Transformers having no assigned rating for natural cooling shall be capable of remaining energized for not less than 1 hour without any load current.
- Transformers fitted with two groups of coolers each capable of dissipating 50 percent of the losses shall be capable of remaining in operation at full load for not less than 20 minutes in the event of failure of a forced cooling associated with one stage of cooler.

AC and DC auxiliary supplies of transformer and accessories should be as specified in schedules.

Transformer shall be designed and assembled in such a manner that the average sound level due to the operation of the transformer and accessories will not exceed from specified value.

2- Design and Construction

2-1- Cores

The cores of the transformer shall be constructed from highest quality, non-aging, cold rolled grain-oriented, silicon steel. The steel shall be in thin lamination (having low losses and high permeability) and have smooth surfaces at the edges. Both sides of each sheet shall have an insulated surface treatment or coating providing the required interlamination resistance. The core shall be carefully assembled and rigidly clamped to insure against any shocks, and to provide adequate mechanical strength to support the windings and to prevent shifting of the laminations during shipment, and also to reduce vibration to minimum under operating conditions. All steel sections used for supporting the core shall be thoroughly shot or sand blasted, and lacquering after cutting, drilling and welding and the core clamping structure shall be designed to minimize eddy current losses.

Insulated pockets of the core are to be connected so that no potential difference will exist between them.
The transformer shall be relatively free from undue or harmful vibration of the tank or accessories, or vibration which will cause audioable noise. Flux distortion shall be minimized to reduce noise level.
The core and coil assembly shall be provided with suitable lugs for purposes of lifting of the entire assembly.
The core stack shall be earthed internally through grounding link, accessible from the manhole to permit disconnecting the link and testing of the core for earth leakage.
The core shall be designed in such a way to not saturate under any credible normal operation conditions.

2-2- Windings

In the design, construction, and treatment of windings, proper consideration shall be given to all factors of service such as dielectric and mechanical strength of insulation, coil characteristics, uniform electrostatic flux distribution, Minimum dielectric losses, minimum restriction for free oil circulation for uniform low operating temperature, elimination of hot spots, voltage distribution between adjacent turns and throughout the winding, prevention of corona formation at normal operating voltages, and the control of dielectric flux under impulse condition for high impulse strength.
The entire design, construction, and treatment of the windings and their assembly on the core shall embody the latest improvements in the art and conform to best modern practice.
The transformer windings shall be designed to withstand specified impulse and dielectric test voltage.
Winding conductors shall be free from scale, burrs, and splinters and shall have rounded corners and shall be uniformly insulated. End turns of coils and windings shall be provided with potential grading or additional insulation to withstand the voltage stresses.
All conductors used for the coil structures shall be made by copper. The turns in the coils shall be thoroughly treated in such a way to develop the full mechanical and electrical strength of the transformer and to minimize deterioration.
The conductors shall be transposed at sufficient intervals in order to minimize eddy currents and equalize the distribution of currents and temperature along the windings.
Coils shall be made up, shaped and braced to provide for expansion and contraction due to temperature changes in order to avoid abrasion of insulation and to provide rigidity to resist movement and distortion caused by abnormal operating conditions. Adequate barriers shall be provided between windings and core and between high voltage and low voltage windings. End coils shall have necessary protection against abnormal disturbance.

The neutral point of the star windings shall brought out via a suitable bushing and shall not be connected to the inside part of the tank.
Both terminals of each winding should be brought out at the same side of the core, at any case half turn winding should not be used.
Winding insulation shall be of uniform or non-uniform quality and composition, which shall provide good insulation, minimum wrapage, resistance to deterioration in hot oil, and adequate mechanical and dielectric strength for the service required.
The assembled core and coils shall be blocked and braced to prevent movement or damage from short circuit stresses.
Crossover and winding tap and terminal leads shall be insulated and lashed or fastened in such a manner as to prevent any movement which will injure the insulation and cause shorting of coil turns or windings.
Varnish and insulating compounds, when used, shall be of a type impervious to hot oil. Varnish application on coil windings may be given only for mechanical protection and not for improvement of dielectric properties.
Materials used in the insulation and assembly of the windings shall be insoluble, non- catalytic, and chemically inactive in the hot transformer oil under the operating conditions.

2-3- Core and Coils Assembled

Each assembled core and coils (active parts) shall be dried in vacuum at not more than 0.5 mm of mercury and shall be impregnated with oil immediately thereafter to ensure proper moisture and air elimination within the insulating structure. Each core and coil assembly shall be impregnated and immersed in moisture– free oil as soon as possible after drying.
Insulation resistance between each winding and ground and between windings shall be measured after completion of dry out for the transformer and included in the test report.
In addition a tabulated or plotted record of insulation resistance versus dry out time shall be included in the test report.

2-4- Short Circuit Withstand Capability

Dimensioning shall be based on the short circuit currents and earth fault currents which can arise for all conceivable faults in the system. The system earthing and existing or planned parallel connection of transformers shall be taken into consideration. Normally, two or more transformers shall be considered to run in parallel.

Making use of reactor in of tertiary winding should be approved by purchaser.
The power transformers shall be capable of withstanding without damage the thermal and dynamic effects of three and two phase short circuit and single line to ground faults for two seconds duration at high, low and tertiary terminals with specified system fault levels.
Transformers with tertiary windings shall be capable of withstanding the mechanical and thermal effects of short circuits resulting from different forms of system faults that can arisen in service taking into account the system earthing conditions inclusive of transfer surges which could be reflected through capacitive couplings with high voltage and secondary windings. The dynamic ability to withstand short circuit shall be demonstrated by tests or reference to tests on similar transformers.
Short circuit calculation for dynamic withstand capability and for computation of the peak value of asymmetrical short circuit current of the transformers shall be generally in accordance with IEC 60076-5 short circuit calculations shall be submitted to the purchaser for approval.

2-5- Over Load/Over Flux

The transformer shall be capable of normal service without damage or accelerated insulation aging under overload conditions according to IEC 60354.
The transformer shall be capable of continues service without damage under conditions of over fluxing where the corresponding ratio of voltage over frequency exceeds the corresponding ratio at rated voltage and rated frequency by no more than 5%.

2-6- Tank

The transformer tank shall be a hot – rolled low carbon steel plate case of substantial construction, which shall be oil tight and provided with an oil tight cover. The tank cover shall be designed to shed water. The joints between the tank and cover (unless the design is such that the cover and top section of the tank are integral) and between sections of the tank, shall be provided with suitable flanges, sufficient properly spaced bolts and gaskets (double gaskets preferred), so that the assembly will be oil tight.
The gaskets shall be made of resilient material which will not deteriorate under the action of hot oil and will remain oil tight.
The tank shall be provided with manhole's of suitable size to afford easy access to the tap changing mechanism, lower ends of bushings, current transformers, terminals, and the upper portions of the coils.
The transformer shall be provided with suitable eyebolts and / or lugs for lifting the essential parts, also for lifting the completely assembled transformer. Lifting lugs shall have ample factor of safety to allow for possible unequalized lifting forces.

The tank shall have 4 pulling eyes for all four directions. The pulling eyes shall be suitably braced to withstand a pull at up to 15° from the horizontal.

All cover opening shall have an upright edge of not less than 5 Cms., and gaskets which can be used again after opening (rubber type, not glued).

The transformer tank, radiators, pipes and conservator shall withstand full vacuum and be oil tight for an over pressure on the liquid surface which measured as a column of oil, shall be equal to the internal height of the tank.

Each tank shall be provided with a minimum of four jacking plate at the same level to enable the transformer, complete with mounted accessories and oil, to be raised or hauled and slewed in any direction.

The transformer tank shall be provided with a pressure relief device of adequate size to protect the tank against an explosion due to arcing below the surface of the oil. The pressure relief should be installed on top of the tank in order to be far from the high voltage equipments. It shall be equipped with alarm and trip contacts suitable for operation on the station service supply voltage. Fire retardant cable from the contacts shall be run in cable duct with cover and terminated in the terminal cabinet.

Each transformer shall be provided with two external ground pads, each with two tapped holes for connection to the ground bus.

The transformer shall be provided with a suitable steel frame base to permit moving the transformer in either direction when completely filled with oil.

The construction of the main tank, auxiliary tank, tap changer tank, and the oil preservation system shall provided for temperature changes attained between no load and maximum rated load operation (taking into consideration an allowable overload).

Oil resisting synthetic rubber gaskets shall not be used.

All pipe entries to the main tank shall have oil– tight shut – off valves arranged to given positive indication of the open and closed positions. Drain and sampling valves shall be provided in stiffeners box with padlock.

Provision should be made to prevent movement of internal parts of transformer during transportation.

Adequate provision should be made for reduction of losses and preventing hot spot in main tank.

The transformer tank shall be provided with at least the following valves (in addition to those required for the proper functioning of the transformer):

- drain valve with 100 mm dia. so located as to completely drain the tank.
- Two oil filter valves on diagonally opposite corners of 50 mm dia.
- Oil sampling valves with app. 8 mm dia. at top and bottom of main tank.
- One 15 mm dia. release plug for gas/air on the top of the tank.
- Two plugged pipe outlets equipped with shut - off valve for applying and measuring vacuum.

2-7- Tapchanger

2-7-1 Off load tapchanger

The transformer, if required, shall be equipped with external manually operated tap changer for changing connection to the taps in tertiary windings.

Tap will be changed only when the transformer is deenergized. The tapchanger shall be mounted on the side of the transformer case at a convenient height for operation from the floor on which the transformer is mounted and shall include operation hand wheel indicating pointer and dial and means for locking the tapchanger in any desired position. The complete tap changing mechanism shall be built with high electrical, mechanical and thermal safety factors.

Te contacts shall be capable of withstanding the full short circuit current of the transformer without injury. The tapchanger shall be capable of carrying overload currents according to IEC 60354.

The tapchanger handle shall also be provided with an electrical interlocking device, having normally open contacts, arranged to trip the transformer when the locking pin is taken out.

Tap position indicator of each phase of tapchanger on the transformers tank shall be provided.

2-7-2- On load tapchanger

The tapchanger shall be capable of carrying overload currents according to IEC 60354.

Where transformers are subject to overload conditions other than stipulations of IEC 60354, the magnitude and duration of overload current should be proposed by the manufacturer and approved by the purchaser.

Devices shall be incorporated to prevent tapchanger operation when the through current is of such a value liable to cause damage to the components.

The OLTC gear shall withstand through fault currents without any damage and shall be suitable for parallel operation with similar power transformers.

The OLTC shall be suitable for automatic voltage regulation and shall be designed for supervisory control from load dispatch center.

The changing of taps shall be by means of motor operated on load tapchanging equipment of proven reliability and requiring minimum maintenance.

When the design of the tapchanger requires an oil expansion tank, it shall be piped to a separate compartment in the transformer conservator. This compartment shall be provided with its own magnetic oil level gauge with low level alarm contacts, filling / filter press valve and drain valve. A fault pressure relay with trip contacts and a dehydrating breather shall be provided in the conservator pipe lines. The breather shall contain a colour indicator and shall be of a type in which the desiccant is not in continuous contact with the atmosphere. All oil level gauges shall be legible from ground level. Filling and drain valves shall be complete with dummy plugs.

The tapchanger shall consist of tap selectors mounted integrally with contactors.

The contractor (diverter switch) compartment shall be provided with an inspection cover and an over-pressure device having trip contacts. The whole unit shall be installed inside the main tank and piped to the conservator compartment as described in the foregoing. Tapchanger pressure relief valve should be explosive type.
The contactor compartment shall permit draining of oil and no connection shall be made between this compartments and the transformer tank in order to prevent the mixing of the oil.

2-7-3- Operating mechanism

The driving mechanism motor shall be suitable for operation on specified station AC or DC service auxiliary supply. The mechanism shall be protected with IP54 or IP55. The feature used in stopping the motor must be by a positioning controller and dynamic braking. If any other methods is proposed, it should be approved by the purchaser. The motor windings shall be given moisture resisting treatment and shall of rugged construction for service under the conditions specified.
A removable handle shall be provided for manual operation of the tapchanger. The handle shall automatically block the electrical control when in its operating position. The driving mechanism shall also house all auxiliary equipment necessary for automatic, remote and local operation.
If any of the on load tapchanger components are not continuously rated, The drive mechanism shall be designed so that it is impossible for the tapchanger to stop in any non- continuously rated position. This shall apply whether the tapchanger is driven by the motor or by hand crank.
All necessary interlocking shall be provided and all necessary precautions shall be taken to avoid false maneuvers and prevent the tapchanger being operated under current beyond its capacity.
The tapchanger shall start on a "raise" or "lower" impulse of short duration and shall "seal- in" and complete the step by itself. The duration of a signal beyond the time required for operation shall not initiate a second operation. In the event of a power failure the initiated operation shall resume as soon as power returns. A counter for registration of the number of operations performed shall be provided. Electrical limit switches and mechanical stops or declutching devices shall be incorporated to prevent over travel beyond the maximum raise and lower positions.
Electrical and mechanical interlocks shall be provided on the "raise" and "lower" contactors.
Tapchanger motor protection shall consist of an overcurrent automatic circuit breaker with manual reset.
Suitable terminals shall be provided for test purposes. Blocking facilities shall be provided to prevent the tap changer from raising of the voltage above an adjustable preset value and from lowering if the voltage falls below an adjustable preset value.

The on load tap changing equipment shall be suitable for parallel operation with any of the similar power transformers in the same substation and be equipped with all necessary wiring, relays, control switches, instruments, etc, required to provide complete manual and automatic control and the necessary arrangement for the selection of any of the similar power transformer for parallel operation.
The remote electrical control shall be arranged for manual and individual or parallel automatic control.
A set of "make" contacts shall be provided for operation of the annunciator to indicate an out - of - step condition when in parallel operation.
In addition to the components essential to the operation of OLTC, the tapchanger control cabinet shall also house the following:

- Tap position indicator with maximum and minimum resetable drag hands. The indicator shall be visible by a man operating the tap changer manually by the handle.
- Five digits operations counter.
- "Raise – lower" push –buttons or switch, for manual electric control.
- "manual – automatic" selector switch.
- Tap changer motor protection and control circuit devices.
- Door actuated light.
- Thermostatically controlled anticondensation heater.
- Mechanical and electrical stops to prevent operation beyond the end positions in both directions.
- Devices for remote operation from the control room/scada.
- Emergency pushbutton for tripping the driving motor circuit breaker.

2-7-4- Remote control panel

Panels shall be provided for remote control of the on load tapchanger of each power transformer from the control room. The panels shall contain all facilities such as tap position indication, tapchanger in progress indication, pushbutton for raising and lowering of taps, selector switches for manual / auto, single/parallel, master and follower operation, relays required for parallel operation of transformers, all facilities related to the automatic voltage regulation and line drop compensation and out of step alarms and other annunciations as specified below.
Normally two transformers will be operated in parallel, for witch a common panel or individual panels incorporating master / follower selection arrangement etc, could be provided.
Wherever specified three or maximum four transformers may be required to operate in parallel for which necessary provisions should be made in tap changer panels with respect to master / follower control. The design and construction of the panel should match with the other control panels in the substation.

2-7-5- Annunciations

The following annunciations shall be provided in the remote control panel:

- motor supply failure.
- Control supply failure.
- Drive motor autotripped .
- Tapchanger in progress.
- Out – of – step operation when the tapchanger is operating in parallel.
- Tapchanger delayed.
- Automatic / manual mode.
- Tapchanging incomplete.

2-7-6- Automatic voltage regulator

The automatic control equipment shall be installed on the OLTC panel or panels in control room which shall include all necessary equipment for automatic voltage regulating.

Preventing for unnecessary regulation in the event of loss of sensed voltage to be furnished. The regulation must be blocked when the transformer is isolated from either of the sides. The tap changer will otherwise, move to one extremity of its travel, but the voltage cannot be affected in this situation.

The automatic control equipment shall be provided with compounding, supplied by current through the transformer for making the regulation function dependant on the load of the network. The regulation shall be of the on – off type with adjustable deadband for adjustment to the steps of the tap changer.

The automatic control equipments for three phase transformer shall be installed on the OLTC panel or panels which shall include all necessary voltage regulating and time– delay relays, aux. current transformer, line drop compensator (suitable for power flow in either direction), rheostats, selector switches and voltmeters for indicating the controlled voltage. Test terminals for measuring regulated voltage and for testing the voltage regulating control shall be furnished.

For 3 * 1 phase transformer approved means shall be provided for automatically maintaining within adjustable limits a predetermined voltage at the lower voltage busbars to which the transformers is connected. In this case the equipment shall be suitable for control of up to four transformers, and shall be so designed that where control of less than four transformers is initially required it shall be possible to extend the facilities to cover up to four transformers at a latter time. In addition to the mentioned methods of control the following methods shall be provided.

a) Automatic independent remote / control

It shall be possible to select remote or local electrical (non-automatic) control, or automatic independent remote control for each transformer irrespective of the method of independent control selected for any of the other associated transformers.

b) Automatic parallel control in one group or two independent groups.

It shall be possible to select any transformer for either group and also select any transformer in a group for master control. Provision shall be made for not more than three transformers in a group.

Local control shall be so arranged that it shall be necessary to have the remote selector on a non-automatic position and the local/remote changeover switch in the marshalling kiosk positioned on "Local" before operation is possible. If the remote selector switch is on any other position the local/remote switch shall be inoperative.

A voltage regulating relay of an approved type designed to operate shall be provided for each transformer. The no load voltage level of the relay shall be adjustable between 80% and 120% of the nominal voltage. Sensitivity of the relay shall be suitable for predetermined adjustment at any value between the transformer tap step percentage and 1.5 times the transformer tap step percentage. The relay shall be insensitive to frequency within reasonable limits.

Associated with the voltage regulation relay a time delay relay shall be provided, the setting of which shall be adjustable between the ranges of 10 and not more than 90 seconds.

Approved means shall be provided either at the remote control point or at a supervisory point, for selection of adjustment in the balancing voltage to give load shedding facilities, together with means for restoration.

If specified equipment shall be provided for compounding (line drop compensation), provision shall be made, within the tapping range, for voltage compounding to a maximum of 15% resistance and 15% reactance in suitable steps, with separate adjustment for each component. It shall be possible to reverse the reactive component by means of a changeover switch or links.

The current transformer for the compounding shall be provided and mounted inside the main transformer tank and shall be rated for a nominal secondary current at full load of 1 ampere.

Approved means either by switch or links, shall be provided for each transformer, to give complete isolation of all supplies at the remote control point without preventing the operation of tapchangers on the other transformers.

2-8- Supervisory Control

Suitable provision should be made in the OLTC panel for supervisory control and indication as per the following main requirements:

The remote operator as well as the local operator shall be able to switch the tap changer from automatic to manual and vice versa. It shall be possible to remotely adjust the automatic voltage regulation set point.

2-9- Cooling Equipment

2-9-1- General

Transformer shall be provided with natural oil cooling system, to be supplemented by two other stages, which are categorized in two alternatives one comprising of two stages of forced-air-cooling and the other comprising of one stage of forced-air-cooling followed by forced-oil-cooling stage. In one stage systems, cooling is done with only one stage of forced air cooling.

Radiators shall be so designed to be accessible for cleaning, painting, to completely drain oil into the tank when the tank is being drained to thoroughly vent into the tank and to insure against formation of gas pockets when the tank is being filled.

Each radiator shall be removable with no need to remove the other and for each of them a separately motor shall be provided. At each radiator connection an indicating shut-off valve which can be locked in either open or closed position shall be provided.

It shall not be necessary to shut-down the entire forced air when removing any radiator. Radiators shall have lifting eyes, an air vent at the top and an oil drain at the bottom (both equipped with suitable plugs).

Protective equipment shall be provided for the fan motors. Test switches shall be provided for testing each group of fans.

The control equipment to be furnished shall be fully automatic, designed to start and stop the two stage fan motors or one stage fan motor and next pump(s) as per the demands of temperature and shall include a magnetic contactor with auxiliary alarm contacts which close with contactor, and any other auxiliaries necessary.

Switches shall be provided for automatic/manual control of each fan group. An under voltage relay or equivalent device to be proposed to alarm for failure of each fan or device or subgroup of fans, and/or for the case of power supply loss.

Motor protective circuit breakers, if not otherwise specified shall be equipped with at least one set of contacts which are closed when the breaker is open.

Each contactor shall have its own fuse and selectivity shall exist between this and other safety devices in the circuit.

Each motor protective circuit breaker shall be equipped with overload and short-circuit protection of such a type and rating that complete selectivity exists, both between these and preceding main fuses or MCB's under all load conditions.

Bird barriers should be installed on fans.

2-9-2- One stage forced air cooling

In this type of cooling system, the transformer will be cooled with natural oil and air circulation in first stage and with forced air cooling in the second stage: ONAN– ONAF.

The control system of fans shall be fully automated, switching fans in case of temperature increase.

2-9-3- Two stage forced – air – cooling

For transformers with first stage of natural and second and third stages of forced air cooling (ONAN / ONAF1 / ONAF2) entire requirement for forced-air-cooling of second stage will remain for third stage too, in addition to the fans of third stage.

2-9-4- Forced oil cooling

Transformers with first stage of natural and second stage of forced air cooling system, are required to be supplemented by the forced-oil cooling equipments, at third stage (ONAN / ONAF / OFAF), with following characteristics:

Oil circulating pumps shall be driven by directly coupled motors. Indication shall be provided for indicating direction of rotation of the pumps.

The non-sensitive area (marginal temperature between setting of start each group of cooling and setting of stop) shall be so large as to avoid unnecessarily frequent cooler starts-stops. The non-sensitive area in°C shall be specified by the supplier.

The supply to fan pump motors and oil circulating pump motors shall be subdivided into two separate groups.

For choice of mode of operation (automatic / manual), twist-grip switches shall be provided.

Switches shall be two pole type, one pole to control the relevant motor– protective circuit breaker, and other for the signal circuit.

Following alarm initiating devices having normally open contacts shall be provided for fault initiation, as applicable for the method of cooling employed:

- Cooling fan / fans failure for each radiator bank / unit cooler
- Failure of oil pump.
- Low oil flow for each pump.

Following initiating contacts shall be provided to illuminate lamp indicators:

- Cooling fans in action for each stage.
- Oil pump in action for individual pumps.
- Cooling system on automatic control.

- Cooling system on manual control.

All parts in the cooling system shall be galvanized in accordance with ISO- 1461, and withstand an inner overpressure of 3 kg/cm^2 for oil at temperature of 90ºC without any oil leakage.

2-10- Bushings

Bushings of same voltage shall be interchangeable between units. All bushings shall be so designed that there will be no deterioration of any parts due to stresses caused by temperature changes and adequate means shall be provided to accommodate conductor expansion. The bushings shall be oil-tight, gas-tight and water-tight.

Bushings rated 63 kV shall be oil or condenser type and bushings rated above 63 kV shall be oil-filled condenser type provided with magnetic oil level indicators visible from ground level and capacitance taps for purposes of voltage measurement and dielectric loss factor testing.

The bushings shall be so constructed that potential devices may be connected without having to drain the oil. Oil filled bushings shall be free from oil leakage. They may be either sealed type or provided with convenient means for sampling the oil and draining the bushing from the bottom.

Two bolt terminals shall be furnished on the bushings.

All porcelain used in the bushings shall be manufactured by the wet process. The glazing of the porcelain should be homogenous, and impervious to moisture. It shall also be free from blisters, cavities or other flows affecting the mechanical strength or dielectric quality.

Oil-filled bushings shall be designed to prevent the accumulation of explosive gases and to provide adequate oil circulation to remove internal heat. Oil in oil filled bushings shall meet the requirements of the transformer oil and be suitable for the duty.

The bushing shall be so designed that when operating at normal rated voltage there will be no electrical discharge between conductors and bushings which will cause, directly or indirectly, or by the formation of chemically active substances, corrosion or injury to the conductors, insulators, or supports.

The bushings shall be free from external and internal corona. The winding connection for condenser bushing shall be by means of conductor lead which shall be connected to the bushing bottom terminal.

The bushing design shall permit installation or removal of current transformers without removing the tank cover and removal of the bushings without disturbing the current transformers.

Bushings rated for 400 A and above shall have non-ferrous flanges and hardware fittings made of steel or malleable iron shall be galvanized.

Bushings shall be located in the transformer so that minimum clearances applicable for the BIL are available between live parts and live parts to earthed structure.

2-11- Bushing Current Transformers

In addition to any current transformers required for the operation of the thermal relays or the on-load tapchanging equipment, bushing type current transformers may be required for protection and metering purposes. When such additional current transformers are required, the requirements should be as specified.

All bushing type current transformers shall be removable without removing the transformer cover.

Current transformers mounted in detachable C.T. wells shall have their secondary leads terminated in a weatherproof junction box on the side of the well, to facilitate field factory connection to the external leads from the transformer control cabinet.

Current transformers and secondary connections shall be designed to withstand without injury the mechanical shocks incident at rated short-circuit current.

Current transformers shall not reduce the transformer insulation level below the specified value. C.T's shall be provided with shorting links.

Current transformers shall be suitable for measuring and relaying service and in accordance with the IEC 60044 and BS 3938 (for class X CT's) with respect to technical specification, thermal and mechanical limits, polarity marking and tests.

Current transformers shall have all taps terminated on terminal blocks in the terminal housing, flexible stranded leads shall be run from each current transformer secondary tap through rigid conduit to the main cabinet.

The current transformers shall be designed for a maximum ambient temperature in the cooling medium of 115 °C and a maximum 24 hour average of 105 °C .

The cores shall be provided with test conductors to allow tests to be carried out on the current transformer without magnetizing and loading the power transformer.

Continuous load currents and thermal short circuit current (2 sec) withstand capability of the current transformers shall comply with the same requirements as those for the power transformer for corresponding voltage level.

One end of the test conductor shall be connected to an extra terminal clamp, clearly marked, and the other end shall be connected to transformer tank.

Insulation requirement shall be in accordance with IEC 60044. However the test voltage shall be 4 kV rms.

2-12- Accessories

All gauges, meters, relays and thermometers shall be mounted in such a way that the vibration from the transformer is not transmitted to these equipment.

Contacts of the accessories shall be insulated from ground and shall be of positive snap action and mercury type. Alarm and control contacts shall be open during normal conditions, and shall be self pressure device, and shall be for the specified DC voltage of the substation.

All contacts and devices for external connections shall be connected to terminals in the terminal cabinet.

Alarm contacts shall be rated 0.5 ampere minimum and control contacts shall be rated 5 amperes minimum. Auxiliary relays shall be used where required.

The transformer shall be provided with the following accessories:

2-12-1- Conservator

Conservator tank should have adequate capacity for the ambient temperature range specified. The tank shall be mounted with proper slope between the ends to facilitate draining, and the lower end shall be fitted with a drain valve of suitable size, complete with dummy plug. The conservator shall be provided with a manhole, correctly sized, filling valve with dummy plug, and lifting eyes. The connecting pipe to the main transformer tank shall be provided with an indicating shut-off valve located on the conservator side of the gas detector relay.

The oil conservators shall have at least volumes of 15% of the total oil volume. The conservator shall be provided with outlets for silicagel breather and be equipped with an oil-level indicator.

The expansion system shall be scaled in order to achieve a low air content in the oil. After filling with degassed oil, the rate of air leakage into the transformer must be lower than 0.3% (volume dissolved air/oil volume) after one month.

Gaseous nitrogen, shall be sealed in the space above the oil level in the conservator. The system furnished should be automatic in operation, shall provide for expansion and contraction of oil over the temperature variations and effectively seal the interior from atmosphere. Particular care should be taken to eliminate gas leakage. The system shall be complete with a gas cylinder filled with high pressure gas, an automatic reducing valve, a breathing regulator and a mechanical relief valve. Sudden pressure relay shall also be supplied having one set of alarm contacts on the pressure switch. The relay should be connected to the nitrogen chamber for monitoring the rate of change of pressure and it should not operate for normal variations of pressure in the tank.

Alternatively, the conservator shall be sealed expansion tank type provided with a flexible oil resistant air bag to prevent air from coming into contact with oil. The air bag shall be designed to withstand repeated expansion and contraction due to changes in temperature. An alarm device shall be provided to give an alarm in the event of rupture of the bag and entering of air into the conservator.

2-12-2- Gas and oil actuated relay (twin float buchholtz relay)

Two element gas detector relay, arranged to collect all involved gas should be provided in the pipe connecting the conservator to the main tank. The relay shall be equipped with two sets of contacts, one set to operate an alarm on slow gas accumulation and one set to trip the transformer on surge accumulation.

The gas-operated relay shall be provided with test push-button and valve equipment for pumping in air for testing the relay function.

The gas-operated relay shall be so arranged and designed that its active parts are accessible for inspection, repairs and replacement without oil being drained from the conservator. This can be achieved by a valve in the pipe to the conservator necessitating of a small quantity of oil or by a shunt pipe with a suitable valve arrangement.

A five mm dia. copper pipe with protective cover or steel pipe shall be connected to relay test-cock to a valve located near ground level to facilitate sampling of the gas.

2-12-3- Conservator oil level indicator

Magnetic oil level gauge, which can be read from ground level should be mounted on the conservator tank. The dial shall indicate the minimum, maximum and normal levels. The oil level gauge should have contacts for annunciation of low and high oil level.

The quality of glass or mica which will be used in oil level indicator should be remain unchanged under all atmospheric conditions.

2-12-4- Winding temperature indicator

One dial type winding temperature indicator only on one phase for each voltage level responsive to the combination of top oil temperature and winding current, calibrate to monitor the hottest spot temperature of the transformer winding should be considered. The dials shall be mounted on the transformer at eye level. The temperature indicators shall be provided with separately adjustable sets of contacts to perform the following functions:

- To control automatically the cooling system.
- Operate an alarm in the event that the temperature reaches a preset value.
- Trip the transformer load-side breaker when the temperature reaches a pre-set value.

Autotransformers and three winding transformers having tertiary loading shall be provided with one winding temperature indicator in such tertiary winding. The winding temperature indicator shall have provision for field calibration.

2-12-5- Oil temperature indicator

Dial type oil temperature indicator with its sensing shall be located in the path of the hottest oil. The dial shall be mounted on the transformer adjacent to the winding temperature indicator. The temperature indicator shall be equipped with separately adjustable alarm contacts to perform the following functions:

- Operate an alarm when the temperature reaches a preset value.
- Trip the transformer load side breaker when the temperature reaches a preset value.
- Automatic control of cooling systems.
- Automatic trip of cooling systems.

2-12-6- Combined winding and oil temperature monitoring system

If specified, instead of normal dial type indicators, one combined oil and winding temperature monitoring system which have the following specifications shall be provided:

- To measure oil and all winding temperatures (range from Min. ambient temperature to highest predicated winding temperature).
- To control the cooling system as specified in this specification and also acc to IEC 60354.
- Temperature monitoring which shall be fully compatible to the digital control system of the substation.
- Required analog and digital output signals.
- Electronic pointer thermometer.
- Required numbers of switching contacts.
- Serial interface compatible with DCS of the substation.
- Other required facilities which to be coordinated with substation general contractor.

2-12-7- Pressure relief device

Pressure relief device which shall be automatic without the use of expendable parts should be considered. The device, and all parts shall have a service life comparable to that of the transformer. Semaphore and trip contacts shall be provided on the device to respectively give visual and electrical indication of operation. The device shall be protected against mechanical impacts by means of steel housing.

2-12-8- Silicagel breather

Silicagel dehydrating breather/or other colour indicator of approved type shall be designed for drying agents with a grain size of least 2.5 mm. The breather shall be located at a convenient height above service level. The design of the breather shall be such that desiccant shall not be in continuous contact with atmosphere.

The breather could be a conventional or maintenance free type. maintenance free silicagel breathers use an integral heater to drive moisture out of the desiccant. The frequency of reheating the desiccant can be set by the operator. This type of breather will reduce maintenance costs and increase the reliability of the transformer.

2-12-9- Wheels

Swiveled wheels shall be suitable for use on the standard rail gauges of 1435/2940 mm, and provided so that they can be turned through an angle of 90°. Suitable means shall be provided for anchoring of the transformer body to the foundation or rails after dismantling wheel's of the transformer.

2-12-10- Copper strap grounding

A copper ground strap of suitable size supported on insulators shall be run from the neutral bushing to clamp type ground connector near the bottom of the tank. This connector shall be suitable for two 120mm copper ground conductors.

2-12-11- Shock meter

A shock meter shall be installed on the transformer from the time of loading to the reception and after the accurate analysis of results, the shock meter will be delivered to the manufacturer.

2-13- Marshalling Kiosk and Cooler Cabinet

2-13-1- Marshalling kiosk

All control and signal wiring shall be in a suitable metal cover. The cabinet shall be of weatherproof construction type and conduit connections to the terminal cabinet shall be of the threaded type. Switch plugs 25 Amp., 230 V and 100 Amp., 400 V shall be mounted externally on the cabinet.

The cabinets shall be equipped with a hinged door with padlock and mounted in an accessible location. A blank bottom steel plate shall be provided for attaching incoming conduit to be installed. The terminal blocks, shall have bases and barriers molded integrally, with brass inserts, and rated for not less than 600 volt service.

Adequate number of marking strips from each size, fastened by screws to the molded section with 10 percent spare shall be provided.

20 percent spare terminals shall also be provided.

Cabinet shall be provided with a door switch for lighting. Thermostatically controlled anticondensation heater shall be provided for cabinet.

2-13-2- Cooler control cabinet

In addition to applicable requirements mentioned above, one control cabinet shall be provided to house the followings:

- Cooler control and auxiliary equipment.
- Heavy duty, properly sized single and three phase convenience outlets for oil handling equipments.
- Door actuated light.
- Thermostatically controlled anticondensation heater together with thermostat.
- Fuses of approved type.

2-14- High Voltage Terminals

High voltage terminal shall normally be of module plate type. Pin type is accepted as an alternative.

The terminal shall be designed according to bending moment owing to wind load or earthquake force together with horizontal pull of the high voltage line conductor.

Module plate terminals shall be designed according to primary current level as following dimensions:

Terminals for maximum rated current up to 1600 A shall be designed as plate of 75×75×15 mm (L×W×T). The plate should have 4 holes of 14 mm diameter with 40±0.5 mm as distance between holes center. Also the distance between plate edge and hole center should be 17.5 mm.

Terminals for maximum rated current up to 3150 A shall be designed as plate of 125×125×35 mm (L×W×T). The plate should have 4 or 9 holes of 14 mm diameter and center to center distance of 40±0.5 mm for two holes side by side.

Pin type terminals shall be designed according to the following cases:

Terminals for maximum rated current up to 1600 A shall be designed as a pin of 125 mm length and having 30±0.15 mm diameter.

Terminals for maximum rated current up to 3150 A shall be designed as a pin of 125 mm length and having 60±0.2 mm diameter.

Terminals of copper (Cu) or a copper alloy shall be tinned to a thickness of minimum of 50 micro meters. A copper alloy which is sensitive to season cracking shall not be used.

Terminals of aluminum or an aluminum alloy shall not be treated. An alloy sensitive to season cracking, shall not be used.

A module plate terminal of aluminum or aluminum alloy shall have a hardness of minimum 750 N/mm.

2-14-1- Tertiary terminals

The tertiary windings shall be terminated to the relevant bushings located inside of a suitable steel box on the transformer. The terminal box shall be suitable for entry of high voltage single core cross linked cables. Cable terminals with glands and / or other necessary accessories for proper connection of the cables to be provided.

2-15- Cost Evaluation (losses and capital cost)

The losses shall be stated in schedule TR(II). In comparing tenders, the capitalized value of the guaranteed losses will be taken in to account and will be added to the tender price. It shall be noted that for this purpose total losses (load loss and no load loss and cooling plant losses) will be considered as the sum of all individual winding losses at related rated powers. This total loss for two winding transformer will be equal to guaranteed load loss of HV/LV at rated power. Total losses for three winding transformer will be calculated as:

HV loss (at rated HV power) + LV loss (at rated LV power) + TV loss (at rated TV power).

Each individual winding loss will be calculated by the binary method from the values of losses at HV/LV, HV/TV & LV/TV, the losses will be capitalized at the specified rate.

2-16- Penalty and Acceptance of Transformers

If the losses as measured on the transformer after manufacturing should be found in excess of the values of guaranteed losses indicated in schedule TR (II), the bidder shall pay the specified penalties.

The acceptance of transformer with higher losses than the guaranteed values shall be governed by one of the following:

- Total losses in excess of the guaranteed values, but within tolerances indicated in IEC 60076-1, transformers shall be accepted, provided that all other technical requirements are met subject to tendered accepting penalty for losses in excess of guaranteed values using the specified rate.
- Total losses exceeding the tolerances given in IEC 60076-1, the acceptance of the transformer shall be entirely at the decision of the purchaser, if accepted, penalty charges as described above shall be applied.

2-17- Tolerance on Rated Current and Power

The continuous current shall not deviate more than 5% of rated current. However, if the current is in the above mentioned range, the manufacturer will pay penalty proportional to the difference between nominal current (nominal power) and actual current (actual power).

2-18- Rejection

The purchaser reserves the right to reject the transformer and demand a new transformer if during test or service, any of the following discrepancies in respect of guaranteed values occurs:

- Measured losses exceed the guaranteed values by more than the tolerance allowed by IEC 60076.
- Percentage impedance measured exceeds the guaranteed value by ≥10% or more.

- Oil or winding temperature rise exceeds the guaranteed values by 5°C.
- Transformer fails on impulse tests.
- Transformer fails on power frequency withstand test.
- If it is proved that the transformer has not been manufactured in accordance with the agreed specification and standards.

The table on the next page gives tolerances to be applied. The transformer is considered as complying with IEC standard when the quantities subject to tolerances are not outside those given in the following table.

Tolerances

Item	Tolerance
a) Total losses b) component losses } See note 1	+ 10% of the total losses + 15% of each component loss, provided that the tolerance for total losses is not exceeded
Voltage ratio at no load on principal tapping for a specified first pair of windings	The lower of the following values: a) ±0.5% of declared ratio b) ±1/10 of the actual percentage impedance on the principal tapping
Voltage ratio on other tappings, same pair	To be agreed, but not less than the lesser of the values in a) and b) above
Voltage ratio for further pairs	To be agreed, but not less than the lesser of the values in a) and b) above
Short- circuit impedance for: - a separate – winding transformer with two windings, or - a specified first pair of separate windings in a multi – winding transformer	
a) Principal tapping	When the impedance value is ≥10% ±7.5% of the declared value When the impedance value is <10% ±10% of the declared value
b) Any other tapping of the pair	When the impedance value is ≥10% ±10% of the declared value When the impedance value is <10% ±15% of the declared value
4. Short- circuit impedance for: - an auto – connected pair of windings, or - a specified second pair of separate windings in a multi-winding transformer	
a) Principal tapping	±10% of the declared value
b) Any other tapping of the pair	±15% of the declared value for that tapping
- Further pairs of windings	To be agreed, but ≥15%
No-load current	+30% of the declared value

NOTES

1. The loss tolerances of multi-winding transformers apply to every pair of windings unless the guarantee states that they apply to a given load condition.
2. For certain auto-transformers and booster transformers the smallness of their impedance justifies more liberal tolerance. Transformers having large tapping ranges, particularly if the range is asymmetrical, may also require special consideration. On the other hand, for example, when a transformer is to be combined with previously existing units, it may be justified to specify and agree on narrower impedance tolerances. Matters of special tolerances shall be brought to attention at the tender stage, and revised tolerances agreed upon between manufacturer and purchaser.
3. "Declared value" should be understood as meaning the value declared by the manufacturer.

2-19- Painting and Finishing

Painting on iron and steel plates and cabinets, shall consist of four coatings containing one primary, two coat of non glossy oil and one final weather resistant coat. Thickness of each coatings and the total thickness is depend on the coating technology but shall not less than a minimum specified by the purchaser.

The interior of the control cabinet and other cabinets shall be painted with three coats, of which the final coat shall be anticondensation finish.

2-20- Earthquake Requirements

The complete assembled and installed transformers including all accessories shall be designed to safely withstand the dynamic earthquake forces. To prove the capability of the equipment to withstand an earthquake, the dynamic response calculations obtained by using an approved method shall be submitted to the purchaser.

2-21- Transformer Oil

The oil shall be refined mineral oil. It shall be clear and completely free from solid particles, and shall not give a positive result when tested on corrosive sulphur in accordance with IEC 60296.

The oil shall be uninhabited type with naphtenic base.

The transformer oil shall be delivered in filled drums and the drums shall be new and made of top quality, that normally used in the oil industry, externally these shall be treated against corrosion and painted with oil and weather-resisting paint.

The drums shall be stenciled on their bung sides with the Employer's emblem, goods designation, serial number and the oils and drums net weights. These marking shall be of oil-and weather-resisting black paint.

10% of the total quantity of oil in the transformer shall be supplied as extra.

2.22. Rating Plate

The rating plate of the transformer shall include information in accordance with IEC 60076, and 60044 and be to the approval of the purchaser.

2.23. Online Gas Monitoring System (OLGM) (if specified)

2.23.1. General

The system shall be capable to monitor continuously key fault dissolved gasses and monitor their evolution. The system shall be capable to work in all variant thermal weather condition. The system shall have facilities to save the detected data and evaluate the evolution of fault gases.

2.23.2. Feature

The system shall have at least a reliable and accurate sensor to detect key gases and if possible moisture and electronic controller to process, save, and analyze the collected data, facilities to communicate with remote SCADA or other monitoring system.

The system should have the ability of reading composite value of gases, in ppm.

In addition the system is required to have following features:

- Hourly and daily trend (ppm changes during target period) with alarm features.
- Adjustable alarms on gas levels and trends.
- Remote communications via optional modem.
- Network capabilities.
- Sensor and system self-test and diagnostics.
- Connection to a SCADA system, either locally at the substation or remotely via optional modem.

The system shall be completed and installed on the transformer for which all provision such as oil inlet, oil outlet, AC supply, alarm wiring, communication connection, etc shall be provided.

In any case even if supplying the system is not in scope of work of manufacturer, all necessary provision for installation of such system by buyer shall be foreseen. i.e:

- Provision for oil inlet, oil outlet (different from sampling or filtering valves)
- Provision for AC/DC supply from cooler control cubicle and related wiring route on the body.
- Provision for routing communication and alarm cables from the unit through cooler control cubicle.
- Provision for easy attachment of the unit on tank body (suitable location).

2.24. Fire Protection for Power Transformers (Optional)

If specified, an automatic fire protection scheme shall be provided for each main power transformer. The principle of operation shall be water sprinkler type.

The fire detection scheme shall automatically start the extinction system and fulfill the following operations.

- Trip all the associated transformer circuit breakers.
- Stop the oil circulating pumps and fans.
- Close the valve between the oil conservator and main tank of the transformers.
- Give audio and visual alarms in the control room.

The system shall be generally designed acc. to NFPA standards No. 15 and shall be well designed to operate properly at the specified site condition.

The system shall have the capability to be operated automatically and manually (from local/ control room).

The system shall be designed to be able to have enough capacity for discharging water for at least 5 minutes on one of the biggest transformers.

2.25. Packing and Shipping

The method of packing shall be such as to protect adequately the tank, and those parts contained within and attached, for transportation. Three axis impact recorder or shock indicator shall be attached to the transformer near the top of the main tank to record maximum shock acceleration during the whole period of loading, shipment, unloading and transportation. The contractor shall take necessary steps, and shall make sure that impact recorders function properly during the whole period of transportation from the factory up to its delivery at the site.

Transformer to be transported in dry nitrogen gas is replaced by the contractor at a pressure (0.3 atmosphere) until the gas is replaced by oil. The gas pressure shall be recorded before dispacking.

Means shall be provided for measuring the pressure in the tank. A gas cylinder shall be connected to the transformer through a pressure reducing valve, pressure gauge and non- return valve.

Inclination of Max. 15 degree from plumb line could not cause any damage to the transformer.

3. Spare Parts and Tools

Following spares shall be supplied along with each of the transformer:

- One complete set of gasket.
- One spare fan in the case of ONAF transformer.
- One spare fan and one spare pump motor in the case of ONAF/OFAF transformer.
- Pressure relief device and contactors one in each type.

- One complete tool box and special tools.
- One precision vacuum gauge.
- Insulation tapes.
- One radiator block.
- One thermometer of each type.
- One set of divertor switch contact.
- Ladder.
- One diverter switch for each substation (If required)
- One bushing of each voltage level (If 3 phase transformer are more than one unit)

In addition to above the manufacturer's recommended spares for 5 years trouble free operation and any special tools necessary for erection and repair should be provided.

4. Tests

The transformer and it's accessories shall be subjected to following tests in accordance with IEC 60076, 60137 and 60044 standards.

4.1. Routine Tests

- Visual inspection
- Measurement of winding resistance
- Measurement of voltage ratio and check of phase displacement
- Measurement of short-circuit impedance and load loss
- Measurement of no-load loss and current
- Dielectric tests
- Tests on on-load loss tap-changers
- Routine tests for bushings according to IEC 60137
- Routine tests for current transformers according to IEC 60044

4.2. Type Tests

- Temperature rise test
- Dielectric tests

- Type test for bushing according to IEC 60137
- Type test for current transformers according to IEC 60044

4.3. Special Tests

- Dielectric tests
- Determination of capacitance of windings to earth, and between windings
- Determination of transient voltage transfer characteristics
- Measurement of zero sequence impedances
- Short circuit withstand test
- Determination of sound levels
- Measurement of the harmonics of the no-load current
- Measurement of the power taken by the fan and oil pump motors
- Measurement of insulation resistance of the windings, to earth and/or measurement of dissipation factor ($\tan\delta$) of the insulation system capacitances.
- Tank pressure test

For bushings a 5 years test certificate could be accepted by purchaser.

Purchaser shall have access to the works for determination or assessment of compliance with the provision of this specification and withness the contractors inspection or tests.

A certification of compliance of the equipment design, type and routine tests stipulated in the applicable standards shall be produces by contractor.

Owner reserves the right to have representative present during final shop and functional testing. The contractor shall advise the date of test at least sixty (60) days in advance.

5. Drawings & Documents

5.1. Documents to be given by tenderer

- Filled schedule power transformer (II)
- Catalogue & technical pamphlets
- Summary of test reports
- Outline drawing
- Detailed summary of exceptions to tender specifications
- Reference list

- List of special tools
- List of spare parts

5.2. Documents to be given by contractor / supplier

The electrical and mechanical design, fabrication, factory testing, working and packing, transportation, erection, site test, operation and maintenance drawings, documents and manuals shall be submitted, not limited to the following:

- Calculation sheets to establish adequacy of transformer in any respect
- Overall dimensions of the assembled transformer
- Location and outlines of all bushings and terminal boxes
- Details of all lifting equipment
- Location and dimensions of manholes and inlet and outlet valves
- Location and size of sampling devices
- Proposed location, dimensions and details of cooling equipment
- Location of tank grounding provisions
- Proposed location, dimensions and details of oil preservation equipment
- Control and wiring diagrams
- Details of miscellaneous devices such as relays, oil level indicators, piping and relief diaphragm
- Assembly drawing
- Mounting details
- Name plate drawings
- Packing details
- Routine test certificate
- Site test instruction manuals
- Shipping, warehousing, assembly, erection, commissioning, operating and maintenance instruction manuals
- Type test documents
- Loading on foundation
- Magnetization curve
- List of components
- Work schedules and monthly progress report

- Drawing list
- Final as built DOC./Dwg
- Dismantling, reassembling and adjusting manuals
- Transformer equivalent circuit for overvoltage and network analysis
- Calculation of surge voltage transfer from primary to secondary and tertiary

6. Quality Assurance Plan

Contractor shall be responsible for planning and developing a quality assurance program, which assures his management design and technical responsibilities for quality that are integrated and executed in accordance with ISO standards or equivalent. The program shall be so set up and implemented as to prevent and properly detect non conference to contractual requirement.
A copy of quality manual and copies of required quality procedures shall be handed over to purchaser. The contractor is responsible for fixing any failure during guarantee interval.

7. Transportation, Storage, Installation and Commissioning

It is essential that the transport, storage, installation and commissioning of power transformer be performed in accordance with instructions given by the manufacturer.

7.1. Inspection and Reception

When a transformer is received, a thorough external inspection should be made before the unit is removed from the vehicle. If there is evidence of damage or rough handing in transit, an inspector representing the carder and the manufacturer should be notified. In all cases, the manufacturer's instructions should be followed. For shipments equipped with impact recorders, representatives from the purchaser and carrier should be present to inspect the transformer and examine the impact recorder chart at the site location.
For gas filled shipments, the gas pressure should remain positive even in the coldest weather. Upon arrival at the site, check the gas pressure in the tank and in the supply cylinder, if one is provided. If the gas pressure is zero, there is a possibility that outside air and moisture may have entered the tank and manufacturer should be notified. Check the oxygen content and dew point of the gas in the tank. It may be safely assumed that the transformer has not been contaminated in transit with outside air or moisture, if the dew point of the gas indicates a relative humidity of less than 1% and the oxygen content is below 1% (if shipped in nitrogen) and more than 10% (if shipped in dry air). If the oxygen content and dew points are outside these values, drying may be necessary and the manufacturer should be notified.

An internal inspection shall be made of the transformer if external inspections or impact recorder indicates possible shipping damage.
Dry air should be continuously supplied into the transformer while the manhole cover is removed. Extreme care must be taken that the oxygen content is 19.5% or more whenever anyone is inside. Dew point should be kept as close as possible to the value as measured at the factory. The transformer should not be left open any longer than necessary preferably less than 2 h.
When the internal inspection is made, the manufacturers recommendations should be followed. Inspection will include, for example, removal of any shipping blocking; examination for indication of core shifting; test for unintentional core grounds; visual inspection of windings, leads, and connections including clamping, bracing, and blocking; inspection of tap switches, including contact wipe, line- up, and pressure; inspection of current transformers, including supports, and condition and clearance of leads; examination of bushing draw leads; and checking for dirt, metal particles, moisture, etc. If any internal damage that may have been due to rough handling handing is found during this inspection, the carrier and the manufacturer should be notified. The manufacturer should also be notified if any foreign material is discovered. The transformer should not be opened under circumstances permit the entrance of moisture such as on days of high humidity.

7.2. Handling

The Transformer should always be handled in the normal upright position unless information from the manufacturer indicates it can be handled otherwise. Where a transformer cannot be handled by a crane or moved on wheels, it may be skidded or moved on rollers or slip plates, depending upon compatibility of transformer base design and the type of surface over which it is to be moved.
Lifting lugs and eyes are normally provided for lifting the complete transformer, and the necessary additional means are provided for lifting the various parts assembly. The lifting lugs and eyes are designed for vertical lift only. When lifting the complete transformer or a heavy piece, the cable should be so attached to provided a vertical force to each lug. Use Lifting cables of appropriate lengths so that the transformer will be lifted evenly.
Jack bosses or pads on all power transformers are provided so that it can be raise by means of jacks. On some transformers, jacks may be placed under the transformer bottom plate at points designated by the manufacturer. The drawings or manufacturers instructions should be consulted.

7.3. Storage

If the transformer will not be installed after reception or will be stored for a long time, the storage shall be done according to the following requirements:

- the storage process shall be in accordance with manufacturer instructions.
- If the transformer has been shipped without oil, it shall be filled with oil before storage.

- The conservator and silicagel breather should be installed on transformer.
- The electric panels witch equipped with heater, shall be supplied with an appropriate power supply.
- Bushings shall be stored in a covered condition in their original packs.
- The radiators can be stored in even covered or uncovered area while in any case, the flanges shall be protected against moisture.

7.4. Installation on Foundation

The foundation shall be capable to carry the complete transformer weight plus 10% safety margin. The transformers equipped with wheels shall be tight to the foundation preventing any movement.
The foundation shall be horizontally balanced. Use appropriate means such as interface plates delivered by the transformer to lead the produced gas in the transformer to the gas relay.
An oil pit shall be provided beneath the transformer used for drain oil. This pit may be also control the distribution of fire in case of transformer failure. The volume of this pit shall be sized such that it can contain all the transformer oil or using a piping system to deliver the oil to other locations.
Foundation height is depend on the carrier vehicle if the transformer is transport with a carriage or deep load truck, the foundation height shall be equal to the carrier vehicle height.
In case of large power transformers, the foundation rails shall be long enough to reach the exchange point and levelized with it.
If the transformer is handled by a crane, the foundation height is not very important but should be done for providing enough space above and sides of the foundation for crane maneuver.

7.5. Assembly of Accessories

Before the assembly process, all the accessories shall be compared with manufacturer list and any deviation shall be declared to the manufacturer.
The radiators, coolers and bushings shall be handled in a way prescribed by the manufacturer of the equipment and before the installation of these accessories, they should be inspected visually.
Bushings should be absolutely clean and dry when installed. Gaskets and gasket recesses should be carefully cleaned. Gaskets should be carefully placed and uniformly clamped so that tight seals are formed. Current – carrying connections should be thoroughly cleaned and solidly bolted.

Radiators or heat exchangers, liquid piping, valves, and fittings should be thoroughly cleaned and flushed (if contaminated) with clean, warm 25-35°C dielectric liquid before fitted to the transformer. Radiators or heat exchangers are usually capable of withstanding full vacuum. If not, these should not be installed until after the tank has been filled with dielectric liquid under vacuum.
Liquid – level gauge, temperature gauges, and other accessories should be installed in accordance with manufacturers instructions.

7.6. Oil Filling

7.6.1. Preparation

Leave the pressure relief device blanked off until after the final vacuum filling, unless the manufacturers instructions indicate the device can withstand full vacuum. If separate liquid expansion tanks or other devices that will not withstand full vacuum are provided, these should be isolated from the main tank before drawing vacuum.
After all parts have been assembled, the tank should be sealed and pressure tested to ensure that all joints are tight. Some manufacturers also recommend using a vacuum test to determine that the pressure rise with the tank sealed does not exceed manufacturers recommendations. With either pressure or vacuum tests it is important to be sure of the pressure differential conditions permissible on the OLTC panel, which may not be capable of withstanding any pressure differential. Check all gasketed joints with a suitable leak detector. The tank should hold the gas pressure for at least 4 h without leakage. All leaks detected in the above manner must be eliminated before starting the vacuum filling.
Any air leakage into the transformer tank, while a vacuum is being drawn on the transformer, may seriously contaminate the transformer insulation.
Ensuring that all leaks have been eliminated, drain the liquid and proceed with the vacuum treatment. The liquid may be drained as quickly as desired, but a rapid rate may create a partial vacuum within the tank. The drain valve should be closed immediately after the tank is empty to prevent entrance of air through the drain connection. Because unforeseen delays may occur before the vacuum treatment is applied, it is recommended that the dielectric liquid be replaced with dry gas during the draining process. After the liquid drain valve is closed, continue to admit dry gas (nitrogen) until a positive gauge pressure exists in the tank.

7.6.2. Vacuum treatment

The principal function of vacuum is to remove trapped air and moisture from the insulation and enable the insulation to attain its full dielectric strength. Small gas bubbles have much lower dielectric strength than the dielectric liquid and may, if located at a point of high stress, lead to failure. By removing most of the gas from the transformer and from the liquid by vacuum filling, the hazard of the small bubbles of free undissolved gas that remain in the windings and insulation is greatly reduced.

The degree of vacuum required depends on the design of the windings and insulation and should be determined in consultation between the manufacture and purchaser before assembly is begun. In general a vacuum treatment at pressures of the order of 2 mmHg (absolute) may suffice for transformers rated below 132 kV.For higher voltage transformers, vacuum treatment at pressures less than 1 mmHg absolute pressure may be required. An additional benefit gained from the treatment at high vacuum is that the moisture introduced into the transformer insulation during assembly can be removed before the transformer is energized.

A vacuum pump of evacuating the tank to the required degree of vacuum in approximately 2-3 h is recommended. Connect the vacuum pump to the vacuum fill connection on top of the transformer with pipe or reinforced house of sufficient size to minimize line losses.

In order to obtain an accurate vacuum value, it is essential that connection of the gauge or manometer be as close to the tank as possible and preferably at a different location on the tank than the vacuum hose. Start the vacuum pump and continue pumping until the tank pressure is constant. Close the vacuum pump valve and check for leaks in the tank or piping. If all joints are tight, there should be no appreciable increase in residual pressure in a period of 30 min.

7.6.3. Vacuum filling

After attaining the required vacuum and holding for 4 h or more, depending on manufacturers instructions, filling may begin (fluid inlet and vacuum connections should be separated as far as possible to keep liquid spray from entering the vacuum pump).

The liquid line should be connected to the upper filter press connection or other suitable connection on top of the tank. The processed liquid is admitted through this connection, the rate of flow being regulated by a valve at the tank to maintain a positive liquid pressure external to the tank at all times and to maintain the vacuum at or near its original value. An oil temperature between 60 to 80°C is recommended. The filling rate should not exceed 1.25 cm/min.

Filling should be done in one continuous operation, at least to a point above the core and coils.

The assembled transformer should not be energized for at least 12 h to allow the insulating oil to absorb residual gas and thoroughly impregnate the insulation.

7.6.4. Commissioning tests

After the transformer has been assembled and filled with dielectric liquid, tests should be made and the test reports preserved to ensure that the transformer is ready for service and to provide a basis for comparison with future maintenance tests. The following tests are suggested. All or any portion of these tests may be made, depending on the equipment available and the importance of the particular transformer.

- insulation resistance test on each winding to ground and between windings.
- Insulation power factor or dissipation factor test on each winding to ground and between windings. Core insulation should also be tested.
- Power factor or dissipation factor test on all bushings equipped with a power factor tap or capacitance tap.

- Winding ratio test on each tap. If OLTC transformer, check winding ratio on all OLTC positions.
- Check winding resistance of all windings with a Kelvin bridge or another suitable test device and compare with factory test results.
- Check operation of liquid and winding temperature indicating devices and their control accessories.
- Check dissolved gas, dielectric strength, power factor, interfacial tension, neutralization number, and water contact of the dielectric liquid.
- Check oxygen content and total combustible gas content of nitrogen gas cushion in sealed tank transformers. A total combustible gas test, where applicable, and a dissolved gas in oil test of the dielectric fluid should also be made soon after the transformer is in service at operating temperature to provide a suitable postenergization reference "bench mark".
- Check operation of auxiliary equipment, such as OLTCs, liquid– circulating pumps, fans, or liquid or water flow meters in accordance with manufacturers instructions.
- Check polarity, magnetization current, and impedance.
- Check resistance, ratio, and polarity of instrument transformers when provided. These tests should be made from terminal blocks from the control cabinet.
- Bushings tests.
- Insulation resistance test on auxiliary and control circuits.
- Check operation and wiring of auxiliary and control panels.
- Check operation of gas relay.
- Check the position of the conservator and silicagel breather.
- Check the secondary of bushing current transformers and be sure to short circuiting the cores which will be not used.
- Check the neutral connection, piping, fire protection system (if any) and oil leakage if any.

SCHEDULE TR (I)

RATINGS AND CHARAGERISTICS OF POWER TRANSFORMER

Item	Description		Technical particulars
1	**Particulars of system**		
1.1	Highest system voltage	kV	*
1.2	Nominal system voltage	kV	*
1.3	Number of phases		3
1.4	Nominal system frequency	HZ	50
1.5	System neutral earthing		Solidly earthed / resistance earthing
1.6	Max. duration of short time current	sec	*
2	**Service conditions**		
2.1	Max. ambient temperature	°C	40/45/50/55
2.2	Min. ambient temperature	°C	-40/-35/-30/-25
2.3	Average value of daily temperature	°C	*
2.4	Solar radiation	w/m^2	*
2.5	Altitude above sea level	m	1000/1500/2000/2500
2.6	Pollution		L/M/H/VH
2.7	Max. wind velocity	m/s	30/40/45
2.8	Wind velocity at ice condition	m/s	20
2.9	Ice coating thickness	m/m	5/10/20/25
2.10	Ground seismic acceleration	m/s^2	0.2g/0.25g/0.3g/0.35g
2.11	Relative humidity	%	90/95/more than 95
3	**Characteristics of transformer**		
3.1	Class (indoor / outdoor)		*
3.2	Type:		
3.2.1	Auto or separate winding		*
3.2.2	Core or shell		*
3.2.3	Single / Three phase		*
3.3	Vector group		*
3.4	Rated voltage		
3.4.1	HV side	kV	*
3.4.2	LV side	kV	*
3.4.3	TV side	kV	*
3.4.4	Permissible overexcitation	%	10

SCHEDULE TR (I)
RATINGS AND CHARAGERISTICS OF POWER TRANSFORMER

Item	Description		Technical particulars
3.5	Highest voltage		
3.5.1	HV side	kV	*
3.5.2	LV side	kV	*
3.5.3	TV side	kV	*
3.6	Rated power, at site condition		
	(irrespective of tap changer position)		
3.6.1	HV side	MVA	*
3.6.2	LV side	MVA	*
3.6.3	TV side	MVA	*
3.7	Impedance voltage		
	(base of HV winding MVA and principal tap)		
3.7.1	HV/LV	%	*
3.7.2	HV/TV	%	*
3.7.3	LV/TV	%	*
3.8	Insulation level		
3.8.1	Winding		
3.8.1.1	P.F.W voltage		
	- HV side	kV	*
	- LV side	kV	*
	- TV side	kV	*
	- Neutral	kV	*
3.8.1.2	L.I.W voltage		
	- HV side	kV_{peak}	*
	- LV side	kV_{peak}	*
	- TV side	kV_{peak}	*
	- Neutral	kV_{peak}	*
3.8.1.3	S.I.W voltage		
	- HV side (if applicable)	kV_{peak}	*
	- LV side (if applicable)	kV_{peak}	*

SCHEDULE TR (I)
RATINGS AND CHARAGERISTICS OF POWER TRANSFORMER

Item	Description		Technical particulars
3.8.2	Bushing		
3.8.2.1	P.F.W voltage		
	- HV side	kV	*
	- LV side	kV	*
	- TV side	kV	*
	- Neutral	kV	*
3.8.2.2	L.I.W voltage		
	- HV side	kV_{peak}	*
	- LV side	kV_{peak}	*
	- TV side	kV_{peak}	*
	- Neutral	kV_{peak}	*
3.8.2.3	S.I.W voltage		
	HV side (if applicable)	kV_{peak}	*
	LV side (if applicable)	kV_{peak}	*
3.9	Max. temperature rise at rated power		
3.9.1	Hot spot	°C	*
3.9.2	Winding	°C	*
3.9.3	Top oil	°C	*
3.10	Radio interference at 1 MHZ and 1.05 rated voltage	μV	*
3.11	Sound level	dB	*
3.12	Cooling system (air or water cooled)		
3.12.1	Mode of cooling (ONAN/ONAF/…)		
3.12.2	HV/LV/TV rated output power at		
	- ONAN	MVA	*
	- ONAF	MVA	*
	- OFAF	MVA	*

SCHEDULE TR (I)
RATINGS AND CHARAGERISTICS OF POWER TRANSFORMER

Item	Description		Technical particulars
3.13	Tapchanger		
3.13.1	Type		
3.13.2	Tapping range		*
3.13.3	Number of tap		*
3.13.4	Max. complete operation time of tap changer	sec	*
3.13.5	Rated current	A	*
3.13.6	Operating mode (parallel/single)		*
3.13.7	Automatic voltage regulator required?	Yes /No	*
3.13.8	Winding location		*
3.13.9	Voltage class (I or II)		*
3.13.10	Remote OLTC control panel required	Yes /No	
3.14	Method of earthing system		
3.14.1	HV side		*
3.14.2	LV side		*
3.14.3	TV side		*
3.15	Bushings		
3.15.1	Rated current (HV/LV/TV)	A	*
3.15.2	Short circuit current (HV/LV/TV)	kA	*
3.15.3	Test tap required?	Yes/No	*
3.15.4	Minimum external creepage distance		
3.15.4.1	HV side	mm	*
3.15.4.2	LV side	mm	*
3.15.4.3	TV side	mm	*
3.15.4.4	Neutral	mm	*
3.16	Short circuit duration	sec	2
3.17	Symmetrical short circuit current		
3.17.1	HV side	kA	*
3.17.2	LV side	kA	*
3.17.3	TV side	kA	*
3.18	Transformer losses (for tender evaluation of transformer losses will be valued)		
3.18.1	No load loss	$/KW	*
3.18.2	Load loss	$/KW	*
3.19	Penalty		
3.19.1	No load loss (iron loss)	$/KW	*
3.19.2	Load loss (copper loss & cooling system)	$/KW	*
3.20	Manual tap changer on TV side is required	Yes/No	*

SCHEDULE TR (I)
RATINGS AND CHARAGERISTICS OF POWER TRANSFORMER

Item	Description		Technical particulars
3.21	Master / flower control is required?	Yes/No	*
3.22	Line drop compensation equipment is required?	Yes/No	*
3.23	Type of terminal		
3.23.1	HV		*
3.23.2	LV		*
3.23.3	TV		*
3.24	Auxiliary power supply voltage		
3.24.1	AC	V	*
3.24.2	DC	V	*
3.25	BCT required?	Yes /No	*
3.26	Phase winding BCT characteristics		
3.26.1	Ratio		*
3.26.2	Accuracy		*
3.26.3	No. of cores		*
3.26.4	Burden	VA	*
3.27	Neutral BCT characteristics		
3.27.1	Ratio		*
3.27.2	Accuracy		*
3.27.3	No. of cores		*
3.27.4	Burden	VA	*
3.28	Max vibration (at rated condition)	micron	*
3.29	Type of tank (bell or conventional)		*
3.30	Wheels required?	Yes/No	*
3.31	Magnetic oil level indicator for main tank required?	Yes/No	*
3.32	Type of conservator (Air bag / conventional)		*
3.33	Hydraulic jacks required?	Yes/No	*
3.34	Oil test kit required?	Yes/No	*
3.35	Oil purification plant required?	Yes/No	*
3.36	Is on line gas monitoring (OLGM) required?		*
	If no, is there need to provision for OLGM?	Yes/No	
3.37	Lightning arrester supports required (HV/LV/TV)	Yes/No	*
3.38	Access ladder required?	Yes/No	*
3.39	Fire protection system required?	Yes/No	*
3.40	Oil (class acc. To IEC 60296)		*
3.41	Whether radiators shall be separately mounted?	Yes/No	*
3.42	Radiators (painted or hot dip galvanized)		*
3.43	Size of copper ground conductor	mm^2	*

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
1	General		
1.1	Manufacturers name and country		
1.2	Type designation		
1.3	Class	outdoor/indoor	
1.4	Applicable standards		
1.5	Applicable condition:		
1.5.1	Max. design ambient temperature	°C	
1.5.2	Min. design ambient temperature	°C	
1.5.3	Average daily temperature	°C	
1.5.4	Solar radiation	w/m^2	
1.5.5	Design altitude above sea level	m	
1.5.6	Design pollution level		
1.5.7	Max. permissible ice thickness	mm	
1.5.8	Design seismic acceleration	m/s^2	
1.5.9	Max. permissible wind velocity	m/s	
2	Type of transformer		
2.1	Shell or core		
2.2	Auto or separate windings		
2.3	Three phases or single phase units		
3	Cooling type		
3.1	First stage		
3.2	Second stage		
3.3	Third stage		
4	Rated frequency	HZ	
5	Vector group		
6	No load voltage	KV	
7	Normal voltage variation range	%	
8	Exceptional voltage variation range	%	
9	Rated power at IEC condition		
	(at first / second and third stage of cooling)		
9.1	HV side	MVA	
9.2	LV side	MVA	
9.3	TV side	MVA	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
10	Continuous maximum rating irrespective of tapping		
	Position when operating under the specified site		
	Condition (at first / second and third stage of cooling)		
10.1	HV side		
10.2	LV side		
10.3	TV side		
11	Rated ratio		
12	Insulation level		
12.1	Winding		
12.1.1	HV side P.F.W voltage	kV	
12.1.2	LV side P.F.W voltage	kV	
12.1.3	TV side P.F.W voltage	kV	
12.1.4	Neural P.F.W voltage	kV	
12.1.5	HV side L.I.W voltage	kV_{peak}	
12.1.6	LV side L.I.W voltage	kV_{peak}	
12.1.7	TV side L.I.W voltage	kV_{peak}	
12.1.8	Neutral L.I.W voltage	kV_{peak}	
12.1.9	HV side S.I.W voltage	kV_{peak}	
12.1.10	LV side S.I.W voltage (if applicable)	kV_{peak}	
12.2	Bushing:	kV	
12.2.1	HV side P.F.W voltage	kV	
12.2.2	LV side P.F.W voltage	kV	
12.2.3	TV side P.F.W voltage	kV	
12.2.4	Neutral side P.F.W voltage	kV	
12.2.5	HV side L.I.W voltage	kV_{peak}	
12.2.6	LV side L.I.W voltage	kV_{peak}	
12.2.7	TV side L.I.W voltage	kV_{peak}	
12.2.8	Neutral side L.I.W voltage	kV_{peak}	
12.2.9	HV side S.I.W voltage (if applicable)	kV_{peak}	
12.2.10	LV side S.I.W voltage (if applicable)	kV_{peak}	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
13	Maximum temperature rise above ambient tem. at rated power		
13.1	Winding		
13.1.1	Hot spot	°C	
13.1.2	Average (measured by resistance test)	°C	
13.2	Oil		
13.2.1	Top oil	°C	
13.2.2	At inlet to cooler	°C	
13.2.3	At outlet of cooler	°C	
14	Maximum flux density in iron at rated voltage and Power frequency and at rated voltage ratio		
14.1	Wound limbs	T	
14.2	Unwound limbs	T	
14.3	Yokes	T	
14.4	Shields	T	
15	Maximum flux density in iron under the most onerous voltage conditions (10% over rated voltage on any tapping at 50 HZ)		
15.1	Wound limbs	T	
15.2	Unwound limbs	T	
15.3	Yokes	T	
15.4	Shields	T	
16	Max. current density in windings at IEC rated power		
16.1	HV side	A/mm^2	
16.2	LV side	A/mm^2	
16.3	TV side	A/mm^2	
16.4	Tapping windings	A/mm^2	
17	Magnetizing current and power (HV winding)		
17.1	At 90% rated voltage	A&KVA	
17.2	At 100% rated voltage	A&KVA	
17.3	At 110% rated voltage	A&KVA	
17.4	At the maximum system voltage	A&KVA	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
18	Losses at site condition		
18.1	Load losses at rated frequency, 75°C & rated current on principal tapping		
18.1.1	First stage of cooling	KW	
18.1.2	Second stage of cooling	KW	
18.1.3	Third stage of cooling	KW	
18.2	Load losses at 75°C & max rise voltage tapping		
18.2.1	First stage of cooling	KW	
18.2.2	Second stage of cooling	KW	
18.2.3	Third stage of cooling	KW	
18.3	Load losses at 75°C & max. lower voltage tapping		
18.3.1	First stage of cooling	KW	
18.3.2	Second stage of cooling	KW	
18.3.3	Third stage of cooling	KW	
18.4	No load losses at rated frequency & rated voltage on principal tapping	KW	
18.5	Cooling plant losses at ONAF1/ONAF2/OFAF rating	KW	
18.6	Proportion of sum of fixed and load losses at ONAN rating, principal tapping, in respect to the rated power Which will be supplied during the temperature rise test	%	
18.7	Total losses at 75°C and rated current and principal tapping		
18.7.1	At IEC rating including input to cooling plant	KW	
18.7.2	At ONAN rating	KW	
19	Impedances		
19.1	Positive sequence impedance at 75°C on principal tapping & on max. relevant MVA base		
19.1.1	Between HV & LV	%	
19.1.2	Between HV & TV	%	
19.1.3	Between LV & TV	%	
19.2	Positive sequence impedance at 75°C, max. raise voltage and on max. relevant MVA base		
19.2.1	Between HV & LV	%	
19.2.2	Between HV & TV	%	
19.2.3	Between LV & TV	%	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
19.3	Positive sequence impedance at 75°C, max.		
	Lower voltage and on max. relevant MVA base		
19.3.1	Between HV & LV	%	
19.3.2	Between HV & TV	%	
19.3.3	Between LV & TV	%	
19.4	Zero sequence impedance at 75°C on principal		
	Tapping & on max. relevant MVA base		
19.4.1	Between HV & LV	%	
19.4.2	Between HV & TV	%	
19.4.3	Between LV & TV	%	
19.5	Resistance of windings at 75°C on		
	Principal tapping & on max. relevant MVA base		
19.5.1	HV side	Ω/phase	
19.5.2	LV side	Ω /phase	
19.5.3	TV side	Ω /phase	
20	Maximum fault current in winding on which		
	mechanical stresses are based		
20.1	HV side winding		
20.1.1	Symmetrical component current	kA	
20.1.2	Asymmetrical crest current	kA_{peak}	
20.2	LV side winding		
20.2.1	Symmetrical component current	kA	
20.2.2	Asymmetrical crest current	kA_{peak}	
20.3	Tapped winding		
20.3.1	Symmetrical component current	kA	
20.3.2	Asymmetrical crest current	kA_{peak}	
20.4	TV side winding		
20.4.1	Symmetrical component current	kA	
20.4.2	Asymmetrical crest current	kA_{peak}	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
21	Maximum fault current on which mechanical		
	Stresses are based for OLTC (main & arcing contacts)		
21.1	Symmetrical current	kA	
21.2	Asymmetrical crest current	kA_{peak}	
22	Winding cross section		
22.1	Minimum cross sectional area of conductor for		
22.1.1	HV winding	mm^2	
22.1.2	LV winding	mm^2	
22.1.3	Tapped winding	mm^2	
22.1.4	TV winding	mm^2	
22.2	Minimum cross sectional area of insulated conductor for		
22.2.1	HV winding	mm^2	
22.2.2	LV winding	mm^2	
22.2.3	Tapped winding	mm^2	
22.2.4	TV winding	mm^2	
23	Type and arrangement of winding		
23.1	HV side		
23.2	LV side		
23.3	Tapping		
23.4	TV side		
24	Conductor material		
24.1	HV windings		
24.2	LV windings		
24.3	Tapping windings		
24.4	TV windings		
24.5	Type of joints		
24.6	Type of insulation of winding (uniform/graded)		
24.7	Insulation material		
25	Exciting current		
25.1	At rated voltage when excited from HV side	A	
25.2	At 110% rated voltage when excited from HV side	A	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description	Technical particulars	
26	Tap changers		
26.1	Off load tap changer		
26.1.1	Type		
26.1.2	Manufacturer		
26.1.3	Rated current	A	
26.1.4	Rated step voltage	V	
26.1.5	Total number of steps		
26.1.6	Voltage class	kV	
26.1.7	BIL to ground	kV_{peak}	
26.1.8	BIL between divertor switch contacts	kV_{peak}	
26.1.9	BIL across regulating winding	kV_{peak}	
26.10	Position of tapping (winding)		
26.2	On load tap changer		
26.2.1	Type (oil /vacuum)		
26.2.2	Manufacturer		
26.2.3	Rated current	A	
26.2.4	Rated step voltage	V	
26.2.5	Rated switching levels	kA	
26.2.6	Position of tapping (winding)		
26.2.7	Voltage class	kV	
26.2.8	BIL to ground	kV_{peak}	
26.2.9	BIL between divertor switch contacts	kV_{peak}	
26.2.10	BIL across regulating winding	kV_{peak}	
26.2.11	Type of AVR		
26.2.12	Method of parallel control		
	- master / follower		
	- minimum circulating current		
	- reverse reactance method		

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
26.2.13	OLTC protection system		
26.2.13.1	oil flow relay type and maker		
26.2.13.2	pressure relief type and maker		
26.2.13.3	over pressure relay type and maker		
26.2.13.4	other protection equipment type and maker		
26.2.14	Type and designation of driving mechanism		
26.2.15	Rated voltage of drive motor	V	
26.2.16	Rated voltage of control circuit	V	
26.2.17	Whether remote control cubicles for AVR control Included in scope of work?	Yes /No	
26.2.18	Full description of remote OLTC control cubicle included in offer?	Yes /No	
27	Capability of transformer to remain in operation from hot condition without injurious heating at rated full load in case of failure of		
27.1	50% of air forced cooling	min	
27.2	100% of air forced cooling	min	
27.3	All of air and oil forced cooling	min	
27.4	Condition of injurious heating (hot spot temp)	°C	
28	Cooling system		
28.1	Number of coolers or cooler banks for ONAF1/ONAF2		
28.2	Number of radiator units in each bank		
28.3	Manufacturer of radiators		
28.4	Number of fans		
28.5	Make and type of fans		
28.6	Number of pumps		
28.7	Make & type of pumps		
28.8	Capacity of each fan and motor	kW	
28.9	Capacity of each pump and motor	kW	
28.10	Rated operating voltage of fans	V	
28.11	Three or single phase		
28.12	Starting current of each fan	A	
28.13	Efficiency of each fan		
28.14	Rated operating voltage of pumps	V	
28.15	Three or single phase		

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
28.16	Staring current of each pump	A	
28.17	Efficiency of each pump		
29	Core data		
29.1	Three limb / five limb		
29.2	Type of core stacking		
29.3	Type of steel core lamination		
29.4	Thickness of steel core lamination	mm	
29.5	Manufacturer of steel core material		
29.6	Insulation of core		
29.6.1	lamination		
29.6.2	core bolts (if applicable)		
29.6.3	strapping		
30	Tank		
30.1	Tank design (conventional /bell shaped)		
30.2	Thickness of transformer tank plates		
30.2.1	Cover	mm	
30.2.2	Sides	mm	
30.2.3	Bottom	mm	
30.2.4	Radiator Plates	mm	
30.2.5	Conservator	mm	
30.3	Vacuum withstand capability		
	Tank	mmHg	
	Radiators	mmHg	
	Conservator	mmHg	
30.4	Positive pressure withstand capability for		
	Complete transformer	mmHg	
31	Vibration at rated frequency and voltage at 75°C	micron	
32	Provisions for tank mounting lighting arrester?	Yes/No	
33	Anti – vibration pad?	Yes/No	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
34	Oil		
34.1	Manufacturer		
34.2	Country of manufacturer		
34.3	Naphtenic or paraphenic based oil?		
34.4	Class (as per IEC 60296)		
34.5	Type (inhibited /non– inhibited)		
34.6	Details of inhibitor (if applicable)		
34.7	Dielectric strength and test standard		
34.7.1	New	kV	
34.7.2	After treatment	kV	
34.8	Quantity of oil:	liters	
34.8.1	Main tank	liters	
34.8.2	Conservator	liters	
34.8.3	Radiator	liters	
34.9	Total oil required for commissioning	liters	
34.10	Total oil provided (including 5% extra)	liters	
34.11	Way of shipping (in drums or by truck)		
34.12	Total number of drums provided		
35	Max. sound level acc. to IEC 60076-10		
35.1	With auxiliaries	dB	
35.2	Without auxiliaries	dB	
36	Applicable standard for overload		
37	Physical data		
37.1	Overall height, including bushings	mm	
37.2	Overall width, including mounted accessories	mm	
37.3	Overall Length, including mounted accessories	mm	
37.4	Height over cover for lifting core and coils	mm	
37.5	Max. shipping dimensions (largest item) L×W×H	m×m	
37.6	Weight of core and coils	kg	
37.7	Weight of tank / cooler and fittings	kg	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
37.8	Weight of oil	kg	
37.9	Weight of on load tap changer	kg	
37.10	Total weight of complete transformer	kg	
37.11	Max. shipping weight (heaviest item)	kg	
37.12	Total weight of windings (copper)	kg	
37.13	Total weight of core (steel lamination)	kg	
37.14	Total weight of steel (tank, fittings, conservator, etc)	kg	
38	Wheels		
38.1	Plain / flanged		
38.2	Unidirectional / bi– directional		
38.3	Gauge	mm	
39	Accessories make and type		
39.1	Buchholz relay		
39.1.1	For conservator main compartment		
39.9.2	For conservator OLTC		
39.2	Temperature indicators		
39.2.1	Oil		
39.2.2	HV winding		
39.2.3	LV winding		
39.2.4	TV winding (if applicable)		
39.3	Conservator type(normal / air bag)		
39.4	Silicagel breather		
39.5	Cables		
39.6	Control cabinets		
39.7	Fire extinguishing system		
40	Online gas monitoring system		
40.1	Whether any system is offered?	Yes/No	
40.2	Type		
40.3	Manufacturer		
40.4	Manufacturer country		

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars
40.5	Sensor range (in ppm)	ppm	
40.6	Accuracy of sensor	%	
40.7	Main key gases detected		
40.8	Moisture detection	Yes/No	
40.9	Relative sensitivity to		
40.9.1	CO	%	
40.9.2	C_2H_2	%	
40.9.3	C_2H_4	%	
40.9.4	Other	%	
40.10	Response time	Minute	
40.11	Hardware		
140.12	Software		
40.13	Operating temperature range (oil/Ambient)	°C/°C	
40.14	Dimension		
	DxH(Cylindrical Type)	cm×cm	
	LxWxH (Cubic Type)		
40.15	Weight	kg	
40.16	Functions		
40.17	External displays		
40.18	Output options		
40.19	Power requirement	W	
40.20	Gas alarm indicator		
40.21	Supervisory link port		
40.22	Communication port		
40.23	Calibrator		
40.24	Host PC software		
40.25	Modem		
40.26	Other accessories		
40.27	Mounted on tank or ground		
40.28	Whether all catalogues and description of the system attached	Yes/No	

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars			
			P	S	T	N
41	Bushings					
41.1	Manufacturer					
41.2	Manufacturers type and identification					
41.3	Rated service voltage	kV				
41.4	Type (oil impregnated / resin type)					
41.5	Nominal current rating	A				
41.6	Thermal short time current rating (2 Sec)	kA				
41.7	Radio interference voltage level measured at 1.1 Um/$\sqrt{3}$ at 1 MHZ	μV				
41.8	Type of insulation					
41.9	Quantity of oil per bushing	Liters				
41.10	Equipped with magnetic oil indicator?	Yes/No				
41.11	Electrostatic capacity of complete bushing	F				
41.12	Loss angle at working voltage					
41.13	Test method for internal discharge tests					
41.14	Voltage level for internal discharge tests	kV				
41.15	Total creepage distance over porcelain externally	mm				
41.16	Protected creepage distance	mm				
41.17	Maximum external diameter of ring type current transformers which can be accommodate	mm				
41.18	Mass of bushing complete with fittings	kg				
41.19	Min corona inception voltage	kV				
41.20	Maximum static bushing load					
41.20.1	Vertical	N				
41.20.2	Horizontal	N				
41.21	Maximum dynamic bushing load					
41.21.1	Vertical	N				
41.21.2	Horizontal	N				
41.22	Whether bushings can be washed when energized (hot washing)?	Yes/No				
41.23	Equipped with test tap?	Yes/No				
42	Bushing current transformer					
42.1	Ratio					
42.2	Burden	VA				
42.3	Accuracy					
42.4	No. of cores					
42.5	Knee point voltage	V				
42.6	No load impedance	Ω				

SCHEDULE TR (II)
GUARANTEED TECHNICAL INFORMATION OF POWER TRANSFORMER
(TO BE SUPPLIED WITH TENDER)

Item	Description		Technical particulars			
			P	S	T	N
41.22	Whether bushings can be washed when energized (hot washing)?	Yes/No				
41.23	Equipped with test tap?	Yes/No				
42	Bushing current transformer					
42.1	Ratio					
42.2	Burden	VA				
42.3	Accuracy					
42.4	No. of cores					
42.5	Knee point voltage	V				
42.6	No load impedance	Ω				