PARTICULIAR TECHNICAL SPECIFICATION
FOR
AUTO-TRANSFORMER AND REACTOR

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1 TECHNICAL DESCRIPTION, REQUIREMENTS AND DATA

1.1 General

These Particular Technical Specifications together with the General Technical Specifications refer to the special technical requirements for establish the required substations.

Wherever possible, these Particular Technical Specifications shall be applied in conjunction with the General Technical Specifications. In case of discrepancies between the Particular and Special Technical Specifications, the Particular Technical Specifications shall prevail.

Single line diagrams, layout and cross section drawings of the substations and main equipment have been presented within the Drawings.

1.2 Main Requirements for New Equipment

The transformers (Auto-transformers and neutral earthing & auxiliary power supply transformers), which are subject of these Technical Specifications, shall be installed in the following Substations:

- **New Aqaba 400/132/33KV (AAWDCP) substation -** New Substation,

In addition, shunt reactors (three-phase and single-phase), which are subject of these Technical Specifications as well, shall be installed in the following Substations:

- **New Aqaba 400/132/33KV (AAWDCP) substation -** New Substation - 33kV three-phase shunt reactors to be connected to tertiary autotransformers 400/132/33kV winding, through dedicated 33kV switchgear.

Transformers shall be designed in accordance with the requirements of the Standard IEC 60076 and other relevant Standards if not otherwise required in this Specification.

Reactors shall be designed in accordance with the requirements of the Standard IEC 60076-6 and other relevant Standards if not otherwise required in this Specification.

Transformers and reactors with associated auxiliary equipment shall be designed in such a manner to meet the requirements required in this Technical Specifications, Schedules of Technical Data (schedule D) and Drawings at climate conditions at the Site defined within General Technical Specifications.

The Contractor shall be responsible for complete scheme (transformer voltage control scheme, transformers parallel operation, transformer cooling scheme, etc.) and proper functioning of the equipment procured within this specification.

The Tenderer/Contactor shall visit the Sites and make himself aware of the details of the existing system/facilities. The modification work at the associated substation shall be compatible with the existing system.

1.3 Technical Description and Data of Existing Equipment (N.A)

Since that new transformer for Substation, shall be able to operate in parallel with other existing transformers in this substation, the characteristics of those transformers are given in the following Table.

Tr. No.			
Manufacturer			
Year of production			
HV/MV (kV/kV)			
Tap changer			
Connection			
Rated Power (MVA)			
Short circuit impedance at principal tapping (%)			

The existing transformers AVR scheme shall be modified in order that the scheme shall be capable of performing the following functions:

- Each transformer shall be able to operate on master mode, while the other transformers working on the follower mode,
- Several transformers cannot be selected to master mode at same time,
- It shall be possible to operate each transformer independently,
- The scheme shall allow selecting any transformer to off position while the other transformers are selected to independent mode,
- All costs of these modifications shall be included in the Tender Price.

— Characteristic of the existing reactor at is given at table below:

– Reactor characteristic	
– Manufacturer	
– Rated power	
– Rated voltage	
– Rated frequency	
– Cooling	

1.4 Guarantees, Penalties and Rejection of Supply

1.4.1 Transformers

Contractor shall guarantee that transformers shall fully comply with characteristics given in Schedule of Technical Data.

In case that the supplied equipment does not comply with requirements stated in these Particular Technical Specifications, as well as those stated in the Schedule of Technical Data, the Client has a right to reject the Supply.

For the transformers the following guarantees are of particular importance:

- Rated power (IEC 60076-1),
- Losses (IEC 60076-1),
- Transformer temperature rise (IEC 60076-2),
- Short-circuit impedance (IEC 60076-1),
- No-load current (IEC 60076-1),
- Voltage ratio,
- Sound pressure/sound power level (max. permitted values according to NEMA TR-1 Standard, calculation of sound power level according to IEC 60076-10).

Tolerances shall not exceed the values specified in IEC 60076.

For the (Transformers) evaluation purpose, main transformer no-load losses and load losses including the transformer cooling power (filled-in financial offer) shall be capitalized in accordance with the following formula:

Total Cost = IC + 7438.54 (P0 + Pc0) + 1880.52 (Pk + Pcs – Pc0), for 400 MVA 400/132/33 KV.
Where:

- IC: Initial offer cost;
- Po: No load losses at rated tap;
- Pco: The cooling power for no load operation;
- Pk: Load losses at rated tap;
- Pcs: Total cooling power at rated Power.

Tenders for (Transformers) shall be evaluated based on the Total Cost.

Alternative proposals are not permitted.

The Client will determine for each tender the evaluated tender price by adjusting the tender price as follows:

(i) Making any correction for arithmetical errors;

(ii) Applying the discounts offered, if any, by the Participant;

(iii) Adding the cost of quantifiable non-material deviations and omissions;

(iv) Adding Capitalized Losses.

The most economically advantageous tender is the tender, which has the lowest evaluated tender price

Guaranteed maximum values of no-load and load losses and auxiliary losses (input to cooling system) shall be filled-in by Tenderer/Contractor in the financial schedule.

If any of the measured values of losses exceeds the guaranteed values, Client will have right to exercise one of the following options:

- Reject the any transformer,
- Penalty for complete shall be recovered from the Contractor for the excess losses of any transformer as under:
  - JOD 11,157.81 per kW for the no-load losses,
  - JOD 2,820.78 per kW for the load losses and auxiliary losses.

It is thereby understood that values of 0.5 kW and above will be rounded up to the next full kW.

In case of either the measured load loss at reference temperature or no-load loss is greater than +15%, or the total loss exceeds 10% of the guaranteed values, the respective transformers shall not be accepted.

1.4.2 Reactors

Contractor shall guarantee that reactors shall fully comply with characteristics given in the Sub-section 5.1: Schedule of Technical Data.

In case that the supplied equipment does not comply with requirements stated in these Particular Technical Specifications, as well as those stated in the Schedule of Technical Data, the Client has a right to reject the Supply.

For the reactors the following guarantees are of particular importance:

- Reactance at rated voltage and rated frequency (IEC 60076-6),
- Linearity of resistance (IEC 60076-6),
- Total losses at rated current and rated frequency at 75^{0}C (IEC 60076-6),
- Reactor temperature rise (IEC 60076-2),
- Sound pressure/sound power level (max. permitted values according to NEMA TR-1 Standard, calculation of sound power level according to IEC 60076-10).

Tolerances shall not exceed the values specified in IEC 60076.

For the purposes of Bid evaluation, these losses are capitalized in accordance with the following formula:

Total Cost = IC + 2603.5 Pk

where:

- IC: initial cost, in JOD
- Pk: Total losses in kW

(Reactors) shall be evaluated based on the Total Cost

Guaranteed maximum values of load losses shall be filled-in by Tenderer/Contractor in the Sub-Section 5.1: Schedule of Technical Data. In case that at the acceptance tests, after manufacture, the reactors have losses higher than the guaranteed values, the following criteria shall govern:

a. Reactors having total losses within the tolerance permitted by IEC 60076 Part 1 shall be accepted subject to full compliance with all technical prescriptions and subject to the acceptance by the Contractor of a reduction in the Contract Price equal to the cost of excess losses obtained using rate 3905.25 JOD/kW.

It is thereby understood that values of 0.5 kW and above will be rounded up to the next full kW.

In case of the measured total loss is greater than +10% of the guaranteed values, the respective reactors shall not be accepted.

b. Reactors having total losses exceeding the tolerance permitted by IEC 60076-6 shall be rejected.

1.5 Applicable Standards

Unless otherwise specified, the transformers and reactors with associated equipment shall be fully designed and manufactured in accordance with these Technical Specifications and the latest editions of the following IEC, BS, and IEEE Standards:

- IEC 60050, International Electrotechnical Vocabulary (IEV),
- IEC 60417 DB, Graphical symbols for use on equipment,
- IEC 60617 DB, Graphical symbols for diagrams,
- IEC 60038, IEC standard voltages,
- IEC 60071, Insulation co–ordination,
- IEC 61936, Power installations exceeding 1 kV a.c.,
- IEC 60721, Classification of environmental conditions,
- IEC 60529, Degrees of protection provided by enclosures (IP Code),
- IEC 61000, Electromagnetic compatibility (EMC),
- IEC 60085, Electrical insulation,
- IEC 60068, Environmental testing,
- IEC 60076, Power transformers,
- IEC 60076-6, Earthing transformers and Reactors,
- IEC 60404, Magnetic materials,
- IEC 60214, Tap-changers,
- IEEE Std C57.91, Guide for Loading Mineral – Oil – Immersed Transformers,
- IEC 60616, Terminal and tapping markings for power transformers,
- IEEE Std C57.148, Standard for Control Cabinets for Power Transformers,

- IEC 60137, Insulated bushings for alternating voltages above 1000 V,
- IEC 60815, Selection and dimensioning of high-voltage insulators intended for use in polluted conditions,
- IEC 62155, Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1 000 V,
- IEC 60296 Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment,
- IEC 62535 Insulating liquids - Test method for detection of potentially corrosive sulphur in used and unused insulating oil,
- IEC 61869-2, Instrument transformers - Additional requirements for current transformers.

If the Tenderer offers design, equipment, workmanship or testing in compliance with any Standard which deviates from the above-mentioned Standards, such deviations shall be submitted along with his Tender.

Application of any Standard other than the above mentioned, shall be the subject of the Client's approval.

1.6 General Design Requirements

Transformers shall be three-phase, two-winding, oil immersed for outdoor installation.

Reactors shall be three-phase, single-winding, oil immersed, gapped-core, for outdoor installation.

The design and manufacture of the transformers and reactors with associated equipment shall be in accordance with the latest state-of-the-art technology in this field and it shall be envisaged for a long-term operation.

Particular attention shall be paid to preparation of adequate conceptual solution, easy access, simple operation and logical arrangement of individual parts.

Spare parts shall be fabricated to enable easy installation and accurate fitting, without the need for subsequent adjustments.

Easy and smooth maintenance of the transformers and associated equipment shall be ensured.

During continuous operation with rated characteristics, no part of the equipment shall be damaged due to overheating.

Transformers of the same type shall be identical and completely interchangeable. Furthermore, transformers parts and devices having the same rated values and characteristics shall be identical and completely interchangeable as well.

Transformers and reactors shall be designed to withstand earthquake loadings of the accelerations which are specified in the *General Technical Specifications*.

The transformers shall be capable to withstand for three seconds (3 s) an external short circuit between phases without any damage. The value of short-circuit current is specified schedule D: Schedule of Technical Data.

The transformers and reactors shall be able to withstand, without any damage, the highest voltages and loads which might occur in any conceivable operating condition.

All elements exposed to significant wear shall have removable wearing parts in order to enable easy and cost-effective repair or replacement.

1.7 Operation at Voltage and Frequency Different than Rated Values

The transformers and reactors shall be designed and constructed to operate within voltage and frequency deviations in the electric power system as defined in the latest edition of NEPCO Transmission Grid Code.

1.8 Ability to Withstand Short Circuit

According to Standard IEC 60076-5, the transformers shall be designed and constructed to withstand without damage the thermal and dynamic effects of external short circuits. Contractor shall submit all necessary calculations to prove ability to withstand these thermal and dynamic effects of external short circuits.

The transformers and all associated facilities (e.g. tap-changer) shall be designed and constructed for the value and duration of the short-circuit current indicated in schedule D: Schedule of Technical Data, when operating on any tapping position

Thermal ability to withstand short-circuit shall be demonstrated by calculation (according to Standard IEC 60076-5).

The ability to withstand the dynamic effects of short-circuit shall be demonstrated by calculation and design consideration (according to Standard IEC 60076-5). Validation by comparison with a previously tested similar transformer or tests on representative models is required.

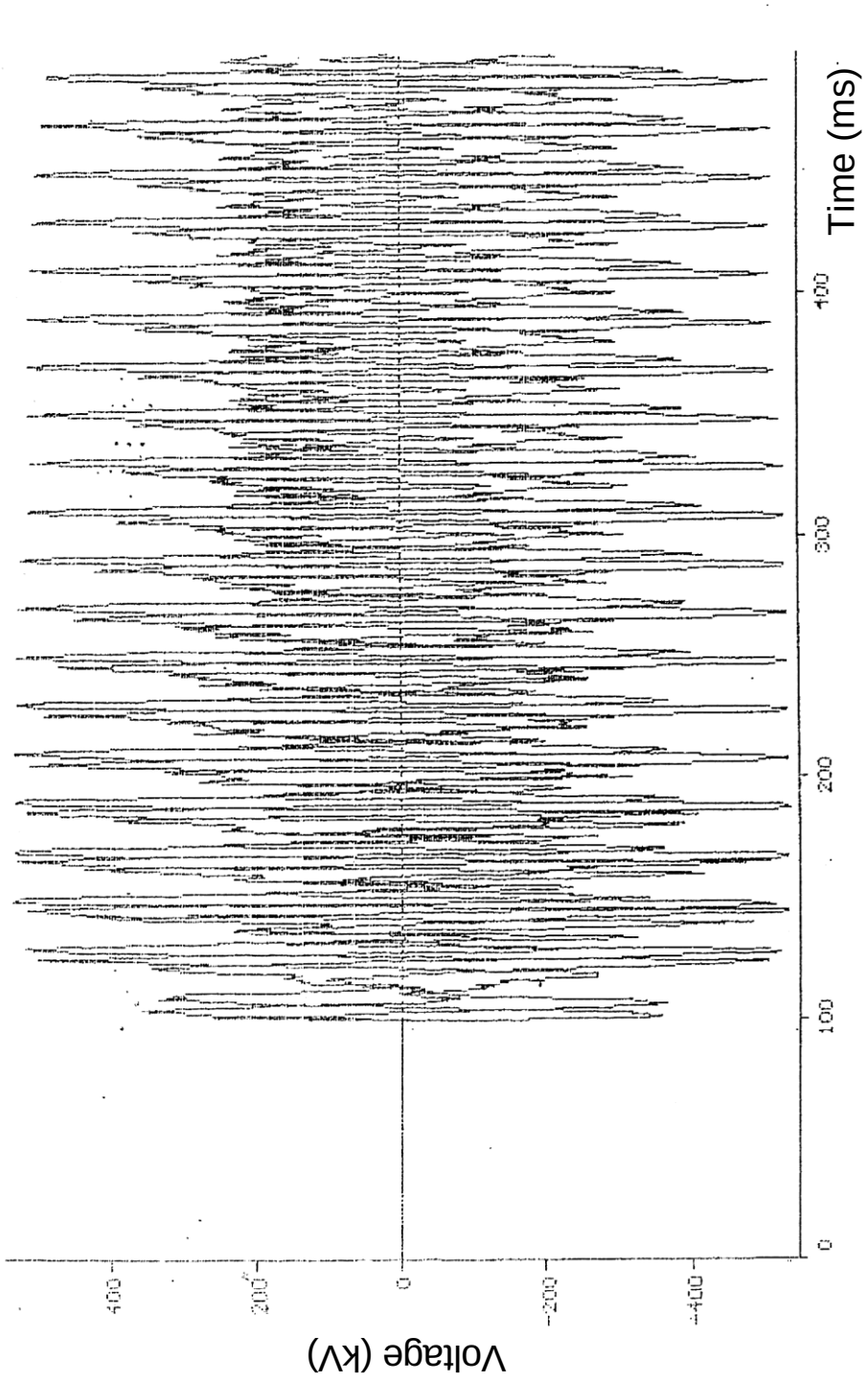
1.9 Ability to Withstand High Temporary Overvoltage (TOVs)

Electro Magnetic Transient Program (EMTP) studies of the NEPCO 400 KV AND 132 kV system indicate that the system is characterised by high Temporary Overvoltage (TOVs). The design of the 400 KV AND 132 kV equipment shall take into account the presence of such TOV's and the Contractor shall guarantee that the life of the 400 KV AND 132 kV equipment shall not be significantly shortened if subjected to such overvoltage.

The voltage-time characteristic of the TOVs is given in the Table below.

Time (sec)	400 (420) kV system (kV Crest/pu)	132 (145) kV system (kV Crest/pu)
0-1	530/1.55	170/1.45
1.5	500/1.45	160/1.35
2.0	460/1.35	150/1.27
6.0	415/1.21	140/1.2
10.0	400/1.17	130/1.1
15.0	342/1.0	(N/A)

A typical voltage waveform for the above conditions is shown on the following page:


Time (ms)
0
100
200
300
400
Voltage (kV)
400
200
0
-200
-400

1

2 POWER TRANSFORMERS

2.1 DESIGN CRITERIA

2.1.1 Codes and Standards

Transformers shall comply with the latest edition of IEC 60076, IEC 60076-6 and with the requirements of this specification.

Document Ref.	Description
IEC 60076-1:2011	Power transformers – General
IEC 60076-2:2011	Power transformers – Temperature rise for liquid-immersed transformers
IEC 60076-3:2013/AMD1:2018	Power transformers – Insulation levels, dielectric tests and external clearances in air
IEC 60076-6:2007	Power transformers – Reactors
IEC 60076-7:2018	Power transformers – Loading Guide for Mineral Oil Immersed Power Transformers
IEC 60076-10:2016	Power transformers – Determination of sound level
IEC 60076-22-1:2019	Power transformer and reactor fittings – Protective devices
IEC 60076-22-7:2020	Power transformer and reactor fittings – Accessories and fittings
IEC 60085:2007	Electrical insulation, thermal evaluation and designation
IEC 60296:2020	Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment
IEC 60404-8-7	Magnetic materials - Part 8-7: Specifications for individual materials - Cold-rolled grain-oriented electrical steel strip and sheet delivered in the fully-processed state
ISO 12944-2:2017	Paints and varnishes – Corrosion protection of steel structures by protective paint systems - Part 2: Classification of environments

If required by the Employer, the Contractor shall provide copy of the applicable standards used for his supply.

2.1.2 Site ambient conditions

The switchyards equipment/materials shall be suitable for operation at their standard ratings under the service conditions as specified in schedules.

2.1.3 HV Systems parameters

HV System parameters as specified in the schedules.

2.1.4 Safety clearances

The clearance to earth shall be adequate for the specified impulse level and, where applicable, the switching surge withstand level and as per IEC 60071.

Minimum clearances in air for transformers as detailed in schedules as per IEC.

2.1.5 AC Auxiliary voltage

The AC auxiliaries of S/S shall be fed at 400/230 V – 50 Hz. Normally the three phases – four wire (3Φ – 4W) circuit configuration shall be used.

Equipment provided under this Contract shall operate reliably within the voltage limits: 80% of nominal voltage up to 110 per cent nominal voltage.

2.1.6 DC Auxiliary voltage

The DC auxiliaries of S/S shall be fed at 110 V nominal voltage, having minimum of -20% and maximum of +20% after a full load discharge of 10 hours.

The auxiliary relays for Supervisory command Signals (Raise/lower, auto/manual, Desired value1/desired value2 Control…) shall be 50 V DC fed by telecommunication system.

2.2 General

Transformers shall be suitable for cyclic overloading and long-time emergency loading duties in accordance with IEC 60076-7 (the cyclic overload of 20% for bushings, CT's, and all ancillary equipment). All CT's, bushings and ancillary equipment inside and outside the transformer should be rated for 20% overloading. Evidence to prove that this condition has been incorporated in the design is required.

All windings of the transformers shall be capable of withstanding short circuit for the periods of time specified in IEC 60076 when operating on any tapping position, including that corresponding to minimum effective impedance, with the fault current available at the terminals.

Irrespective of the direction of power flow, all transformers shall be capable of operating continuously without injurious heating when delivering the specified winding currents under conditions of continuous operation with voltages higher than tapping voltages.

The design of the transformers must take into account the presence of TOV's and the Contractor must guarantee that the life of the transformers will not be significantly shortened if subjected to overvoltage of the voltage-time characteristic detailed in the design criteria.

The design and manufacture of the transformers and auxiliary plant shall be such that the noise level is a minimum and that the level of vibration does not adversely affect any clamping or produce excessive stress in any material. Noise levels shall be measured in accordance with IEC 60076-10.

The maximum acceptable Sound Level **is 75 dBA.**

The vibration pads under the transformers are required.

If required by the Employer, the transformers shall be subject to vibration tests. The magnitude of vibration of the transformer tank, coolers and pipework shall be measured by scanning the vibrating surface with calibrated transducers.

The transformers and shall be designed with particular attention to the suppression of harmonic currents, especially the third and fifth, so as to minimize interference with communications circuits. The transformers shall be designed with particular attention to Geomagnetic Disturbances (GMD)/Geomagnetic

Induced Currents (GIC) events and their impacts on the grid in the form of harmonics, VAR consumption, losses, and transformer heating shall be considered.

The transformers shall be designed to ensure that leakage flux does not cause overheating in any part of the transformer.

The transformers shall be designed to operate satisfactorily in parallel with existing transformer while both are on the same tap position.

The transformer shall be designed and manufactured to withstand a constant acceleration of at least 20 m/s² in all directions (in addition to the acceleration due to gravity in the vertical direction) without any damage, demonstrated by static force calculations based on a constant value of acceleration.

2.3 Tertiary windings

The tertiary winding of the transformer is required for the purpose of suppressing harmonics and of providing connection to an earthing transformer to provide an earth and an auxiliary services supply. Furthermore, they will be used for connection of reactive (capacitive or inductive) compensation equipment.

The winding shall be capable of withstanding the forces to which it is subjected under all conditions, particularly the forces due to a short circuit between terminals or between any terminal and earth, with full voltage maintained on all other windings intended for connection to external sources of supply.

Suitable surge arresters are to be provided to protect the winding against overvoltage. If the winding is connected by cable the surge arresters shall be mounted in the disconnecting chamber.

2.4 Magnetic circuits

Particular care shall be taken to secure even mechanical pressure over the whole of the core laminations. Each lamination shall be insulated with a material that will not deteriorate under pressure and the action of hot oil.

Where the magnetic circuit is divided into packets, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between packets.

The transformer core shall be built up of high-grade, non-aging, low-loss, high-permeability, grain-oriented steel sheets (Hi-B-type; W17/50: max. 0.95 W/kg) without burrs and conforming to IEC 60404-8-7 and IEC 60404-1-1. (Note: 1.7 T is used only for the purpose of comparing the grade). The maximum magnetic flux density in the legs and yokes of the core shall not exceed 1.6 T at rated voltage and frequency.

The transformer core shall be free from over fluxing liable to cause damage or to cause mal operation of the protection equipment when operating under the continuous overvoltage condition specified. Under this steady overvoltage condition, the maximum flux density must not exceed 1.9 tesla and the magnetizing current must not exceed 5 percent of the rated load current at normal rated voltage.

The cores, framework, clamping arrangements and general structure of the transformers and shall be capable of withstanding any shocks to which they may be subjected during transport, installation and service. Adequate provision shall be made to prevent movement of internal parts of the transformer relative

to the tank, to support the core structure in the tank and to carry the weight of the core and windings when suspended.

Structural members shall be made of steel.

2.5 Windings

Winding insulation and all non-metallic material used in winding stacks shall be so treated that no further shrinkage shall take place after assembly.

Coils shall be constructed to avoid abrasion of the insulation, (e.g. on transposed conductors), allowing for the expansion and contraction set up by changes of temperature or the vibration encountered during normal operation. The insulation on the conductors between turns shall be of oil-impregnated paper.

The windings shall be designed to reduce to a minimum the out-of-balance forces inherent in the transformer. Tappings shall be arranged at such positions on the windings as will preserve, as far as possible, electro-magnetic balance at all voltage ratios.

Tappings shall not be brought out from the inside of a coil nor from intermediate turns.

The windings and connections shall be braced to withstand shocks, which may occur during transport or due to switching or other transient conditions during service.

Where the yoke supporting channels are adapted for taking up shrinkage in the windings, the arrangement shall be such as to throw a minimum amount of stress on any core bolt insulation.
If the winding is built up of sections or disc coils separated by spacers, the clamping arrangements shall be such that equal pressure is applied to all columns of spacers. All such spacers shall be securely located and shall be of suitable material.

2.6 Internal earthing arrangements

All metal parts of the transformers, with the exception of the individual core laminations, core bolts and associated individual side plates shall be maintained at some fixed potential.

The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link with a captive bolt and nut, accessibly placed beneath an inspection opening in the tank cover. The connection to the link shall be on the same side of the core as the main earth connection, and taken from the extreme edge of the top yoke in close proximity to the bridging pieces. Alternatively, the core earth connection may be brought out through a bushing for earthing to the outside of the tank, in close proximity to the main yoke clamping structure earth point.

Where coil clamping rings are of metal at earth potential each ring shall be connected to the adjacent core clamping structure on the same side of the transformer as the main earth connection.

The main yoke clamping structures shall be connected to the tank body by a copper strap located at the top of the tank. If there is no metal-to-metal contact between the top and bottom clamping structure, the latter shall be earthed.

Core clamping structures having an insulated sectional construction shall be provided with a separate link for each individual section.

All earthing connections with the exception of those from the individual coil clamping rings shall have a cross-sectional area of not less than 80 mm2. Connections inserted between laminations shall have a cross-sectional area of not less than 20 mm2.

2.7 Tanks

Transformer and tanks shall be of welded steel and designed to allow the complete transformer or, when arranged for transport, to be lifted by crane and transported without overstraining any joints and without causing subsequent leakage of oil. Each tank shall be provided with a minimum of four jacking lugs, to enable the transformer , complete with all tank mounted accessories and filled with oil, to be raised or lowered by jacks. The jacking points shall be not less than 700 mm above base level. Facilities shall also be provided to enable the transformer to be hauled or slewed in any direction.

The base of each tank shall be so designed that it will be possible to move the complete transformer in any direction without injury when using rollers, plates or rails. A design, which necessitates either slide, rails being placed in particular positions or detachable under bases shall not be used.

The main tank body, tap changing compartments, radiators and coolers, shall each be capable of withstanding, when empty of oil, the vacuum test level specified. The plate thickness for the tank sides shall be a minimum of values detailed in the schedule D1.

Tank stiffeners and mounting brackets shall be continuously welded to the tank.

Wherever possible, the transformer tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipe. The vent pipes shall have a minimum inside diameter of 20 mm and, if necessary, shall be protected against mechanical damage.

All joints other than those, which may have to be broken, shall be welded. Caulking of defective welded joints will not be permitted. Such defective joints may be re-welded subject to the written approval of the Employer.

Tank covers shall not permanently distort when lifted. Inspection openings of ample size shall be provided to give easy access to bushings, for changing ratio or winding connections, and for testing the earth connections. Inspection covers shall be provided with lifting handles. The tank cover shall be fitted with a thermometer pocket, with captive screwed cap, located in the position of maximum oil temperature at continuous maximum rating.

It must be possible to remove any bushing without removing the tank cover.
Ladders with climbing loops and lock to prevent unauthorised access from the ground were to be fitted to the transformer tanks but not the coolers.

A pressure relief device of sufficient size capable of functioning without electrical power shall be provided for the rapid release of any pressure that may be generated within the tank and which might result in damage to the equipment, but it shall be capable of maintaining the oil tightness of the transformer under all conditions of normal service. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer tank and shall be designed to prevent further oil flow from the transformer following its operation. In the event that the device is a spring operated valve type it shall be provided with one set of normally open contacts, which will be used for tripping purposes.

The relief device shall be mounted on the main tank and if mounted on the cover it shall be fitted with a skirt projecting inside the tank to prevent an accumulation of gas within the device.

Terminals shall be provided close to each corner at the base of the tank for earthing purposes.

The following plates shall be fixed to the tank at an approximate height of 1.75 m above the ground level:

a. A rating plate bearing the data specified in IEC 60076.
b. A diagram plate on which the transformer tapping voltages in kilovolts shall also be indicated for each tap, together with the transformer impedances at minimum and maximum voltage ratios and for the principal tapping.
c. A property plate of approved design and wording.
d. A title plate.
e. A valve location plate showing the location and function of all valves, drain and air release plugs and oil sampling devices.

Plates shall be subject to the approval of the Employer.

2.8 Bushings

All bushings shall comply with the requirements of IEC 60137 and the associated barrel porcelains shall comply with IEC 62155 together with the requirements of this Specification.

Transformer bushings for 420 and 145 kV shall be either of the oil impregnated paper or resin impregnated type. When filled with transformer oil there shall be no connection with the oil in the transformer and an oil gauge shall be provided. The visible oil levels in the gauge shall correspond to average oil temperatures from the minimum stated ambient temperature to plus 90°C. The oil levels at 15°C and 35°C shall be marked. Connections from the main windings to bushings shall be flexible and shall be such that undue mechanical stresses are not imposed on them during assembly on site.

Bushings shall be mounted on the tank in such a manner that external connection can be made free of all obstacles.

Neutral Bushings shall be mounted in position from which a connection can be made to a neutral current transformer.

2.9 Oil conservator vessel, oil level gauges and breathers

Each oil conservator shall have a filling cap, an adequate sump and be so designed that it can be completely drained by means of a drain valve. One end of the conservator shall have a removable end cover, complete with integral lugs for lifting purposes and secured by nut and bolt fixings, to permit internal cleaning of the conservator.

An oil level gauge shall be provided for each conservator. The indicated minimum oil level shall occur when the feed pipe to the main tank is covered with not less than 12 mm depth of oil. The indicated oil level range shall correspond to average oil temperatures from the stated minimum ambient temperature to plus 90°C. The oil levels at 15°C and 35°C shall be marked on the gauge. The oil level gauge shall incorporate alarm contacts, which close when the oil level falls below a predetermined level.

Taps or valves shall not be fitted to oil gauges.

The main oil feed pipe from the conservator vessel to the transformer shall be connected to the highest point of the tank and shall be arranged at a rising angle towards the conservator of from 3 to 7 degrees to the horizontal. A valve shall be provided at the conservator to cut off the oil to the transformer.

Oil shall be not in direct contact with air.

Whether the oil is in direct contact with air or gas the air outlet from each conservator vessel shall be connected to a dehumidifying breather, which shall be mounted at approximately 1.4 m above ground level. This breather should be at least one size larger than would be fitted for use in a temperate climate. The refrigeration type breather is preferred.

Where a conservator vessel contains two compartments, one for oil in the main tank and the other for the oil associated with the current making and breaking contacts of the tap changing equipment, there shall be no communication between the two compartments in respect of the oil and air spaces. Each compartment shall be provided with the fittings detailed in the preceding paragraphs as if it were a separate conservator vessel.

2.10 Valves

Valves shall be of the fully sealing full-way type and shall be opened by turning counter-clockwise when facing the hand wheel. They shall be suitable for working between the minimum ambient and the maximum oil temperatures stated in the Schedules.

Padlocks shall be provided for locking all valves other than individual radiator valves in the "open" and "closed" positions. Valves shall be provided with an indicator readily visible from ground level, to show clearly the position of the valve.

All valve handwheels shall be fitted with nameplates, which shall be Stainless Steel not less than 3 mm thick with the engraving filed with enamel. All valves shall be fitted with spoked handwheels, the spokes and rims of which shall be smooth and where necessary.

All valves opening to atmosphere shall be fitted with blanking plates.

Each transformer tank shall be fitted with the following:

a. One 100 mm valve at the top and one 100 mm valve at the bottom of the tank mounted diagonally opposite each other, for connection to oil circulating and oil filtering equipment. The lower valve shall also function as a drain valve.
b. An oil sampling device at the top and bottom of the main tank.
c. All parts containing oil, and liable to trap air during filling, shall be fitted with a flanged type air release plug at their highest points.

2.11 Cooling plant

Cooling system of the transformers NEPCO preferable **separately mounted**.

Transformers shall have ONAN/ONAF/OFAF cooling and facilities shall be provided at the marshalling kiosk or cubicle for the selection of AUTOMATIC or MANUAL control of the cooling plant motors.

Transformers shall be fitted with two cooling banks each capable of dissipating 50 percent of the losses at continuous maximum rating. Transformers shall be capable of remaining in operation at full load for 20 minutes in event of failure of the cooling fans and for 10 minutes in the event of failure of the oil circulating pump without the calculated winding hot spot temperature exceeding 150°C. Failure of one fan in each group of fans shall not reduce the continuous maximum rating of the transformer.

Radiators and coolers shall be designed so that all painted surfaces can be readily cleaned and subsequently painted in position.

Detachable radiators and separate cooler assemblies connected to the main tank shall be provided with machined flanged inlet and outlet pipes.

Plugs shall be fitted at the top and bottom of each radiator for filling and draining.

Mal-operation of gas and oil actuated relays shall not occur on starting or stopping of forced-oil circulation.

The oil circuit of all coolers shall be provided with the following as appropriate to tank mounted or separate bank coolers:

a. A valve at each point of connection to the transformer tank.
b. A valve in the main oil connection at the bottom of each cooler.
c. Loose blanking plates to permit the blanking off of the main oil connection to the top of each cooler.
d. A 100 mm oil filtering valve at the top and bottom of each cooler, the bottom valve shall also function as a drain valve.
e. A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each cooler.
f. Visual oil flow indicators in the pipework adjacent to the coolers. In the event that this will offer impedance to oil flow under ONAN conditions a differential pressure gauge of approved design and manufacture may be connected across the pumps, as an alternative.

The material of the tube plates and tubes shall be such that corrosion shall not take place due to galvanic action.

Drain plugs shall be provided in order that each section of pipework can be drained independently.

Each forced oil cooler shall be provided with a fully weatherproof motor driven oil pump. The motor shall be of the submersible type. It shall be possible to remove the pump and motor from the oil circuit without having to lower the level of the oil in the transformer or coolers.

Where forced air cooling is provided it shall be possible to remove the fan, complete with its motor and supporting structure without disturbing or dismantling the cooler framework or pipework.

Wire mesh guards galvanized after manufacture shall be provided to prevent accidental contact with the fan blades. Metal guards shall also be provided over all other moving parts. The guards shall be designed such that neither the blades nor other moving parts can be touched by a Standard Test Finger to IEC 60529.

The heat due to losses shall be dissipated by radiators (natural oil flow) attached to the collecting pipes via shut-off valves.
The radiators shall consist of single members of special steel for deep drawing, welded into a header (tube).
The members shall be shaped to allow free air access and to withstand full vacuum.
All radiators to be tested on oil tightness at an overpressure of 2 bar.

For dismounting a radiator, the shut off valves shall be closed or opened by means of a shaft with square head A pointer on the operating shaft indicates the position. The valves are oil-tight and should be flanged off by using the supplied covers when the radiators are detached.

2.12 Cooler control

Each motor or group of motors shall be provided with a three-pole electrically operated contactor and with control gear of approved design for starting and stopping manually.

Where forced cooling is used on transformers, provision shall be included under this contract for automatic starting and stopping from contacts on the winding temperature indicating devices. The control equipment shall be provided with a short time delay device to prevent the starting of more than one motor, or group of motors in the case of multiple cooling, at a time.

Where motors are operated in groups the group protection shall be arranged so that it will operate satisfactorily in the event of a fault occurring in a single motor.

The control arrangements are to be designed to prevent the starting of motors totalling more than 15 kW simultaneously either manually of automatically. Phase failure relays are to be provided in the main cooler supply circuit.

All contacts and other parts, which may require periodic renewal, adjustment or inspection, shall be readily accessible.

All wiring for the control gear accommodated in the marshalling kiosk together with all necessary cable boxes and terminations and all wiring between the marshalling kiosk and the motors shall be included in the contract.

Two independent sources of power shall be made available to ensure loss of cooling capacity for a single contingency is not greater than 50 per cent.

2.13 Voltage control (On Load Tap Changer)

Equipment shall be provided for varying the turns ratio without producing phase displacement.

Tap changer must be from original reputable supplier; a tap changer manufactured by a licensed Company is not accepted. Only Manufacturers complying with qualification experience as required shall be accepted.

All leads and connections to fixed and moving contact assemblies and between the transformer and the voltage control device shall be supported and adequately braced to withstand the short circuit current for which the associated transformer is designed.

Equipment for varying the effective turns ratio when the transformer is dead shall consist of tap-changing switches located inside the tank under oil and rigidly attached to the core structure as near as possible to the tapped coils.

The switches shall be operated mechanically from the outside of the tank; the arrangement shall be such that it can be operated with the transformer out of its tank. The design shall be such as to prevent the ingress of moisture into, or the leakage of oil from the tank. Means shall be provided to ensure that the operating mechanism can be locked only when the switches are making full contact. Padlocks shall be provided and the tap change equipment shall be suitable for padlocking in any switch position.

Off circuit tapping switches shall be provided with mechanical end stops, which prevent movement beyond an end position.

Equipment for varying the effective turns ratio on-load shall consist of tap changing gear arranged for local hand and electrical operation and remote electrical operation. It shall also be so designed that it may be easily adapted to operate by automatic control.

The tap changing switches and mechanism shall be mounted in an accessible position in oil tanks or compartments and shall be supported from the main tank or its base. It is required that examination and repair of both selector and diverter switches including their associated equipment shall be carried out without lowering the oil level in the main tank.

It shall not be possible for the oil in those compartments of the tap changing equipment which contain contacts used for making and breaking current, to mix with the oil in the main transformer or with the oil in the compartments containing contacts not used for making or breaking current. A drain valve shall be provided.

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

Each compartment in which the oil is not maintained under conservator head shall be provided with an oil gauge.

Any enclosed compartment not oil filled shall be adequately ventilated and designed to prevent the ingress of vermin. All contactors, relay coils or other parts shall be suitably protected against corrosion or deterioration due to condensation.

Tap changing shall be prevented when the transformer is carrying a load above a predetermined maximum or when on short circuit.

Limit switches shall be provided to prevent over-running of the mechanism and shall be directly connected in the circuit of the operating motor. Limit switches may be connected in the control circuit of the operating motor provided that a mechanical de-clutching mechanism is incorporated.

A mechanical stop or other approved device shall be provided to prevent over-running of the mechanism under any condition within resulting damage.

Thermal devices or other approved means shall be provided to protect the motor and control circuits. Switches for the initiation of a tap change shall bear the inscription "Raise Tap Number", as applicable.

Tripping contacts associated with any thermal device used for the protection of tap changing equipment shall be suitable for making and breaking 150 VA at 0.35 power factor, between the limits of 30 and 250 volt ac or breaking 150 VA and making 500 VA between the limits of 110 and 250 volt dc.

A device shall be fitted to the tap changing mechanism to indicate the number of operations completed by the equipment.

A permanently legible lubrication chart shall be fitted within the driving mechanism chamber.
The terminals of the operating motor shall be clearly and permanently inscribed with numbers corresponding to those on the leads attached thereto.

Equipment for local and remote electrical and local hand operation shall comply with the following conditions:

a. It shall not be possible to operate the electric drive when the hand operating gear is in use.
b. It shall not be possible for any two electrical control points to be in operation at the same time.
c. Each step movement shall require separate initiation at the control point.
d. All electrical control switches and the local operation gear shall be clearly labelled in an approved manner to indicate the direction of tap changing.
e. The local control switches shall be housed in the marshalling kiosk.
F. raise command mean raising tap , lower command means lowering tap

The equipment shall be arranged so as to ensure that when a step movement has been commenced it shall be completed independently of the operation of the control relays or switches. If a failure of the auxiliary supply during a tap change, or any other contingency, would result in that movement not being completed, means shall be provided to safeguard the transformer and its auxiliary equipment.

Apparatus shall be provided with:

g. Mechanical indication of actual tap position locally at the transformer and electrically at the remote control point. The indicator at the transformer shall show the number of tapping in use and the indicator at the remote control point shall show clearly the actual voltage ratio in kilovolts and the tap number representing this ratio. The numbers shall range from 1 upwards.

h. Indication at the remote control point that a tap changing is in progress by means of an illuminated lamp and alarm buzzer. If the tap change is not completed in its specified time the buzzer shall continue to sound until switched off by hand but the lamp shall remain illuminated until the tap change is completed.

i. Indication at the remote control point by means of an approved illuminated indicator and the buzzer alarm as described in g. above when the units of a group of transformers arranged to operate in parallel are operating at different ratios.

On-load tap changing equipment shall be suitable for supervisory control and indication and a separate multi-way switch, having one fixed contact for each tap position, shall be provided for this purpose and wired to the marshalling kiosk or cabinet.

2.14 AVR and Control Panel

An Automatic Voltage Regulation relay (AVR) shall be provided. The relay shall be responsive to variation in the measured voltage and cause the necessary tap change to be made to restore the voltage to the desired level within pre-determined limits.

The following operation modes shall be possible for the AVR scheme:

- Each transformer can be operated on master mode, while the other transformer working on the follower mode.
- Two transformers cannot be selected to master mode at the same time.
- It is possible to operate each transformer independently.
- The scheme should allow selecting any transformer to independent mode.

The reference voltage side shall be assigned during engineering stage. The measured voltages will be derived from voltage transformers, supplied under a separate contract, having secondary windings rated at 110 volts phase-to-phase and having an accuracy not inferior to Class 1. The relay shall have a nominal voltage rating to unit.

The relay setting voltage, expressed as a percentage of the relay nominal voltage, shall be adjustable over a range of not less than ±10 percent of nominal.

The relay sensitivity band relative to the setting voltage shall be adjustable from not more than 1.5 times to not less than 2.5 times the percentage equivalent of one tap change step.

Settings for relay operating time shall be adjustable. For definite time relays, the setting range shall be from 10 s to 120 s and the timing device shall be of the "slow resetting" type. Relays having time dependent characteristics shall have a range of adjustments allowing a delay of up to at least 120 s for a voltage deviation 1 percent greater than the sensitivity setting and not more than 10 s for a deviation of 5 times sensitivity or 10 per cent voltage, whichever is the greater.

The relay shall be insensitive to frequency variation between the limits of 47 Hz and 51 Hz and shall incorporate an undervoltage blocking facility to render the control inoperative if the reference voltage falls to 80 per cent of nominal value with automatic restoration of control when the reference voltage rises to 85 per cent of nominal value.
The relay setting voltage must be capable of adjustment from a remote/supervisory location.

On-load tap change transformers provided with fully automatic control and required to operate in parallel as a group shall be provided with means to ensure proportionate sharing of watts and VARs.

A scheme intended to maintain step-by-step operation to within one tap difference at all times of parallel operation shall be provided. Operation with more than one tap difference between any two transformers shall automatically be prevented and an "out-of-step" alarm signal transmitted to the control point(s).

Control equipment supplied under this contract shall include all alarm, indication and repeat relays necessary to identity faulted equipment. Each relay shall have not less than two electrically separated normally open

contacts, one of which is fleeting and the other non-fleeting. The fleeting contact shall reset (open) when the relay is de-energized. The non-fleeting contact shall be wired to a terminal strip.
All equipment shall be suitable for operation within the limits 85 percent - 110 percent of the auxiliary voltage supply.

On each transformer the voltage transformer supply to the voltage regulating relay shall be monitored for partial or complete failure. If the circuit breaker controlling the lower voltage side of the transformer is open or when the tap changer is on other than automatic control, then any alarm or indication should be made inoperative.

Requirement for remote adjustment (supervisory/telecontrol) of the AVC setting voltage will be defined in accordance with the particular scheme. Relays equipped to accept electrical signals to control the actual set point (e.g. drive stepping motors to alter rheostat position or input digital signal to reset level detector etc) shall be capable of set point adjustment in steps not exceeding 1 percent.

For relays having a manually adjusted setting, means shall be provided to allow remote adjustment via interposing relays having contacts available to enable the effective setting to be altered by altering the measured voltage (e.g. by switching resistors in the relay input measuring circuit).

All control and relay panels shall have a continuous earth bar of sectional area not less than 70 mm2, run along the bottom of the panels, each end being connected to the main earthing system. Metal cases of instruments and metal bases of relays on the panels shall be connected to this bar by conductors of cross sectional area not less than 3 mm2.

Cubicles shall be constructed from sheet steel designed to be self-supporting and be vermin and termite proof. They shall not be less than 800 mm wide, and in no case shall the depth exceed the width. The doors shall be hinged to lie back flat to avoid restricting access. Hinges shall be of the lift off type. Doors shall be secured by lockable handles which shall not be more than 1.8 m above floor level.

Circuit labels shall be provided on the front and back of each panel and on the outside of the cubicle doors.

Indicating lamps and lamp-holders shall be so arranged that replacement of lamps and the cleaning of glasses and reflectors employed can be readily affected.

Indicating lamp glasses on relay panels shall be white.

Panels shall have a continuous earth bar of sectional area not less than 70 mm2, run along the bottom of the panels, each end being connected to the main earthing system. Metal cases of instruments and metal bases of relays on the panels shall be connected to this bar by conductors of cross sectional area not less than 3 mm2.

The closing circuit, signalling circuits and each tripping circuit shall be separately protected. The tripping circuits shall be provided with withdrawable link facilities.
Where specified accommodation shall be provided for ancillary apparatus (remote metering and signalling equipment, transducers and interposing current transformers, etc) provided under a separate Contract.

Alarm and indication equipment as specified in the Schedules and all other alarms which are required for the satisfactory operation of the complete installation.

All control circuits shall be provided with suitable means of isolation. Single phase power socket of an approved type and an interior light controlled by a door operated switch located inside the cubicle.

All cubicles shall be fitted with anti-condensation heaters.

The AVR panel should include as a minimum the following equipment:

- Voltage regulating equipment (AVR)
- Motorized voltage setting potentiometer
- Auto/Manual selector switch
- Raise/Lower Pushbuttons.
- Remote/ supervisory selector switch
- Master/Follower/Independent switch
- Voltmeter
- Tap position indicator
- Oil temperature indicators
- Winding temperature **separate for series, common winding and tertiary.**
- Indicating lamps for "alarm fascia supply fail" "tap changer in progress"
- Buzzer.
- Alarm facia with accept (to silence the buzzer), reset and lamp test pushbuttons, to indicate the following alarms (not limited to the following, it will be confirmed during engineering stage):
    - Tap change incomplete
    - Out of step
    - VT fail
    - Motor supply fail
    - DC supply fail
    - **AC supply fail**
    - Stage 1 fan failure
    - Stage 2 fan failure
    - Stage 1 fan ON
    - Stage 2 fan ON
    - Fan auto/manual
    - **Oil pumps auto/manual**
    - **Oil Pumps running**
    - **Oil Pumps Failure**
    - Marshalling box AC supply failure
    - Motor drive on local
    - 20% spare alarms
- Transducers (0-10 mA) for tap position
- All necessary relays, contactors, supervising control interposing relays, labels, wiring, terminals, test facilities, fuses, trip switches, etc to complete the scheme.
- **Five cards** (19 step contact or BCD cards).
- **Panel dimension should be not less than 800X800 (Width X Depth).**
- **Panel shall be consutructed from 2.5mm folded and welded sheet steel.**

- **The door spindle shall be to the left side of each panel/cabinet. Cubicle protection class shall be IP41 for indoor**.
- All circuits, equipment, control switches…..etc. shall be clearly labelled as to their purpose and function.

2.15 Temperature indicating devices, alarms and gas and oil actuated relays

Temperature indicating devices and alarms.

Oil temperature indicating devices shall be fitted with alarm and trip contacts.

Winding temperature indicating devices shall indicate the temperature of the hottest spot of the winding and shall have a load-temperature characteristic approximating to that of the main winding. Alarm and trip contacts shall be provided.

Alarm contacts of oil and winding temperature indicating devices shall be adjustable over a range of 60°C to 110°C and trip contacts adjustable over a range of 80°C to 150°C. Alarm and trip contacts shall be suitable for making and breaking 150 VA at 0.35 power factor, between the limits of 30 and 250 volts ac or breaking 150 VA and making 500 VA between the limits of 110 and 250 volts dc.

For transformers having or being suitable for mixed or forced cooled ratings whether the forced cooling is to be supplied initially or at a later date, an additional contacts shall be provided to automatically control the forced cooling plant.

Temperature indicating devices shall incorporate a dial and a pointer indicator and a separate pointer to register the maximum temperature reached.

The capillary connected sensing bulbs of temperature indicators shall be positioned in separate oil-tight pockets arranged in the top oil.

Winding temperature indicators shall be associated with one phase only in the case of auto-transformers there shall be separate indicators for the series and common windings.

The winding temperature indicating devices shall be so designed that it shall be possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment. The working parts of the instruments shall be made visible by the provision of cut-away dials and glass fronted covers.

The characteristics of the winding temperature indicating devices shall be forwarded to the Employer for approval prior to the delivery of the transformers and shall also be included in the operating and maintenance instructions.

All temperature indicators shall be housed in the marshalling kiosk or cabinet and shall be mounted so that they will not be affected by vibration.

Gas and oil actuated relays.

Gas and oil actuated relays shall be fitted to each transformer and to each tap selector compartment. They shall have alarm contacts which close on collection of gas or at low oil level and tripping contacts which close following an oil surge.

The normally open, electrically separate, alarm and tripping contacts shall not be exposed to oil.

The relays shall be fitted in the expansion pipe connecting the transformer tank to the conservator.

Each relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

A 5.0 mm inside diameter pipe shall be connected to the gas release cock of the relay and brought down to a point approximately 1.4 m above ground level where it shall be terminated by a cock.

Oil flow indicators.

Forced oil cooled transformers shall be provided with a visual oil flow indicator in each outlet pipe connection from the coolers. These indicators shall incorporate contacts which close under conditions of no oil flow.

2.16 Condition Monitoring System

The transformer shall be equipped with an online Transformer Monitoring System (TMS) to provide condition assessment.

The transformer Monitoring System consists of a subsystem installed on the transformer, and a computer (server) with monitoring application, placed in the control room

Measurements shall be used to derive the following data:

a. Hot spot temperature in accordance with IEC 60076-7
b. Ageing rate in accordance with IEC 60076-7
c. Continuous overload current capacity of the transformer.
d. Overvoltage detection including a lightning surge and overcurrent.
e. Variation in the capacitance of bushings.
f. Tan delta and partial discharge function.

The monitoring system shall be capable of recording the following quantities:

a) Measurement of current and voltage on the HV, LV and tertiary winding.
b) Top oil temperature.
c) Moisture in the oil.
d) Gas in the oil by means of a Hydran unit or similar.
e) Status of the tap changer fans and pumps.
f) Tap changer motor power requirement.

All necessary sensors in addition to those already specified shall be supplied with the transformer.

The monitoring unit shall be mounted in the transformer marshalling kiosk and be suitable for outdoor operation.

The monitor shall be suitable for connection to fibre optic /LAN to provide remote monitoring data to National Control Centre. Data shall be recorded locally, with date stamped from the substation GPS time system.

All needed accessories and associated equipment to complete the connection shall be supplied by the transformer contractor.

Detailed connection list/terminal list/cable list shall be supplied by the transformer contractor.

2.17 Earthing/auxiliary transformers

When specified each earthing transformer shall be of the oil immersed ONAN type suitable for outdoor installation and shall have an interconnected star winding which will be directly connected to the tertiary windings of the main transformer and an auxiliary star connected winding arranged to give a three-phase 4-wire supply, via a switch MCB unit and or MCCB/ACB

The neutral point of the interconnected star winding of each earthing transformer shall be brought out of the tank through a bushing insulator similar to those on the phase terminals. This point may be isolated or may be connected to earth either directly or through an impedance in order to provide an earthing point for the neutral of the lower voltage system.

The interconnected star winding of each earthing transformer, when at its maximum temperature due to continuous full load on the auxiliary winding, shall be designed to carry for thirty seconds without injurious heating an earth fault current not less than the value given in the Schedules.

The auxiliary winding of each earthing transformer shall have an IEC continuous rating equal to that stated in the Schedules.

Earthing and auxiliary transformers shall be provided with the following fittings: -

a. One thermometer pocket with captive cap.

b. Dehumidifying breather.

c. Filter valve and combined filter and drain valve.

d. A sampling device at the bottom of the tank.

e. Conservator vessel with removable end cover and prismatic oil gauge.

f. Double float gas oil actuated relay.

g. Pressure Relief Device

The earthing transformers shall comply with the provisions of this Specification relating to the main transformers wherever these are applicable.

Unless otherwise specified all connections between the earthing transformers, the main transformers, earth and auxiliary circuits, will be provided under other contracts.

The earthing & auxiliary transformer (core, winding, ...etc.) shall comply with the requirements stated the Particular Technical Specifications relating to the main transformers wherever these are applicable.

2.18 Topping up with oil and drying out on site

When oil is to be added to a transformer or at Site prior to commissioning, the oil in the transformer shall first be tested for dielectric strength and water content and each container of make-up oil shall be similarly tested. The Supervisor shall witness all tests.

Should it be found necessary to resort to oil treatment before the transformer is commissioned, the Contractor shall submit to the Engineer, in writing, a full description of the process which shall be adopted, the equipment to be used and a statement of the precautions being taken to prevent fire or explosion.

Should a transformer arrive on site without positive pressure of gas in the tank, it shall be dried out on site

Clear instructions, in English shall be included in the Maintenance Instructions regarding any special precautionary measures, which must be taken before vacuum treatment can be carried out. Any special equipment necessary to enable the transformer to withstand vacuum treatment shall be provided with each transformer. The maximum vacuum which the complete transformer, filled with oil can safely withstand without any special precautionary measures being taken, shall be stated in the Maintenance Instructions.

2.19 Firefighting equipment

Transformer firefighting system will be supplied as part of another Contract. The Transformer Contractor shall therefore make allowance for the addition of pipes, nozzles, etc around the transformer and be prepared to provide details and co-ordinate designs with the firefighting equipment supplier.

2.20 Oil handling and test equipment

The oil Treatment plant is required to remove solid matter, dissolved gases and moisture from the oil.

The oil treatment plant is required and should be able to achieve a standard of oil purity similar to that specified by the transformer manufacturer for the first filling, and the rate of flow shall be suitable for filling the transformers in this specification but have a minimum value of 10000 litres/hour.

The flow rate shall be variable, but when adjusted it should be steady, continuous and automatic in operation. The degasifier and the filter shall be able to operate together or independently.

The pumps shall be rated suitably for the treatment of the required quantities of oil at ground level, and to deliver oil into the highest part of the oil system of the transformers specified herein.

The plant should be complete with vacuum pump, air cleaning set, cooling unit, suitable rubber hoses for use with oil and all other necessary accessories.

2.21 Infra-Red Instrument

IR Instrument shall meet the specification of IEC 60666 or equivalent.
The instrument shall provide **the type and quantity** of each antioxidant additives, inhibitors passivators..etc.

2.22 Sweep Frequency Response Analyser*:

The measuring device shall be supplied and shall comply with the IEC 60076-18 requirements

No.	Item	Specification
1	Output voltage	Adjustable from 0.1 Vpp to 10 Vpp at 50Ω
2	Output frequency	20 Hz- 25 MHz
3	Measurement accuracy	±0.3 dB (+10dB to -40dB) ±1 dB (-40 dB to – 100 dB)
4	Cables connection	Must not affect the readings
5	Size and weight	Portable or movable by trolley
6	Test report/graph/records	- Must be automatically generated and movable to PC or USB memory. - Shall match the requirements mentioned in the IEC 60076-18.
7	Dynamic Range	>150 dB
9	Noise level	<-140 dB
10	Operating temp	-5C to 55C
11	Input voltage	220V-240V 50Hz

The followings shall be provided:

1. Hard case/s (for transportation) are/is to be provided.
2. All connection cables shall be according to the specs mentioned in IEC 60076-18, clause 5.2.
3. Connection cables must be suitable for testing 400/132/33 kV transformers.
4. The instrument shall be calibrated to a traceable reference standard and Calibration certificate valid for two years is to be provided.
5. Original copy of user manual, catalogues and PC software (full package) are to be provided.
6. Ground loop detection
7. Ability to test single phase and three phase transformer (Y, Δ or Zig-Zag) in addition to auto transformers with voltage levels of 400, 132, 33 & 0.4 kV

3 REACTORS

3.1 General

Reactors shall comply with IEC 60076 -6 and with all requirements of this specification.

Reactor shall be suitable for cyclic overloading and long-time emergency loading duties in accordance with IEC 60076-7 (the cyclic overload of 20% for bushings, CT's, and all ancillary equipment). All CT's, bushings and ancillary equipment inside and outside the Reactor should be rated for 20% overloading. Evidence to prove that this condition has been incorporated in the design is required.

All windings of the Reactor shall be capable of withstanding short circuit for the periods of time specified in IEC 60076-6 when operating, including that corresponding to minimum effective impedance, with the fault current available at the terminals.

Irrespective of the direction of power flow, all reactors shall be capable of operating continuously without injurious heating when delivering the specified winding currents under conditions of continuous operation with voltages higher than tapping voltages.

The design of the reactors must take into account the presence of TOV's and the Contractor must guarantee that the life of the reactors will not be significantly shortened if subjected to overvoltage of the voltage-time characteristic detailed in the design criteria.

The design and manufacture of the reactors and auxiliary plant shall be such that the noise level is a minimum and that the level of vibration does not adversely affect any clamping or produce excessive stress in any material. Noise levels shall be measured in accordance with IEC 60076-10 at 0.3m distance from Shunt reactor and the maximum acceptable sound pressure level for reactor shall be LpA=70 dB.

The vibration pads under reactors are required.

If required by the Employer, reactors shall be subject to vibration tests. The magnitude of vibration of the reactor tank, and pipework shall be measured by scanning the vibrating surface with calibrated transducers.

Reactors shall be designed with particular attention to the suppression of harmonic currents, especially the third and fifth, so as to minimize interference with communications circuits. The reactor shall be designed with particular attention to Geomagnetic Disturbances (GMD)/Geomagnetic Induced Currents (GIC) events and their impacts on the grid in the form of harmonics, VAR consumption, losses, and reactor heating shall be considered.

The reactor shall be designed to ensure that leakage flux does not cause overheating in any part of the reactor.

3.2 Magnetic circuits

Particular care shall be taken to secure even mechanical pressure over the whole of the core laminations. Each lamination shall be insulated with a material that will not deteriorate under pressure and the action of hot oil.

Where the magnetic circuit is divided into packets, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between packets.

The reactor core shall be free from over fluxing liable to cause damage or to cause mal operation of the protection equipment when operating under the continuous overvoltage condition specified. Under this steady overvoltage condition the maximum flux density must not exceed 1.9 tesla and the magnetizing current must not exceed 5 percent of the rated load current at normal rated voltage.

The cores, framework, clamping arrangements and general structure of the reactors shall be capable of withstanding any shocks to which they may be subjected during transport, installation and service. Adequate provision shall be made to prevent movement of internal parts of the reactor relative to the tank, to support the core structure in the tank and to carry the weight of the core and windings when suspended.

Structural members shall be made of steel.

3.3 Windings

Winding insulation and all non-metallic material used in winding stacks shall be so treated that no further shrinkage shall take place after assembly.

Coils shall be constructed to avoid abrasion of the insulation, (e.g. on transposed conductors), allowing for the expansion and contraction set up by changes of temperature or the vibration encountered during normal operation. The insulation on the conductors between turns shall be of oil-impregnated paper.

The winding shall be designed to reduce to a minimum the out of balance forces inherent in the reactor.

The windings and connections shall be braced to withstand shocks, which may occur during transport or due to switching or other transient conditions during service.

Where the yoke supporting channels are adapted for taking up shrinkage in the windings, the arrangement shall be such as to throw a minimum amount of stress on any core bolt insulation.

If the winding is built up of sections or disc coils separated by spacers, the clamping arrangements shall be such that equal pressure is applied to all columns of spacers. All such spacers shall be securely located and shall be of suitable material.

The winding shall be capable of withstanding the forces to which it is subjected under all conditions, particularly the forces due to a short circuit between terminals or between any terminal and earth, with full voltage maintained on all other windings intended for connected to external sources of supply.

3.4 Internal earthing arrangements

All metal parts of the reactors, with the exception of the individual core laminations, core bolts and associated individual side plates shall be maintained at some fixed potential.

The magnetic circuit shall be earthed to the clamping structure at one point only through a removable link with a captive bolt and nut, accessibly placed beneath an inspection opening in the tank cover. The connection to the link shall be on the same side of the core as the main earth connection and taken from the extreme edge of the top yoke in close proximity to the bridging pieces. Alternatively, the core earth

connection may be brought out through a bushing for earthing to the outside of the tank, in close proximity to the main yoke clamping structure earth point.

Where coil clamping rings are of metal at earth potential each ring shall be connected to the adjacent core clamping structure on the same side of the reactor as the main earth connection.

The main yoke clamping structures shall be connected to the tank body by a copper strap located at the top of the tank. If there is no metal-to-metal contact between the top and bottom clamping structure, the latter shall be earthed.

Core clamping structures having an insulated sectional construction shall be provided with a separate link for each individual section.

All earthing connections with the exception of those from the individual coil clamping rings shall have a cross-sectional area of not less than 80 mm2. Connections inserted between laminations shall have a cross-sectional area of not less than 20 mm2.

3.5 Tanks

Reactor tanks shall be of welded steel and designed to allow the complete reactor, when arranged for transport, to be lifted by crane and transported without overstraining any joints and without causing subsequent leakage of oil. Each tank shall be provided with a minimum of four jacking lugs, to enable the reactor, complete with all tank mounted accessories and filled with oil, to be raised or lowered by jacks. The jacking points shall be not less than 700 mm above base level. Facilities shall also be provided to enable the

reactor to be hauled or slewed in any direction.

The base of each tank, radiators shall be so designed that it will be possible to move the complete reactor in any direction without injury when using rollers, plates or rails. A design, which necessitates either slide, rails being placed in particular positions or detachable under bases shall not be used.

The main tank body shall each be capable of withstanding, when empty of oil, the vacuum test level specified. The plate thickness for the tank sides shall be a minimum of values detailed in the schedule of technical data.

Tank stiffeners and mounting brackets shall be continuously welded to the tank.

Wherever possible, the reactor tank and its accessories shall be designed without pockets wherein gas may collect. Where pockets cannot be avoided, pipes shall be provided to vent the gas into the main expansion pipe. The vent pipes shall have a minimum inside diameter of 20 mm and, if necessary, shall be protected against mechanical damage.

All joints other than those, which may have to be broken, shall be welded. Caulking of defective welded joints will not be permitted. Such defective joints may be re-welded subject to the written approval of the Employer.

Tank covers shall not permanently distort when lifted. Inspection openings of ample size shall be provided to give easy access to bushings, for changing ratio or winding connections, and for testing the earth connections. Inspection covers shall be provided with lifting handles. The tank cover shall be fitted with a

thermometer pocket, with captive screwed cap, located in the position of maximum oil temperature at continuous maximum rating.

It must be possible to remove any bushing without removing the tank cover.

A pressure relief device of sufficient size capable of functioning without electrical power shall be provided for the rapid release of any pressure that may be generated within the tank and which might result in damage to the equipment, but it shall be capable of maintaining the oil tightness of the reactor under all conditions of normal service. The device shall operate at a static pressure of less than the hydraulic test pressure for reactor tank and shall be designed to prevent further oil flow from the reactor following its operation. In the event that the device is a spring operated valve type it shall be provided with one set of normally open contacts, which will be used for tripping purposes.

The relief device shall be mounted on the main tank and if mounted on the cover it shall be fitted with a skirt projecting inside the tank to prevent an accumulation of gas within the device.

Terminals shall be provided close to each corner at the base of the tank for earthing purposes.

The following plates shall be fixed to the tank at an approximate height of 1.75 m above the ground level:

a. A rating plate bearing the data specified in IEC 60076.
b A property plate of approved design and wording.
c. A title plate.
d. A valve location plate showing the location and function of all valves, drain and air release plugs and oil sampling devices.

Plates shall be subject to the approval of the Employer.

The design shall include ladder to be used during erection and maintenance work

3.6 Bushings

All bushings shall comply with the requirements of IEC 60137 and the associated barrel porcelains shall comply with IEC 62155 together with the requirements of this Specification.

Connections from the main winding to the bushings shall be flexible and shall be such that undue mechanical stresses are not imposed on them during assembly on site.

Bushing shall be mounted on the tank in such a manner that the external connection can be made free of all obstacles.

3.7 Cable boxes

Cable boxes, where applicable, shall be suitable for cables entering from above or below as may be specified. They shall be weatherproof, rodent and insect-proof and be complete with all gaskets, compression glands wiping glands and associated fittings as may be required to make-off the cables.

Gland plates shall be insulated from the cable boxes and in the case of single core cables shall be of non-magnetic or insulating material. If metallic gland plates are used, single core cable glands shall be insulated

from the gland plate. Gland plate insulation shall be capable of withstanding a dry high voltage test of 2000 volts ac for one minute.

Where cable boxes are provided for three core cables, the sockets on the outer phases shall be inclined towards the centre to minimize opening of the cable cores. Cable sockets shall be supplied under this Contract.

The boxes shall be air insulated and designed to accommodate all the fittings required by the cable manufacturer. The cables information will be confirmed during Engineering Stage, coordination is needed with substation contractor.

Cable boxes shall be capable of withstanding on site the cable high voltage test level in accordance with IEC 60502.

The 33kV cables box at the reactor shall be bottom entry, with busbars, post insulator supports…etc. suitable for termination of 3 cables per phase. Exact design of the box to be coordinated with Substation Contractor.

Suitable surge arrester to be provided to protect the winding against over voltages. If the winding is connected by the surge arrester shall be mounted in the disconnecting chamber.

Removable links shall be provided for testing purposes. During the test, the links in the disconnecting chamber will be withdrawn and the reactor windings will be earthed.

3.8 Oil and insulating compounds

Sufficient oil shall be supplied for the first filling of all oil filled portions of the equipment. The oil shall be Inhibited Super Grade type for Reactors and shall comply with the requirements of latest IEC 60296 and shall be suitable in all respects for use in the equipment when operated under the conditions laid down in this Specification and according to the characteristics and normative references specified in Schedule of Technical data (Inhibited insulating oil).

Insulating compound shall comply with the requirements of BS EN 60296, ASTM D 3487 6th Edition and IEC 60296 5th edition 2020.

Resin insulation shall comply with the requirements of IEC 60455.

3.9 Oil conservator vessel, oil level gauges and breathers

Each oil conservator shall have a filling cap, an adequate sump and be so designed that it can be completely drained by means of a drain valve. One end of the conservator shall have a removable end cover, complete with integral lugs for lifting purposes and secured by nut and bolt fixings, to permit internal cleaning of the conservator.

When filled with reactor oil there shall be no connection with the oil in the reactor and oil gauge shall be provided

An oil level gauge shall be provided for each conservator. The indicated minimum oil level shall occur when the feed pipe to the main tank is covered with not less than 12 mm depth of oil. The indicated and visible oil level range in the gauge shall correspond to average oil temperatures from the stated minimum ambient temperature to plus 90°C. The oil levels at 15°C and 35°C shall be marked on the gauge. The oil level gauge shall incorporate alarm contacts, which close when the oil level falls below a predetermined level.

Taps or valves shall not be fitted to oil gauges.

The main oil feed pipe from the conservator vessel to the reactor shall be connected to the highest point of the tank and shall be arranged at a rising angle towards the conservator of from 3 to 7 degrees to the horizontal. A valve shall be provided at the conservator to cut off the oil to the reactor.

Oil shall be not in direct contact with air.

Whether the oil is in direct contact with air or gas the air outlet from each conservator vessel shall be connected to a dehumidifying breather, which shall be mounted at approximately 1.4 m above ground level. This breather should be at least one size larger than would be fitted for use in a temperate climate. The refrigeration type breather is preferred.

Where a conservator vessel contains two compartments, one for oil in the main tank and the other for the oil associated with the current making and breaking contacts of the tap changing equipment, there shall be no communication between the two compartments in respect of the oil and air spaces. Each compartment shall be provided with the fittings detailed in the preceding paragraphs as if it were a separate conservator vessel.

3.10 Valves

Valves shall be of the fully sealing full-way type and shall be opened by turning counter-clockwise when facing the hand wheel. They shall be suitable for working between the minimum ambient and the maximum oil temperatures stated in the Schedules.

Padlocks shall be provided for locking all valves other than individual radiator valves in the "open" and "closed" positions. Valves shall be provided with an indicator readily visible from ground level, to show clearly the position of the valve.

All valve handwheels shall be fitted with nameplates, which shall be Stainless Steel not less than 3 mm thick with the engraving filed with enamel. All valves shall be fitted with spoked handwheels, the spokes and rims of which shall be smooth and where necessary.

All valves opening to atmosphere shall be fitted with blanking plates.

Each reactor tank shall be fitted with the following:

a. One 100 mm valve at the top and one 100 mm valve at the bottom of the tank mounted diagonally opposite each other, for connection to oil circulating and oil filtering equipment. The lower valve shall also function as a drain valve.
b. An oil sampling device at the top and bottom of the main tank.
c. All parts containing oil, and liable to trap air during filling, shall be fitted with a flanged type air release plug at their highest points.

3.11 Cooling plant

The material of the tube plates and tubes shall be such that corrosion shall not take place due to galvanic action.

Drain plugs shall be provided in order that each section of pipework can be drained independently.

Radiators shall be designed so that all painted surfaces can be readily cleaned and subsequently painted in position.

Detachable radiators assemblies connected to the main tank shall be provided with machined flanged inlet and outlet pipes.

Plugs shall be fitted at the top and bottom of each radiator for filling and draining.

Reactors shall be ONAN cooled.

The heat due to losses shall be dissipated by radiators (natural oil flow) attached to the collecting pipes via shut-off valves.

The radiators shall consist of single members of special steel for deep drawing, welded into a header (tube). The members shall be shaped to allow free air access and to withstand full vacuum.

All radiators to be tested on oil tightness at an overpressure of 2 bar.

For dismounting a radiator, the shut off valves shall be closed or opened by means of a shaft with square head A pointer on the operating shaft indicates the position. The valves are oil-tight and should be flanged off by using the supplied covers when the radiators are detached.

3.12 Temperature indicating devices, alarms and gas and oil actuated relays

Temperature indicating devices and alarms.

Oil temperature indicating devices shall be fitted with alarm and trip contacts.

Winding temperature indicating devices shall indicate the temperature of the hottest spot of the winding and shall have a load-temperature characteristic approximating to that of the main winding. Alarm and trip contracts shall be provided.

Alarm contacts of oil and winding temperature indicating devices shall be adjustable over a range of 60°C to 110°C and trip contacts adjustable over a range of 80°C to 150°C. Alarm and trip contacts shall be suitable for making and breaking 150 VA at 0.35 power factor, between the limits of 30 and 250 V ac or breaking 150 VA and making 500 VA between the limits of 110 and 250 V dc.

Temperature indicating devices shall incorporate a dial and a pointer indicator and a separate pointer to register the maximum temperature reached.

The capillary connected sensing bulbs of temperature indicators shall be positioned in separate oil-tight pockets arranged in the top oil.

The winding temperature indicating devices shall be so designed that it shall be possible to move the pointers by hand for the purpose of checking the operation of the contacts and associated equipment. The working parts of the instruments shall be made visible by the provision of cut-away dials and glass fronted covers.

The characteristics of the winding temperature indicating devices shall be forwarded to the Employer for approval prior to the delivery of the reactor and shall also be included in the operating and maintenance instructions.

All temperature indicators shall be housed in the marshalling kiosk or cabinet and shall be mounted so that they will not be affected by vibration.

Gas and oil actuated relays.

Gas and oil actuated relays shall be fitted to each Reactor. They shall have alarm contacts which close on collection of gas or at low oil level and tripping contacts which close following an oil surge.

The normally open, electrically separate, alarm and tripping contacts shall not be exposed to oil.

The relays shall be fitted in the expansion pipe connecting the reactor tank to the conservator.

Each relay shall be provided with a test cock to take a flexible pipe connection for checking the operation of the relay.

A 5.0 mm inside diameter pipe shall be connected to the gas release cock of the relay and brought down to a point approximately 1.4 m above ground level where it shall be terminated by a cock.

3.13 Topping up with oil and drying out on site

When oil is to be added to a reactor at Site prior to commissioning, the oil in reactor shall first be tested for dielectric strength and water content and each container of make-up oil shall be similarly tested. The Supervisor shall witness all tests.

Should it be found necessary to resort to oil treatment before the reactor is commissioned, the Contractor shall submit to the Engineer, in writing, a full description of the process which shall be adopted, the equipment to be used and a statement of the precautions being taken to prevent fire or explosion.

Should a reactor arrive on site without positive pressure of gas in the tank, it shall be dried out on site

Clear instructions, in English shall be included in the Maintenance Instructions regarding any special precautionary measures, which must be taken before vacuum treatment can be carried out. Any special equipment necessary to enable the reactor to withstand vacuum treatment shall be provided with each reactor. The maximum vacuum which the complete reactor filled with oil can safely withstand without any special precautionary measures being taken, shall be stated in the Maintenance Instructions.

3.14 Control, Operation, Indication and Alarm Circuits for reactor

Device	Function	Operating supply voltage	If Required
Reactor Buchholz relay	Alarm Trip	110Vdc	Yes
Reactor Pressure relief device	Trip	110Vdc	Yes
Reactor oil level indicator	Alarm Trip	110Vdc	Yes
Reactor Winding Temperature Indicator	Alarm Trip	110Vdc	Yes
Reactor oil temperature indicator	Alarm Trip	110Vdc	Yes

Note:

The above mentioned control, operation, indication and alarm circuits are the minimum requirement and not final, the final will be determined during engineering stage.