Particular Technical Specifications
(PTS)

PARTICULAR TECHNICAL SPECIFICATIONS for 132 KV transformer

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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 (main transformers and neutral earthing & auxiliary power supply transformers), which are subject of these Technical Specifications, shall be installed in the installed **in the new Aqaba 400/132/33KV (AAWDCP) substation and 33/11 kV BPS01 substation and feeding IPS & RO SS**.

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.

Transformers with associated auxiliary equipment shall be designed in such a manner to meet the requirements required in this Technical Specifications, Schedules of Technical Data (Schedules D) and Drawings at climate conditions at the Site defined within Clause 3 of General Technical Specifications.

The rated characteristics of main transformers, earthing & auxiliary transformers are given in: schedule A Scope of Supply & Schedule of Technical Data (Schedules D).

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 tender.

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 (not applicable)

Since that new transformer for Substation "name of substation" 132/33 kV, 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.

Transformer Characteristic	Substation 132/33 kV		Substation 132/33 kV		Substation 132/33 kV
	TR1	TR2	TR1	TR2	TR2
Manufacturer					
Year of production					
Rated power					
Rated transformation ratio					

Vector group					
Tap changer					
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.

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) + 1473.01 (Pk + Pcs – Pc0), for 80MVA 132/33 KV.
Total Cost = IC + 7438.54 (P0 + Pc0) + 2040.88 (Pk + Pcs – Pc0), for 63MVA 132/33 KV.

Where:

- IC: Initial offer cost;
- P0: No load losses at rated tap;
- Pc0: 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 3,061.32 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. Technical requirement and evaluation

- **Energy performance**

Following standards and technical specification define the energy performance for medium and large power transformers:

BS EN 50708-1-1:2020, Power transformers — Additional European requirements:

Part 1-1: Common part — General requirements

BS EN 50708-2-1:2020 Power transformers — Additional European requirements:

Part 2- 1: Medium power transformer — General requirements,

BS EN 50708-3-1:2020 Power transformers — Additional European requirements:

Part 3-1 Large power transformer — General requirements,

IEC TS 60076-20:2017, corr 2018, Energy efficiency

BS EN 50708-1-1 gives general requirements for energy performance and capitalisation of losses. In Annex A (normative) gives Peak efficiency calculation.

BS EN 50708-3-1 covers "large power transformer" means a power transformer with at least one winding having either rated power greater than 3 150 kVA or highest voltage for equipment greater than 36 kV and gives minimum value of Peak Efficiency Index (PEI).

IEC TS 60076-20:2017 covers medium and large power transformers and gives maximum level of losses for no-load losses and for load losses and minimum value of Peak Efficiency index, respectively.

- **Tender procedure and documentation**

NEPCO will state PEI requirements for each transformer rating in Data Schedule.

PEI requirements must be fulfilled; otherwise, NEPCO will reject any offered transformer.

The Bidder shall state guaranteed values of losses and peak efficiency index for each transformer rating in Data Schedule and price schedule.

- **Tender evaluation**

Energy performance - Peak efficiency index

Tender evaluation is relatively simple because it is only to check that guaranteed energy performance proposed by Bidder fulfill NEPCO energy performance requirements. NEPCO will use the following equation to calculate the minimum Peak efficiency index, according to BS EN 50708-1-1:2020:

$$min.PEI = 1 - \frac{2}{S}\sqrt[2]{(P_O + P_{C0})P_{K1}}$$

- S = Maximum Rated Power
- P_O= No load Losses
- P_{C0}= Cooling Losses
- P_{K1}= Load Losses

The reference Table 1 from EN 50708-3-1:2020.

TIER2 shall be applied from 1 July 2021 for the values of losses following Commission Regulation (EU) No548/2014 of 21 May 2014 and its amendment No 2019/1783 of 1 October 2019.

The guaranteed min PEI value is 99.745 % for 63 MVA
The guaranteed min PEI value is 99.758 % for 80 MVA

NEPCO will recalculate this value using the same formula after the qualification and during financial evaluation. The submitted value by the tenderer must be equal to the calculated value by NEPCO. Any deviation is not accepted, and if the value doesn't fulfil the requirement in reference table 1 from EN 50708-3-1:2020, the offer will be directly rejected.

- **Tolerance during tests**

- During tests, the Peak Efficiency Index values obtained from the measured values of no load, load losses and auxiliary losses shall not be below the respective minimum values specified in EN 50708-3-1:2020 without tolerances.
- Actual min PEI shall be determined during FAT, and the tested transformer is subjected to rejection in case of failure of reaching the accepted min. PEI.

2. Design, Materials and Workmanship

2.1. General

The design, materials and workmanship shall be in compliance with the General Technical Specifications and particularly with the Clause 3 of these Particular Technical Specifications.

The transformers shall be designed and manufactured to fully correspond to the climatic and operating conditions specified in the General Technical Specifications

2.2. Applicable Standards

Unless otherwise specified, the transformers 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,
- 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.
- BS EN 50708-1-1:2020, Power transformers — Additional European requirements:
- Part 1-1: Common part — General requirements
- BS EN 50708-2-1:2020 Power transformers — Additional European requirements:
- Part 2- 1: Medium power transformer — General requirements,
- BS EN 50708-3-1:2020 Power transformers — Additional European requirements:
- Part 3-1 Large power transformer — General requirements,
- IEC TS 60076-20:2017, corr 2018, Energy efficiency

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.

2.3. General Design Requirements

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

The design and manufacture of the transformers 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 shall be designed to withstand earthquake loadings of the accelerations which are specified in the Clause 3 within 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 in Schedule of Technical Data.

The transformers 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.

2.4. Operation at Voltage and Frequency Different than Rated Values

The transformers 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.

2.5. 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 of Technical Data (Schedule D), 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.

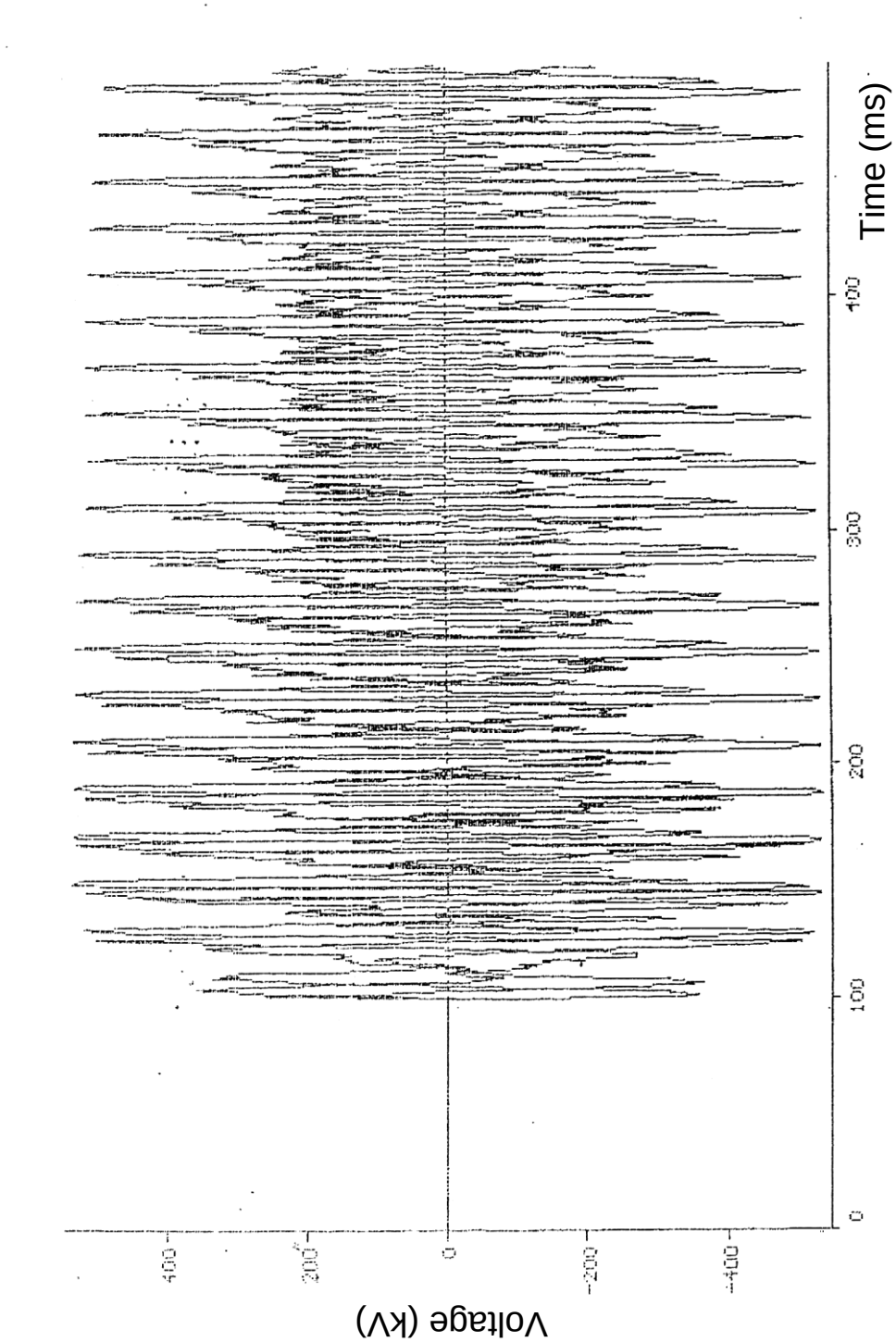
2.6. Ability to Withstand High Temporary Overvoltage (TOVs)

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

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

Time (s)	132 (145) kV system (kV peak/p.u.)
0-1	170/1.45
1.5	160/1.35
2.0	150/1.27
6.0	140/1.2
10.0	130/1.1
15.0	(N/A)

A typical voltage waveform for the above conditions is presented on the Figure below.



2.7. Packing and Transport

2.7.1. General

Packing and transport shall be arranged according to General Technical Specifications. In addition, the following requirements shall be fulfilled.

Transformer shall be transported with oil, and they shall be filled to such a level as to cover the windings completely.

The method of packing shall provide adequate protection to the tank, and those parts contained within and attached without, for transportation.

All openings for transformer components, e.g. bushings which have been removed from the transformers during transport, shall be covered by blinking-off plates. Transformers shall be equipped with instruments to register "shock" loading suffered during transport.

All parts shall be carefully packed for transport in such a manner that they are protected against mechanical injury and the injurious effects of water and climatic conditions encountered during transit to their destination, as well as during long storage before installation.

2.7.2. Specification

According to IEC 60076-1 Clause 9.5, the centre of gravity of the transformer in the transport configuration shall be permanently marked on at least two adjacent sides of the transformer.

The transformer shall be designed and manufactured to withstand a constant acceleration of at least 20 m/s^2 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. The Calculation shall be submitted by Contractor along with the Tender.

The transformers shall be transported and shipped in a contamination and moisture proof, seaworthy container in accordance with international standards.

The transformer shall be well protected against rain during transportation to prevent rainwater from wetting the transformer.

2.7.3. Electronic Impact Recorder

One electronic impact (shock) recorder shall be rigidly attached to each transformer, in order to record all horizontal and vertical impacts suffered during transportation. The recorder shall be of supplier/manufacturer property, to be suitably sealed, and the seal shall only be broken by the NEPCO on arrival at site in order to release the registered data.

The recorder is to be operative from time of packing in factory to whole Contract period, in order to provide an uninterrupted record of all registered data. All means to ensure uninterrupted work of impact recorders during that period shall be provided (e.g. spare batteries).

The instruments shall be removed by supplier/manufacturer after final installation at site. Impact recorder should be stopped before it is removed from the transformer.

The supplier / manufacturer has to provide data to NEPCO when transformer is installed on site. Removal of impact recorder, downloading and interpretation of data shall be done in the presence of NEPCO representative. Impact recorder memory must not be erased before the data is proven complete and properly stored. Stored data should be easily accessible with recognizable file name backed up. Any irregularities concerning the impact recorders shall be noted.

Acceptance criteria for constant acceleration during transportation downloaded from impact recorder, at frequency 2 ÷ 20 Hz shall be:

- Longitudinal: max. 3 g,

- Vertical: max. 2 g,
- Transverse: max. 2 g.

An appropriate instruction book for interpretation of the registered data and a user manual for the equipment shall be supplied to the NEPCO, prior to shipment.

3. Detailed Requirements for the Equipment

3.1. Main Transformer

3.1.1. General

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.

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, as stated in the Schedule of Technical Data. Temperature rise of the top oil, average winding and hot-spot winding shall not exceed the following limits:

Design ambient temperature	Top oil	Average winding (by winding resistance variation)	Hot-spot winding
50 ^{o}C	50 K	55 K	68 K

With reference on temperature rise correction -10 K from IEC 60076-2, Table 2, referred to the values given in Table 1. For the hot-spot winding temperature rise calculation, hot spot factor (H) shall be applied with 1.3 and 1.1 for main and earthing & auxiliary transformer respectively.

Transformers shall be suitable for normal cyclic loading, short-time and long-time emergency loading duties in accordance with IEC 60076-7 (the emergency overload of 50% for tap changer, bushings, CTs and all ancillary equipment). Tap changer, all bushings, CTs and ancillary equipment inside and outside the transformers should be rated for 50% overloading evidence to prove this fact is required.

The design and manufacture of the transformers and associated equipment 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. Transformer noise levels shall be measured in accordance with IEC 60076-10.

The maximum acceptable sound pressure level for transformer measured as per IEC 60076-10 shall be LpA=70 dB(A) considered no-load condition and all forced cooling in operation at 1 meter distance. The design and clamping of the core and windings shall be such that excessive vibrations shall not be transmitted from the magnetic circuits to the tank and accessories. The maximum limit of vibration shall be 100 µm.

The transformers shall be designed with particular attention to the suppression of harmonic voltages, especially the third and fifth ones, so as to eliminate wave form distortion and any possibility of high frequency disturbances, inductive effects or circulating currents between the neutral points at different substations reaching such a magnitude as to cause interference with communication circuits.

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 when the transformers tap-changers are in the same tap position.

Protective devices shall be high-quality product in accordance with IEC 60076-22-1 and shall be sourced from internationally reputed manufacturers only.

Accessories and fittings shall be high-quality product in accordance with IEC 60076-22-7 and shall be sourced from internationally reputed manufacturers only.

The Contractor shall provide the following information, data and documentation related to transformers:

- Information about materials, used for magnetic core, windings and insulation,
- Magnetic core material (grad, steel code name, insulation as per IEC 60404-11, hysteresis curve, etc.) and production description,
- Solid proof that no corrosion effect to any part of the magnetic core,
- Detailed windings materials certificate, testing report and product description.

3.1.2. Magnetic core

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.

Both sides of each steel sheet shall be insulated with a durable, hot oil and heat resistant baked enamel varnish or other chemical treatment. Cutting of lamination shall be done in such a way that magnetic field is applied in the direction of rolling.

The core shall be clamped and braced to withstand, without damage or deformation, the forces caused by short-circuit stresses, transportation, or handling, and to prevent the shifting of the core laminations. The bolts, nuts, and end plates of the assembly and clamp structure shall be of a nonmagnetic type and shall be effectively insulated and locked so that they ensure an even pressure on the whole core assembly and are not loosened by vibrations caused by transport and operation.

The supporting framework of the core shall be designed to avoid the presence of pockets which could prevent complete draining of the tank or cause the trapping of air when filling during service.

Suitable axial cooling ducts shall be provided to ensure free circulation of oil and efficient cooling of the core. The ducts shall be so dimensioned that the maximum temperature at any point remains with the admissible limits.

Particular care shall be given to the design and construction of the corner joints between columns and yokes to avoid concentration of mechanical and magnetic stresses whilst allowing an easy dismantling of the joint for maintenance at site.

Adequate metallic bridges shall be provided between the core lamination packets in order to keep all portions of the core assembly at the same potential.

Lifting eyes or lugs shall be provided at suitable points of the core assembly.

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 in the Schedules. Under this steady overvoltage condition, the maximum flux density must not exceed 1.9 T and the magnetising current must not exceed 5% of the rated load current at normal rated voltage.

Maximum flux density at 110% rated voltage shall be at least 10% below saturation flux density and the core shall be designed to exhibit linear magnetization characteristics up to 120% rated voltage.

The magnetic core shall be insulated from all structural parts and shall be capable to withstand a test voltage of 2.5 kV AC for 1 min. to core bolt (if any) and tank/frame.

Core and core clamps shall be insulated from each other and from the main body with a minimum of 2 kV AC for 1 min. Leads from core and clamps shall be brought outside to facilitate single point earthing through a disconnecting link and shall have a protective cover. Disconnecting link shall be arranged in such a way that It shall be possible to check the insulation resistance of core to earth, clamp to earth and core to clamp. Core and clamp shall also be identified using durable stainless-steel labels.

Structural members shall be made of steel.

3.1.3. Windings

The windings shall be of high conductivity electrolytic copper. Paper shall be used for conductor insulation.

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

For transformer, only thermally upgraded insulation material and enamelled copper for conductors and lead connections shall be used. The conductors shall be transposed at sufficient intervals to minimize eddy currents and equalize the current and temperature distribution along the winding. 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 windings shall be so designed as to obtain an optimal value for series and shunt capacities in order to ensure a favourable distribution of the voltage for full impulse waves and chopped impulse waves. Also, windings shall be designed to reduce to a minimum the out-of-balance forces inherent in the transformer.

Leads from winding to bushings shall be adequately supported to prevent damage from vibration and short-circuit forces.

Permanent current-carrying joints or splices shall be welded or braced, properly formed, finished and insulated to avoid concentration of dielectric stresses.

The windings shall be subjected to a thorough shrinking and seasoning process. Compensation devices shall be provided for possible further shrinkage of the coils in service. The coils, windings and leads shall be sufficiently braced and fastened to form rigid assemblies, preventing any relative movement due to transport, vibrations or other circumstances that may occur in service.

Tapings shall be arranged at such positions on the windings as will preserve, as far as possible, electro-magnetic balance at all voltage ratios.

Tapings 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.

The assembled core and windings shall be dried in a vacuum to ensure proper moisture removal.

3.1.4. Internal Earthing Arrangements

All metal parts of the transformers apart from 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 on 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 apart from 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.

3.1.5. Tank

Transformer tank shall be of welded steel and designed to allow the complete transformer, 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 300 mm above base level for transport masses up to 10 tonnes and not less than 700 mm for greater transport masses. Facilities shall also be provided to enable the transformer to be hauled or moved 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.

Precautions shall be taken to prevent corrosion between the base or under-base of tanks of aluminium alloy construction and the concrete plinth on which they are finally positioned.

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 in the Clause 4 of these Particular Technical Specifications. The plate thickness for the tank sides shall be a minimum of 6 mm.

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 shall not be permitted. Such defective joints may be re-welded subject to the written approval of the Client.

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 transformer under all conditions of normal service. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer or tanks and shall be designed to prevent further oil flow from the transformer following its operation. If 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 rating plate bearing the data specified in IEC 60076-1,
- A diagram plate on which the transformer tapping voltages in kV shall also be indicated for each tap, together with the transformer impedances at minimum and maximum voltage ratios and for the principal tapping,
- A property plate of approved design and wording,
- A valve location plate showing the location and function of all valves, drain and air release plugs and oil sampling devices.

The transformer design shall include ladder to be used during erection and maintenance work. The ladder shall have safety locking arrangement.

3.1.6. Transformer Bushings

Transformer bushings shall comply with the requirements of Standards IEC 60137 & IEC 62155 and other relevant Standards if not otherwise required in this Specification.

Bushings shall be of the highest quality, made of brown-glazed porcelain and they shall be envisaged for the minimum creepage distance defined in the Clause 3 of General Technical Specifications. Provision shall be made for the fitting of arcing horns as per schedule D and IEC standard improving at engineering stage.

Since main transformers shall be subjected to overload duties in accordance with IEC 60076-7, bushings shall be suitably rated to accommodate these overload duties.

All the transformer bushings for power transformers delivered in this tender shall be interchangeable with specific creepage distance SCD of 38 mm/kV, i.e. unified specific creepage distance USCD of 65.8 mm/kV, as per latest version of the IEC 60815-1.2008.

Transformer bushings for HV side 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 ambient stated in the Schedules 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.

3.1.7. Conservator Vessels, Oil Level Gauges and Breathers

Each 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.

Where conservator tanks are mounted on the separate coolers, a flexible stainless-steel piece (expansion joint) shall be included in each oil pipe connection between the transformer and the conservator tank.

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 minimum ambient temperature stated in the Clause 3 of General Technical Specifications 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.

Whether or not 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 generally according to IEC 60076-22-7 and at least one size larger than would be fitted for use in a temperate climate.

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 change 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.

3.1.8. 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 temperature stated in the Clause 3 of General Technical Specifications and the maximum oil temperatures stated in the Sub-section 5.1: Schedule of Technical Data.

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 clearly show the position of the valve.

All valve hand wheels shall be fitted with nameplates, which shall be chromium plated brass not less than 3 mm thick with the engraving filed with enamel. All valves shall be fitted with spoked hand wheels, the spokes, and rims of which shall be smooth and where necessary, for appearance, shall be chromium plated.

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

Each transformer tank shall be fitted with the following:

- One (1) 100 mm valve at the top and one (1) 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,
- An oil sampling device for the top and bottom oil of the main tank,
- 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.

3.1.9. Transformer Mineral Insulating Oil

Mineral insulating oils shall be high-quality product in accordance with latest version of IEC 60296 and other relevant Standards if not otherwise required in this Specification and shall be sourced from internationally reputed manufacturers only.

The transformers shall be shipped filled with insulating oil.

The oil shall be a highly refined uninhibited mineral naphthenic oil suitable for use as an insulating and cooling medium in transformers. The oil shall be free from corrosive sulphur (as per IEC 62535), PCB, DBDS (dibenzyl disulphide), Antioxidant, passivator, metal deactivator and other additives.

Transformer oil shall be tested for its Full Chemical Analysis including oxidation stability, according to IEC 60296 and the test reports shall be submitted along with Factory Acceptance Test reports of the transformer. The Manufacturer shall also submit the compliance certificate for additives as per IEC 60296.

3.1.10. Cooling System

3.1.10.1. *General*

Transformers shall have 54/80 MVA ONAN/ONAF cooling system and facilities shall be provided at the transformer cooling system control cabinet for the selection of AUTOMATIC or MANUAL control of the cooling system.

Transformers shall be equipped with two (2) cooling groups/banks, each capable of dissipating 50% of the transformer losses at continuous maximum rating. Each transformer cooling group shall be complete with its radiators & fans, and other accessories.

The cooling fans shall have provision of LOCAL-MANUAL, REMOTE-MANUAL and REMOTE-AUTOMATIC controls, all in two (2) stages. The automatic operation of the cooling system shall be actuated from the Winding Temperature Indicator (WTI) contacts under "AUTOMATIC" condition of remote selector switch. All local control devices shall be mounted in the transformer cooling system control cabinet.

The cooling system shall be designed to meet the following requirements, with both cooling groups in service and without exceeding the specified temperature rise under continuous mode of operation:

- All fans running - 100% ONAF capacity,
- All fans stopped - 100% ONAN capacity.

Also, transformers shall be capable of remaining in operation at full load for 20 minutes in event of failure of the cooling fans without the calculated winding hot spot temperature exceeding 150°C. Failure of one (1) fan in each group of fans shall not reduce the continuous maximum capacity of the transformer.

3.1.10.2. *Radiators*

The radiators of the transformer cooling system shall be detachable type and shall be provided with suitable isolation valves at the top and bottom to enable the removal of radiators without completely draining the oil from the tank.

The radiators shall be designed for same pressure and vacuum conditions as specified for main tank.

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

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

The oil circuit of all coolers shall be provided with the following:

- A valve at each point of connection to the tank,
- Isolating valves at the bottom of each individually detachable radiator. The valves shall be located on header side of the radiator attachment point,
- A valve in the main oil connection at the bottom of each cooler in addition to those mounted on the tank,
- Removable/Loose blanking plates to permit the blanking-off of the main oil connection to the top of each cooler,
- A 100 mm oil filtering valve at the top and bottom of each cooler, the bottom valve shall also function as a drain valve,
- A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each cooler.

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

Where separately mounted cooling equipment is provided a flexible stainless-steel piece (expansion joint) shall be included in each oil pipe connection between the transformer and the oil coolers.

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

3.1.10.3. Cooler Fans

The fans shall be so arranged that they are easily accessible and can be easily replaced.

The cooler fans used for air-forced cooling, shall be motor driven and shall be suitable for continuous outdoor operation and capable of dealing with the maximum output required in service. The fans shall be mounted such a way that airflow through the radiators will be upwards.

The cooler fan shall be capable of withstanding the stresses imposed when brought up to speed by the direct application of full line voltage to the motor.

The cooling fans and radiators shall be designed so that they operate with a minimum of noise or drumming. In order to reduce the transmission of noise and vibration, the fans shall be either mounted independently from the radiators, or, alternatively, an approved form of anti-vibration mounting shall be adopted. It shall be possible to remove the cooler fan complete with motor without disturbing or dismantling the cooler structure framework.

Blades or runners fabricated to form hollow sections shall not be used. Unless otherwise approved, blades shall be of galvanised steel and painted or aluminium casting.

The ducts and casings shall be made of galvanised steel not less than 2 mm thickness, suitably stiffened by angles or tees or made of aluminium casting of rigid construction to minimise undue vibration.

Galvanised/aluminium wire-mesh guards with a mesh not greater than 25 mm shall be provided to prevent accidental contact with the blades. Guards shall be provided over all moving shafts and couplings.

3.1.10.4. Cooler Control

Each transformer shall have two (2) independent sources of auxiliary power to ensure back-up of power supply in case of loss of one source. Auxiliary power supply shall not be looped from one transformer to another transformer.

Each motor or group of motors shall be provided with a three-pole electrically operated contactor fitted with auxiliary alarm contacts and with control gear of approved design both for starting and stopping the motor manually and also automatically from the contacts on the winding and oil temperature indicating devices.

The control arrangements shall be such that motors arranged in a minimum of two (2) groups shall be started sequentially.

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

Auto start and stop of fans shall be arranged such that all fans shall be running in 2 stages during ONAF rating and stops during ONAN rating. Both Winding Temperature Indicators (WTI) and Oil Temperature Indicators (OTI)

contacts shall be used in parallel for start/stop of cooler fans at stage 1 and stage 2. The temperature setting for cooler start/stop shall be subject to Client's approval.

If the second group starts on auto, it shall also bring in Group 1 if this had failed to start on its normal sequence.

An alarm indicating "Transformer Cooling Fault" is to be provided and initiated in the event of any cooling fan motor trips, power and control supplies are interrupted.

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

The control equipment for transformer cooling system shall be accommodated in a weatherproof cabinet, with a IP55 degree of mechanical protection, mounted on the transformer.

All wiring for the control gear accommodated in the transformer cooling system control cabinet together with all necessary wiring between the control cabinet and the motors shall be provided by Contractor.

3.1.11. Tap Changer

Each main transformer shall be provided with an On-Load Tap-Changer (OLTC), on the HV winding, for varying its effective transformation ratio whilst the transformer is on load and without producing phase displacement. The voltage control equipment shall be designed so that it may be easily adapted to operate by automatic control.

On-load tap changer shall be high-quality product in accordance with IEC 60214-1 and other relevant Standards if not otherwise required in this Specification, of a robust construction and shall be sourced from internationally reputed manufacturers only.

Main transformer On-Load Tap-Changer shall be maintenance free with vacuum type interrupter in the diverter switch and the complete OLTC design shall be subject of the Client's approval.

The diverter switch unit shall be placed in a separate gas tight compartment, which shall be, like the whole tap-changer, integrated in the transformer tank (in-tank mounting).

The diverter switch shall have an oil system completely separated from other transformer's oil and shall be equipped with a conservator, pressure relief device with alarm/trip contacts and other devices stated for the main tank. A separate gas actuated relay shall be provided in the connection between the on-load tap-changer tank and conservator. Each diverter and/or selector switch (tap selector) shall be equipped with an internal suction pipe led to the ground of the compartment and to be connected to an external drain, filter and sampling valve mounted at a convenient floor height.

The diverter switch compartment shall be easily accessible for inspection and it shall be possible to remove the diverter switch without difficulties for maintenance purposes. The inspection and maintenance of the diverter switch shall be possible without lowering the oil level in the main tank. One set of each type of lifting device shall be supplied to facilitate removal of the tap-changer unit. Necessary attachment facilities shall be incorporated in the main tank design.

Padlock facilities shall be provided and 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 end position.

Equipment for local and remote/supervisory electrical and local hand operation shall be provided and shall comply with the following conditions:

- It shall not be possible to operate the electric drive when the hand-operating gear is in use,
- It shall not be possible for any two electric control points to be in operation at the same time,
- Each step movement shall require separate initiation at the control point,
- All electrical control switches and the local operating gear shall be clearly labelled in an approved manner to indicate the direction of tap changing,
- The local control switches shall be housed in the OLTC drive mechanism box (transformer OLTC control cabinet).

In the above context "local" means at the transformer, "remote" means at the remote tap-changer control (RTCC) panel and "supervisory" means via SCADA system.

The equipment shall be so arranged as to ensure that when a tap change 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, approved means shall be provided to safeguard the transformer and its auxiliary equipment. Electrical and mechanical means shall also be provided to prevent damage to the tap changing mechanism when end of operation has not been reached.

Apparatus of approved type shall be provided for each transformer:

- To give indication mechanically at the transformer and electrically at the remote and supervisory control point, of the tapping in use. The indicator at the transformer shall show the number of the tapping in use and the indicator at the remote and supervisory 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, the lowest number representing the tapping position corresponding to the maximum number of winding turns, i.e. the plus percent position, and the highest number representing the tapping position corresponding to the minimum number of winding turns, i.e. the minus percent position,
- To give indication at the remote and supervisory control point that a tap change is in progress by means of an illuminated lamp and alarm buzzer. If the tap change is not completed within the 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,
- To give an indication at the remote and supervisory control point by means of an approved illuminated indicator and the buzzer alarm as described above when the units of a group of transformers arranged to operate in parallel are operating at different ratios.
- Full supervisory control facilities shall be provided. A selector switch located at the local point shall be provided to transfer control to the remote point. The facility shall also be provided, through the operation of auxiliary relays to select and deselect tap change control from the supervisory point. A lamp at the remote panel shall indicate when supervisory control is selected. All necessary equipment on the RTCC panels, including the provision of auxiliary relays and indication devices shall be included.

All indicating devices shall operate correctly at any voltage between the limits of 85% and 110% of nominal value.

The tap changing switches and mechanism shall be mounted in oil tanks or compartments mounted in an accessible position on the transformer tank and shall be supported from the main tank or its base. It is preferable that examination and repair of both selector and diverter switches including their associated equipment should be carried out without lowering the oil level in the main tank. Other designs of tap-changer shall be subject of Client's approval.

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.

The oil in those compartments of the main tap-change 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.

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

When a conservator is provided and used to maintain oil level in compartments, which contain contacts used for making and breaking current, it shall be clearly separate from the main transformer conservator. Two oil gauges shall be provided. One shall be of the prismatic type and the second one of the magnetic type shall be fitted with contacts for initiation of a low oil level alarm. A silica gel breather shall be fitted to each such conservator.

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

Limit switches shall be provided to prevent over-running of the mechanism and shall be directly connected in the circuit of the operating motor. In addition, a mechanical stop, or other approved device shall be provided to prevent over-running of the mechanism under any condition. Limit switches may be connected in the control circuit of the operating motor provided that a mechanical declutching mechanism is incorporated.

Thermal devices fitted with alarm contacts or other approved means shall be provided to protect the motor and control circuits. All relays, switches, fuses, etc. shall be clearly marked to indicate their purpose. Switches for the initiation of a tap change shall bear the inscription "Raise Tap Number" or "Lower Tap Number".

Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking 150 VA between the limits of 30 V and 250 V AC and DC and for making 500 VA between the limits of 110 V and 250 V DC.

Complete tap changing equipment shall be of robust design and capable of giving satisfactory service without undue maintenance under the conditions to be met in service, including frequent operation.

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

A permanent legible lubrication chart shall be fitted within the driving mechanism chamber.

After installation and commissioning tests, the terminals of the operating motor shall be clearly and permanently marked.

Means shall be provided for ensuring that the tapping or other switches are making full contact. When such contact is made it shall be possible to lock the apparatus at any setting.

When two or more transformers are to be operated in parallel at the same substation, means shall be provided to ensure that the voltage control equipment is automatically synchronised before and while the transformers are operated in parallel. This feature shall operate irrespectively of whether the voltage control equipment is operated by the remote electrical operating gear or automatically. It shall be possible to operate the voltage control equipment for each transformer independently, whether on load or for test purposes, and to obtain independent indications.

A lifting device shall be provided to allow easy removal of the tap changer for maintenance.

3.1.12. Automatic Voltage Control

Approved means shall be provided for automatically maintaining within adjustable limits a pre-determined voltage value at the low-voltage busbars to which the main transformer is connected.

An automatic voltage control (AVC) relay and all other associated equipment shall be provided for each main transformer. 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 reference voltage shall be taken from the LV side of the main transformer. The measured voltages shall be derived from voltage transformers, having secondary windings rated at 110 V phase-to-phase and having accuracy class of 0.5. The relay shall have a nominal voltage rating equal to the VT secondary winding rating.

The voltage transformer secondary circuit to the AVC relay shall be monitored for failure.

The relay setting voltage, expressed as a percentage of the relay nominal voltage, shall be adjustable over a range of not less than ±10% 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% greater than the sensitivity setting and not more than 10 s for a deviation of 5 times sensitivity or 10% 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 under voltage blocking facility to render the control inoperative if the reference voltage falls to 80% of nominal value with automatic restoration of control when the reference voltage rises to 85% of nominal value.

The relay setting voltage shall be adjustable from a remote/supervisory location. When selected to either supervisory or remote and selected for automatic operation the control signal shall vary the set point of the AVR relay. When selected to manual the control signal shall operate the tap changer directly to raise or lower the tap position as required. It shall be possible to select auto/manual control from the supervisory location.

The AVC relay shall be suitable to work in automatic independent control mode, where the tap-changer is controlled irrespectively of the method of control selected for the other associated transformer, and automatic parallel control mode, where in a group of parallel working transformers it shall be possible to select any transformer for master control from RTCC (Remote Tap-Changer Control) Panel and SAS (Substation

Automation System). During a master/follower tap change operation, tap changing shall be sequential of slightly time staggered to ensure that at any time only one transformer is changing tap.

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

All transformers operating in a group shall be on the same tap. Operation with a tap difference between transformers n a group shall be automatically prevented by an “out-of-step” device and an ”out-of-step” alarm signal shall be transmitted to control point(s). The tap change scheme shall be arranged so that the maximum difference between the transformers during a tap changing sequence is one tap.

All equipment shall be suitable for operation within the limits of 85% and 110% of the nominal auxiliary supply voltage. In the event of the reference supply voltage being outside the specified operating limits the voltage control relay shall initiate an alarm and block further operation of the tap-changer until voltage is restored.

Requirement for remote adjustment (supervisory) of the AVC setting voltage shall be defined in accordance with the particular scheme. AVC relays equipped to accept electrical signals to control the actual set point shall be capable of set point adjustment in steps not exceeding 1%.

The AVC relay shall support IEC 61850 protocol and shall have a self-supervision and internal failure diagnostic function.

3.1.13. Remote Tap-Changer Control (RTCC) Panel

The control of transformer tap-changer shall be arranged in local, remote or supervisory modes.

A Remote Tap-Changer Control (RTCC) panel shall be provided with the following devices and accessories:

- Voltage regulator,
- Motorised voltage setting potentiometer,
- Auto/Manual selector switch,
- Raise/lower control selector switch,
- Remote/supervisory selector switch,
- Master/follower/Independent/off selector switch,
- Voltmeter,
- Tap position indicator,
- Oil temperature indicator and winding temperature indicator,
- Indicator lamps for "Tap changer in progress",
- Annunciator with accept (to silence the Buzzer), reset and lamp test push buttons applicable for the following alarms:
    - Tap changer incomplete,
    - Out-off step,
    - VT fail,
    - Motor supply fail,

- AC supply fail,
- DC supply fail,
- Tap changer in progress,
- Stage 1 fan failure,
- Stage 2 fan failure,
- Stage 1 fan on,
- Stage 2 fan on,
- Fan auto/manual,
- Motor drive on local,
- Two (2) spare alarms,

– 4-20 mA Transducers for tap position,

– All necessary relays, contactors, supervisory control interposing relays, labels, wiring, terminals, test facilities, fuses, trip switches, etc. to complete the scheme.

The Contractor shall provide adequate number of step contact cards, BCD cards and transducers in RTCC panels and motor drive units according to Contractor's Design approved by Client.

"The AVR (RTCC) panel should include three step contact cards and two BCD cards."

The control switches on local tap-changer control cabinet and on the remote tap-changer control (RTCC) panel shall be either lockable spade type or push button as required by the Client.

Remote Tap-Changer Control Panel shall be completely wired, with voltage regulator, instruments, control switches, relays and other auxiliary devices.

The preferred front view of the RTCC panel has been presented on Drawings.

RTCC Panels shall be made of steel sheet with thickness not less than 2 mm, painted in RAL 6019 colour. Panels shall be for indoor installation with IP41 degree of mechanical protection. The indication lamps on RTCC Panel shall be of neon or LED type.

3.1.14. Temperature Indicating Devices and Gas & Oil Actuated Relays

3.1.14.1. *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 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.

Where winding temperature indicators are specified, they shall be associated with one phase only.

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 submitted to the Client 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 transformer control cabinet and shall be mounted so that they will not be affected by vibration.

3.1.14.2. 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.

3.2. Earthing and Auxiliary Transformer

3.2.1. General

Since the main transformer secondary (LV) winding shall be connected in delta, for each power transformer, an earthing transformer shall be provided for the 11 KV AND 33-kV system neutral point.

The earthing transformer shall be used as auxiliary power supply transformer as well.

The 33-kV neutral point shall be earthed through resistance and the protection will be arranged to limit the duration of earth fault current to the maximum of 10 s.

3.2.2. Requirements

Each earthing transformer shall be of the oil-immersed, ONAN type transformer, suitable for outdoor installation and shall have an interconnected star (zig-zag) winding which shall be directly connected to the LV winding of the main transformer and an auxiliary star connected winding arranged to give a 3-phase, 4-wire power supply, via a switch fuse unit. Switch fuse unit of adequate rating shall be installed within earthing & auxiliary transformer cabinet mounted on the transformer.

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 a resistance.

The maximum flux density at any point in the core with normal applied voltage shall not exceed 1.9 T.

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 30 s, without injurious heating, an earth fault current not less than the value given in the Schedules**. The current density under such condition shall not exceed 23 A/mm2. The value of zero sequence impedance of the high voltage winding shall not exceed 45 Ω/phase.**

Mineral insulating oils shall be high-quality product in accordance with IEC 60296 and other relevant Standards if not otherwise required in this Specification and shall be sourced from internationally reputed manufacturers only.

De-energized tap changer (DETC) shall be high-quality product in accordance with IEC 60214-1, of a robust construction and shall be sourced from internationally reputed manufacturers only.

Protective devices shall be high-quality product in accordance with IEC 60976-22-1 and shall be sourced from internationally reputed manufacturers only.

Accessories and fittings shall be high-quality product in accordance with IEC 60976-22-7 and shall be sourced from internationally reputed manufacturers only.

Earthing and auxiliary transformer shall be provided with the following accessories:

- One thermometer pocket with captive cap,
- Dehumidifying breather,
- Filter valve and combined filter and drain valve,
- A sampling device at the bottom of the tank,

- Conservator vessel with removable end cover and prismatic oil gauge,
- Double float gas oil actuated relay,
- Pressure Relief Device.

The earthing & auxiliary transformer (core, winding, …etc.) shall comply with the requirements stated in Clause 3 of this Particular Technical Specifications relating to the main transformers wherever these are applicable.

3.3. Control, Operation, Indication and Alarm Circuits for Transformers

Item No	Device	Function	Operating supply voltage	Required	To be supplied by Contractor
1	Gas and/or oil actuated relay	a. Alarm b. Trip	110 V DC 110 V DC	Yes Yes	Yes Yes
2	Winding temperature indicator	a. Alarm b. Trip c.Cooler Control	110 V DC 110 V DC 230 V AC	HV LV	Yes Yes Yes
3	Winding temperature indicator remote repeater	Indication		HV LV	Yes Yes
4	Oil temperature indicator	a. Alarm b. Trip	110 V DC 110 V DC	Yes Yes	Yes Yes
5	Tap-changing equipment	a. Control b. Indication	230 V AC 110 V DC	Yes Yes	Yes Yes
6	Fan failure	Alarm	110 V DC	Yes	Yes
7	Oil flow failure	-	-	-	-
8	Remote electrical indicator to show if units of a group of transformers are in parallel on different tapping	a. Indication b. Alarm	110 V DC -	Yes No	Yes No
9	Transformer “tap change in progress” remote electrical indication	a. Indication b. Alarm	110 V DC 110 V DC	Yes Yes	Yes Yes
10	Transformer “voltage ratio” remote electrical indication	Indication	110 V DC	Yes	Yes
11	Main transformer pressure relief device	Trip	Voltage operated relay	Yes	Yes
12	Earthing transformer pressure relief device	Trip	Voltage operated relay	Yes	Yes
13	Earthing transformer Oil temp alarm	Alarm Trip	110 V DC Voltage operated	Yes	Yes

			relay		
14	Earthing transformer Oil level	Alarm	110 V DC	Yes	Yes

NOTE: 110 V VOLTAGE OPERATED RELAYS WILL BE USED FOR TRIP AND ALARMS.

THE COLOR CODE INTERNAL WIRING AT PANELS (LTCC, RTCC) SHALL AS FOLLOW:

Control wiring	1.5 mm2	Gray or black
AC circuit	2.5 mm2	- single phase: Red/ Black - three phase: Red/yellow/blue/black
DC circuit	2.5 mm2	Red/ Black
CT and VT circuit	2.5 mm2	Red/yellow/blue/black
Earthing	4 mm2	Green with yellow
Trip signal	1.5 mm2	Gray with red color ferrules with “T” marks

4. Inspection and Tests

4.1. General

The Contractor shall carry out the tests stated in this Technical Specification and, without extra charge, such additional tests as in the opinion of the Client are necessary to determine that the Contract Works comply with this Technical Specification under all possible working conditions.

All testing laboratories shall be accredited according to ISO/IEC 17025 by ILAC (The International Laboratory Accreditation Cooperation).

All materials used, shall be subjected to and shall withstand satisfactorily such routine tests as are customary in the manufacture of the types of equipment included in the Contract.

All tests shall be carried out to the satisfaction of the Client and in his presence, at such reasonable times as he may require, unless agreed otherwise.

Not less than 28 calendar days, notice of all tests shall be given to the Client in order that he may be represented if he so desires. Failure of the Contractor to give such notice which results in a delay in the completion of the tests cannot be used by the Contractor as a reason for failure to meet the overall completion date and any extra costs incurred by the Contractor shall not be recoverable. As many tests as possible shall be arranged together. Three (3) copies of the Contractor's Test Reports shall be submitted to the Client.

Measuring apparatus shall be approved by the Client and if required shall be calibrated at the expense of the contractor at an approved laboratory.

All the adjustable devices and all accessories shall be calibrated and adjusted for the anticipated operating conditions and shall be interlocked in order to prevent readjustment on the Site.

The Contractor shall be responsible for the proper testing of the work completed or equipment or materials supplied by a sub-contractor to the same extent as if the work, equipment or materials were completed or supplied by the Contractor himself.

All apparatus, instruments and connections required for the above tests shall be provided by the Contractor.

The Contractor shall supply suitable test pieces of all materials as required by the Client at the Site.

The cost of all inspection and tests and/or analyses shall be borne by the Contractor. Furthermore, all expenses including economy class air fares, hotel accommodation, local transportation, visa fees, medical insurance, etc. of the Client’s personnel during Factory Acceptance Tests (FATs) shall be borne by the Contractor. Any costs incurred regarding the re-inspection and re-testing as a result of a failure of the equipment under test, shall be borne by the Contractor.

No inspection or lack of inspection, or passing by the Client of work, equipment or materials, whether carried out or supplied by the Contractor or sub-contractor, shall relieve the Contractor from his liability to complete the Contract Works in accordance with the Contract or exonerate him from any of his guarantees.

After successfully completed tests, all the sensitive equipment within the cubicle, panel or any other device, shall be disassembled and transported specially packed and protected. Also, each detachable part shall be adequately marked to insure proper reassembly on the Site.

In addition to the general requirements for inspection and tests stated above, the following shall also be applied:

- Factory Acceptance Tests (FAT) shall include type tests for representative transformer, and routine tests for each type of equipment to be installed.
- Tests shall be performed to determine whether the materials and the equipment comply with the technical requirements. All tests shall be performed in the conditions which, as much as possible, correspond to the operating conditions,
- The Contractor shall submit to the Client for approval, the Test Program for all the necessary tests. For each performed test, the Contractor shall prepare the appropriate Test Report and shall submit it to the Client for approval,
- All tests on the equipment, both at the Manufacturer's factory and after completion of installation at the Site, shall be performed in accordance with IEC, BS, and IEEE Standards, unless otherwise agreed with the Client.
- All additional tests, except those specified further below, which might be necessary for confirmation of the equipment guaranteed characteristics, shall be performed at the Clients' request and with no additional cost to the Client,
- Appropriate standard instruments and other measuring equipment, as well as technical personnel, necessary for performance of the Factory Tests shall be provided by the Contractor,
- Appropriate measuring equipment, as well as technical personnel, necessary for performance of the Site Tests and Commissioning of the equipment shall be provided by the Client, while the Contractor shall provide technical Supervision during execution of Site Tests and Commissioning,
- The tests shall not diminish characteristics and reliability of the tested equipment or shorten its lifetime,
- The Detailed Program of the Factory Tests shall be submitted minimum 28 calendar days before commencement of the tests and shall be submitted to the Client for approval. These tests shall comprise minimum the tests specified in Clauses 4.2 & 4.3 of these Particular Technical Specifications. These Detailed Programs shall also comprise the procedures and all details of the procedures and charts of measurements, conditions, and implementation of the testing procedures, as well as the sequence of equipment preparation, the operating procedures to be applied, etc.,
- The Detailed Program of the Factory Tests shall be approved by the Client 21 calendar days after the documents have been submitted,
- The details of the tests are given further below.

4.2. Factory Tests on Transformer

4.2.1. General

Factory tests shall be performed in the presence of the Client; however, some tests may be performed in the Client's absence, with his prior consent.

Factory Acceptance Tests (FAT) shall include type tests for representative transformer, and routine tests for each type of equipment to be installed.

After satisfactory completion of the witnessed tests at the Factory, the Contractor shall submit Shipping Release request for Client.

No item of equipment shall be dispatched to Site until the Client has given his approval and issued the relevant Shipping Release.

4.2.2. Type Tests Certificates

It is required that all equipment will have type test certificates. Type Tests Certificates shall be submitted for the equipment same as required in ITT, issued by an international independent, recognized, accredited testing laboratory.

All testing laboratories shall be accredited according to ISO/IEC 17025 by ILAC (The International Laboratory Accreditation Cooperation).

At least the following type tests certificates for transformers (according to IEC 60076) shall be provided:

- Temperature-rise type test,
- Dielectric type tests,
- Determination of sound level (IEC 60076-10) for each method of cooling for which a guaranteed sound level is specified,
- Measurement of the power taken by the fans,
- Measurement of no-load loss and current at 90 % and 110 % of rated voltage,
- Evidence from demonstrably similar units and/or mechanical and thermal calculations shall be provided to demonstrate clear margins of short-circuit current withstand at system fault levels for transformers. All tests and calculations shall be fully in accordance with IEC 60076-5,
- Calculation proof of overloading capability according to IEC 60076-7,
- Type tests for the transformer bushings, in accordance with IEC 60137,
- Type tests for tap changers in accordance with IEC 60214-1&2.
- Type tests for the current transformers within transformer bushings, in accordance with IEC 61869-1&2.

At least the following type tests certificates for earthing transformers (according to IEC 60076-6) shall be provided:

- Temperature rise test
- Dielectric tests.

4.2.3. Type tests

Type tests shall be made on a transformer which is representative of other transformers, to demonstrate that these transformers comply with the specified requirements not covered by the routine tests. A transformer is considered to be representative of others if it is built to the same drawings using the same techniques and materials in the same factory.

The following tests shall be carried out as part of the Factory Acceptance Test (FAT):

- Temperature Rise Test. The test shall be in accordance with IEC 60076 and shall be carried out on one (1) main transformer, one (1) earthing & auxiliary transformer. Type temperature-rise test at any time shall be performed by feeding transformer with the total measured losses or total guaranteed losses, whichever is higher. During temperature rise test, winding thermal time constants shall be estimated from the hot resistance cooling curve,
- During the temperature rise test the accuracy of oil and/or winding temperature indicating devices shall be determined,
- Capability of sustaining the guaranteed overload conditions shall be demonstrated by calculation method according to IEC 60076-7. Measured (actual test) values of winding and oil thermal parameters (temperature rise and thermal time constant) defined during temperature-rise tests shall be used for calculation input data. Appropriate overload curves reflecting permissible duration of the overload as function of stated overloads and ambient temperatures should be provided,
- Noise level measured in accordance with IEC 60076-10,
- Dielectric type tests
- The measurement of zero sequence impedance,
- Leakage test,
- Vacuum test,
- Power consumption of cooling system.

Type tests shall be performed in accordance with the latest version of IEC 60076. Tests shall take place at an internationally recognised testing station or in manufacturer own accredited laboratories, witnessed by Client. All type testing costs shall be included in the tender prices for the transformers.

4.2.4. Routine Tests

Routine tests shall be performed at the Manufacturer's factory and in the Client's presence, on each part of the equipment foreseen for delivery, for the purpose of detecting failures in the material or in the structure. Tests shall be performed in accordance with the latest edition of the relevant IEC, BS, and IEEE Standards, unless specified otherwise. The test results shall be submitted to the Client for consideration, immediately after completion of the tests.

At least, but not limited to, the following routine tests for transformers (according to IEC 60076) shall be performed:

- Measurement of winding resistance,
- Measurement of voltage ratio and check of phase displacement,
- Measurement of short-circuit impedance and load losses,

- Measurement of no-load loss and current at rated frequency and rated voltage, 90% rated voltage and 110% rated voltage,
- Dielectric routine tests,
- Dielectric tests on oil including Dissolved Gas Analysis (DGA) before and after dielectric tests. Measurement of DGA in oil shall be from each separate oil compartment. All tests according to IEC 60296 and IEC 62535 shall be carried out on the samples from each type of oil supplied by the Contractor/Manufacturer and Test Certificate shall clearly indicate that oil is free from PCB, DBDS (dibenzyl disulphide), Antioxidant, passivator, metal deactivator and other additives),
- Tests on on-load tap-changers,
- Leak testing with pressure (tightness test),
- Check of the ratio and polarity of built-in current transformers,
- Check of core and frame insulation,
- Determination of capacitances windings-to-earth and between windings,
- Measurement of d.c. insulation resistance between each winding to earth and between windings,
- Measurement of dissipation factor (tanδ) of the insulation system capacitances.
- Routine tests for the transformer bushings, in accordance with IEC 60137,
- Routine tests for the current transformers within transformer bushings, in accordance with IEC 61869-1&2.

At least, but not limited to, the following routine tests for earthing transformers (according to IEC 60076-6) shall be performed:

- Measurement of winding resistance
- Measurement of zero-sequence impedance
- Measurement of no-load loss and current
- Dielectric tests
- Measurement of voltage ratio and check od voltage vector relationship
- Measurement of short-circuit impedance and load loss
- Separate source a.c. withstand voltage test of the auxiliary winding and of the control and measuring wiring, where appropriate

The Test Report shall be signed by all the parties involved.

4.3. Factory Tests on Transformer Components

4.3.1. General

Tests during and after manufacturing shall be carried out on the transformer components in order to verify compliance with the Specifications, good workmanship and their capability to perform the required duties when in service.

Unless otherwise specifically mentioned these tests shall be made in accordance with the one of the applicable international standards, subject to the approval of the Client, or according to a method proposed by the Contractor and approved by the Client.

4.3.2. Transformer Tanks and ONAN Coolers

4.3.2.1. *Type Tests Certificates*

Type Test Certificates shall be provided for the following:

Vacuum test:

One transformer tank, tap-changing compartment, radiator and cooler of each size shall be subjected when empty of oil to the vacuum test level specified in the Schedule of Technical Data. There shall be no permanent deflection of the stiffeners, nor shall the permanent deflection of the panels exceed the value specified in the following Table.

Major dimension of panel between stiffeners (Metres) vertical or horizontal	Maximum permanent deflection
Up to 1.5 m	3 mm
1.5 m - 3 m	8 mm
Above 3 m	13 mm

Pressure test:

One transformer tank of each size shall be subjected to a pressure corresponding to the normal pressure plus 35 kN/m2. After the release of the excess pressure there shall be no permanent deflection of the stiffeners nor shall the permanent deflection of panels between stiffeners exceed the value specified in the above table. This test may be combined with a routine oil leakage test.

The tap-changer barrier shall be shown to withstand an over pressure test of normal pressure plus 35 kN/m2 for 12 hours.

If required by the Client one pressure relief device of each size shall be subjected to increasing oil pressure and shall operate before reaching normal pressure plus 35 kN/m2.

The operating pressure shall be recorded on the Test Certificate.

4.3.2.2. *Routine Tests*

Oil leakage test:

All tanks and oil filled compartments including all forms of radiator shall be tested for oil tightness by being completely filled with oil of a viscosity not greater than that of IEC 60296 insulating oil at a temperature of 150 ºC and subjected to a pressure equal to the normal pressure plus 35 kN/m2. This pressure shall be maintained for a period of not less than 24 hours, during which time no leakage shall occur.

The tap-changer barrier shall be subjected to normal oil pressure head for 24 hours, during which time there shall be no leakage from the panel or bushings.

Detachable radiators may be tested as separate units.

4.3.3. Fans, Motors, Pipe work, Valves and Oil Sampling Devices

4.3.3.1. *Type Tests Certificates*

Type Test Certificates shall be provided for the following:

Motors:

Performance tests shall be in accordance with IEC 60034-1, however, certificates of type tests in accordance with IEC will be accepted.

Valves and Oil Sampling Devices:

Except for non-return valves, all valves and oil sampling devices which are subject to oil pressure in service or during maintenance shall withstand, when empty of oil, absolute pressure not exceeding 350 m bars. In the case of valves this test is to be applied to the body only. This type test shall subsequently be followed by a repeat oil leakage test.

4.3.3.2. *Routine Tests*

Oil filled equipment:

The bodies of all oil pumps complete with submerged motors, if any, and the oil pipe work, oil sampling devices and valves shall withstand a hydraulic pressure of 140 kN/m2 for 15 minutes.

Fans:

Static and dynamic balance shall be checked on all fan impellers.

Control gear:

All control gear shall be subjected to the tests specified in the appropriate IEC.

Motors:

Each motor shall be subjected to the following tests where applicable:

- Measurement of winding resistance (cold),
- No load test at rated voltage for determination of fixed losses,
- An overvoltage test at 1.5 times rated voltage applied with the machine running at no load, for a period of 3 minutes, to test inter-turn insulation,
- High voltage in accordance with IEC 60034-1.

4.3.4. Transformer Oil

4.3.4.1. *Type Tests Certificates*

Type Tests Certificates for transformer oil shall be provided in accordance with IEC 60296.

4.3.4.2. *Sample Tests*

Oil samples shall be taken for testing during and after FAT. Samples of oil from each consignment shall be tested in accordance with IEC 60296 before dispatch and the oxidation stability test shall be included. Test Certificates shall be submitted to the Client.

Subject to the agreement with the Client, a Test Certificate, confirming that the oil from which the consignment was drawn has been tested in accordance with IEC 60296, may be accepted.

Test evidence from the Manufacturer shall be submitted for each type of oil and the Test Reports shall be submitted to the Client for the following contents:

- Corrosive Sulphur (tested as per IEC 62535),
- Antioxidants (tested as per IEC 60666),
- PCBs (tested as per IEC 61619),
- DBDS (tested as per IEC 62697),
- Passivator (tested as per IEC 60666),
- Metal Deactivator.

4.3.5. Gas and Oil Actuated Relays

4.3.5.1. *Routine Tests*

The following tests shall be made on relays when completely assembled. Where oil is referred to, it shall have a viscosity not greater than that of IEC 60296 insulating oil at 150 °C.

Oil leakage:

The relay, when filled with oil shall be subjected to an internal pressure of 140 kN/m2 for 15 minutes. No leakage shall occur either from the casing or into normally oil free spaces, such as floats, within the casing.

Gas Collection:

With the relay mounted as in service and at a rising angle of 5 degrees (tank to conservator) and full of oil, gas shall be introduced into the relay until the gas collection contacts close. The oil level contacts shall not close when gas is escaping freely from the relay on the conservator side. These contacts shall, however, close when the pipe work is empty of oil.

The empty relay shall be tilted, as if mounted in pipe work rising from tank to conservator, at an increasing angle until the gas collection contacts open. The angle of tilt shall then be reduced, and the gas collection contacts shall close before the angle is reduced to less than 13 degrees to the horizontal.

With the relay mounted at a falling angle of 16 degrees to the horizontal and full of oil, the gas collection contacts shall be open.

Oil surge:

With the relay mounted as in service and full of oil at approximately 150 °C, the surge contacts shall close within the steady oil flow limits specified in the Sub-section 5.1: Schedule of Technical Data. This operation shall not be adversely affected when the gas collection contacts have already closed and gas is escaping freely.

Voltage:

With the relay empty of oil, a voltage of 2 kV shall be applied in turn between each of the electrical circuits and the casing for one minute, the remaining circuits being connected to the casing.

4.3.5.2. *Sample Tests*

At the discretion of Client, the following tests shall be made:

– Variation of performance with mounting angle with the mounting conditions as in service, the mounting angle shall be varied within the rising angle limit 10 and 90 and tests repeated in the manner prescribed for the routine tests.

4.3.6. Voltage Control Equipment

Type test certificates and factory tests for transformer voltage control equipment shall be carried out in accordance with IEC 60214.

4.3.7. Transformer Bushings

It is not intended to test the bushings separately during the transformer factory tests.

Factory tests for transformer bushings shall be carried out in accordance with IEC 60137.

4.3.8. Current Transformers in Transformer Bushings

Factory tests for current transformers in transformer bushings shall be carried out in accordance with IEC 61869-1&2.

4.3.9. Secondary Wiring

4.3.9.1. Routine Tests

All secondary wiring, including panel wiring and control circuits and all apparatus connected thereto shall be subjected to the following routine tests:

– High voltage test with 2 kV applied for one minute, unless otherwise specified or required by a British Standard, to which item the appropriate test shall be applied,

– Insulation resistance measurement by megger of not less than 500 V.

4.3.10. Galvanizing

4.3.10.1. Sample tests

Samples selected by the Client of all galvanized material shall be subjected to the galvanizing tests set out in BS EN 10244 or BS EN ISO 1461, whichever is applicable.

4.3.11. Oil Filtering Equipment

All tests which Client considers necessary to show that the guaranteed particulars in the Sub-section 5.1: Schedule of Technical Data are met.

4.4. Factory Acceptance Tests (FAT)

Prior to delivery, the transformers and associated equipment shall be factory tested.

The equipment, Cubicles and panels shall be completely assembled in the factory and wired.

Factory Acceptance Tests (FAT) shall be performed at the Manufacturer's factory, in presence of the Client, according to the latest edition of the relevant IEC, BS, and IEEE Standards, unless specified otherwise, in order to prove that the equipment corresponds to the General and Particular Technical Specifications

The scope of tests shall be in accordance with the Detailed Test Program approved by the Client, but any of the tests performed during manufacturing can be repeated. Reports from tests performed during production shall be available to the Client during the FAT.

For the purpose of FAT tests, the Contractor shall provide all necessary works and conditions needed to conduct all tests, sufficient number of copies of detail Design documentation, Test reports from previously conducted tests, testing protocols and procedures, as well as other required by these Technical Specifications.

The Contractor is obliged, after the conducted tests, to prepare Test Report from FAT tests. Test results shall be submitted to the Client for approval. The Test Report shall be signed by all parties involved.

All expenses including economy class air fares, hotel accommodation with meals, local transportation, visa fees, medical insurance, etc. of the Client's personnel during FAT shall be borne by the Contractor. Any costs incurred regarding the re-inspection and re-testing as a result of a failure of the equipment under test, shall be borne by the Contractor.

The Contractor shall also give priority to the Royal Jordanian Airlines for airfreights shipment and transport of personnel.

It is anticipated that the Client will have continuous presence during execution of the Factory Acceptance Tests.

In line with price schedule and its notes, the contractor shall include the expenses for employer representative attending the test in the total equipment price.

Note: The offered FAT period shall be specified in days, excluding travel days, and must be sufficient to conduct all required tests as per IEC and Particular technical specifications.

5. Documentation

5.1. Documentation to be Submitted with the Tender

Together with the Tender, completed with pertaining Schedule of Technical Data duly filled-in, the Tenderer shall submit the following documentation/information:

- General arrangement drawings, showing particulars of all associated equipment and accessories, their overall dimensions, shipping and lifting dimensions, mass of the complete transformers, their components, and oil, etc. as well as details about the required foundations. These drawings shall also indicate the necessary capacity of the crane for transformer installation and size of lifting lugs or eyes. Parts to be removed for transport shall be indicated and their masses stated as well,
- Detailed descriptions with characteristics of the proposed transformers and associated equipment (catalogues, descriptive literature, manufacturing Specifications),
- Reference list of similar transformers, oil, tap-changer and bushing installed in similar climatic and service conditions,
- Type Test Certificates for the equipment same as required in ITT.
- The End-User Certificates shall follow the required in ITT.

5.2. Documentation to be Submitted after Contract Commencement Date

Within the one (1) month upon Contract Commencement Date, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

- Detailed Time Schedule for execution of Works under this Contract (Program of Works), comprising all activities from the design to taking-over,
- List of complete documentation to be submitted under this Contract,

Within the three (2) months upon Contract Commencement Date, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

- Outline drawings of the transformers and associated equipment to be supplied under this Contract,
- Outline drawing showing the transformer accommodation in the truck for transport to the Site,
- Foundation drawings with all necessary details for fixation for the equipment to be supplied under this Contract,
- Detailed technical description of the complete equipment to be supplied under this Contract,
- Details (Information, data, etc.) necessary for connection with the equipment which shall be supplied under other Contracts.
- Necessary calculations for dimensioning/sizing of the equipment,
- All other data that Contractor considers as necessary for submission to the Client.

Within the five (5) months upon Contract Commencement Date, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

- Detailed front view and cross section drawings of the equipment supplied under this Contract, including all dimensions, weights and transport details,
- Detailed layout drawings of the equipment supplied under this Contract, including the existing equipment,
- Detailed electrical schematic diagrams, including block-diagrams, single line diagrams, circuit diagrams, I/O signal list, wiring diagrams and connection diagrams.
- Cable list with defined interconnections of the equipment supplied under this Contract, with connections between the equipment supplied under this Contract and the equipment to be supplied under other Contracts and existing equipment as well,
- Detailed Program of the Factory Tests,
- Detailed Program of the recommended Site Tests,
- Instructions for Equipment Installation (review only),
- Operation and Maintenance Manuals (review only),
- Program of Training for the installation, operation, maintenance and testing of the equipment to be delivered,
- All other data that Contractor considers as necessary for submission to the Client.

At least one (1) month prior to shipment, the Contractor shall submit the following documentation as a minimum to Client for review and approval:

- Signed approved Factory Test Reports,
- Clear evidence that all comments during FATs have been corrected,
- Detailed packing lists, transport program and insurance documentation,
- Instructions for loading, unloading, handling and particular safety measures to the applied during storage (review only).