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TECHNICAL SPECIFICATION
POWER TRANSFORMERS
(132/33kV & 132/11kV)

TABLE OF CONTENTS

Page

1.0 TYPES OF TRANSFORMERS AND OPERATING CONDITIONS 5

2.0 CONTINUOUS MAXIMUM RATINGS AND OVERLOADS 5

3.0 ELECTRICAL CONNECTIONS 5

3.1 132/11KV AND 132/33 KV TRANSFORMERS 6
3.1.1 132kV Connections and Terminations 6
3.1.2 33kV Connections (Not applicable for this project) 6
3.1.3 11kV Connections 6
3.1.4 132kV Cable Box & Sealing End Chambers 6
3.1.5 Disconnecting arrangement 7
3.1.6 General Requirement on Terminals and terminations 7

4.0 DUTY UNDER FAULT CONDITIONS 7

5.0 FLUX DENSITY 7

6.0 VIBRATION AND NOISE 8

7.0 SUPPRESSION OF HARMONICS 8

8.0 TOLERANCES 8

9.0 MAGNETIC CIRCUIT 8

10.0 MECHANICAL CONSTRUCTION OF CORES 8

11.0 WINDINGS - GENERAL 9

12.0 BRACING OF WINDINGS 9

13.0 TERTIARY WINDINGS 10

14.0 INTERNAL EARTHING ARRANGEMENTS 10

15.0 EARTHING OF TERTIARY WINDINGS 11

16.0 TANK CONSTRUCTION 11

17.0 TANK LIFTING AND HAULAGE FACILITIES 12

18.0 TANK COVER 12

19.0 CURRENT TRANSFORMER ACCOMMODATION 13

20.0 CONSERVATOR VESSELS, OIL GAUGES AND BREATHERS 13

21.0 FILTER AND DRAIN VALVES, SAMPLING DEVICES AND AIR RELEASE PLUGS 14
22.0 VALVES 14
23.0 PRESSURE RELIEF DEVICE 14
24.0 EARTHING TERMINALS & BONDING 15
24.1 BONDING 15
25.0 RATING, DIAGRAM AND PROPERTY PLATES 15
26.0 JOINTS AND GASKETS 16
27.0 COOLING PLANT - GENERAL 16
28.0 RADIATORS CONNECTED DIRECTLY TO THE TANK 16
29.0 COOLERS 16
30.0 COOLER FANS 17
31.0 COOLER CONTROL 17
32.0 TAP CHANGE CONTROL 18
33.0 AUTOMATIC VOLTAGE CONTROL 21
33.1 REMOTE TAP CHANGER CONTROL PANEL 22
34.0 TEMPERATURE INDICATING DEVICES AND ALARMS 23
35.0 GAS AND OIL ACTUATED RELAYS 24
36.0 DRYING OUT 25
37.0 TRANSPORT 25
38.0 ERECTION 26
39.0 TERMINAL BOARDS 26
40.0 INSTRUMENT CABLES AND ACCESSORIES 26
41.0 MARSHALLING KIOSKS 27
42.0 TRANSFORMER OIL 28
43.0 TESTS AT FACTORY 28
43.1 Routine Tests 28
43.2 Type Tests 29
43.3 Special Tests 29

43.4 TESTS ON VOLTAGE CONTROL EQUIPMENT 30
43.4.1 Routine Tests 30
43.4.2 Type Tests on Voltage Control Equipment 30
43.5 ROUTINE TESTS ON MAGNETIC CIRCUITS 30
43.6 ROUTINE TESTS ON CABLE BOXES AND DISCONNECTING CHAMBERS 30
43.7 ROUTINE TESTS ON TANKS 31
43.8 TYPE TESTS ON TANKS 31
43.9 ROUTINE TESTS ON GAS AND OIL ACTUATED RELAYS 32
43.10 SAMPLE TESTS ON GAS AND OIL ACTUATED RELAYS 32
44.0 SUBMISSION OF DRAWINGS/DOCUMENTS 33
45.0 APPLICABLE STANDARDS 33

1.0 TYPES OF TRANSFORMERS AND OPERATING CONDITIONS

All transformers shall be of core type and shall be suitable for outdoor installation at an ambient temperature of 50°C at site. The transformer shall be designed to meet the requirements as per schedule of requirement and "Design criteria and technical requirements common to all equipments and materials".

Transformers with forced air cooling shall be capable of remaining in operation at full load for 10 minutes after failure of the cooling fans without the calculated winding hot spot temperature exceeding 140°C. Transformers fitted with two sets of cooling fans each capable of dissipating 50% of the losses at full rated output shall be capable of remaining in operation for 20 minutes in the event of failure of one set of cooling fans associated with one cooler bank without the calculated winding hot spot temperature exceeding 140°C.

The following items are to be supplied along with each transformer:

- First filling of the oil inclusive of 10% excess in non-returnable container.
- Special tools and tackles for operation and maintenance of each transformer.

All transformers shall be provided with conservator vessels.

2.0 CONTINUOUS MAXIMUM RATINGS AND OVERLOADS

Equipment shall comply, as regards rating, temperature rise and overload, with the appropriate requirements of IEC 60076 and IEC 60354.

All equipment except where stated below shall be capable of operation continuously without injurious heating at full rated output at any ratio, irrespective of the direction of flow of power and with the voltage of the untapped winding maintained at the rated voltage.

The transformers shall meet the temperature rise limits specified, on all tappings under continuous maximum rated current conditions without the spare fans in service and without injurious heating.

If the system has an earthed neutral the manufacturer shall take into account any change of impedance per phase due to the zero sequence component resulting from unsymmetrical currents.

3.0 ELECTRICAL CONNECTIONS

Transformers shall be connected in accordance with the Group Symbol specified.

Easy access shall be provided for internal connections of bushings without extensively dismantling any external mountings such as radiators etc.

3.1 132/11kV and 132/33 kV Transformers

3.1.1 132kV Connections and Terminations

i) Connection to 132 kV GIS

Wherever connections are to be made to 132kV GIS, transformers shall be designed such that the 132kV connections are via 132kV single core copper/ XLPE cable of 630 mm^2 of cross sectional area.

The 132kV winding shall be terminated in an oil filled cable box through oil/oil condenser bushings of suitable rating. The cable box shall be suitable for interconnecting the transformer with gas-insulated switchgear using single core cable as specified above. The transformer manufacturer must ensure that the cable box design is fully co-ordinated between the transformer and cable/termination manufacturers and shall be subject to the approval of the Authority.

ii) 132kV neutral point shall be provided by means of the outdoor type bushing with minimum continuous voltage rating of 33 kV. The neutral point shall be brought down through copper busbar of size 10 x 100mm supported through 15kV insulators up to 500mm above the ground level for connecting with earth grid using 300 sq.mm. insulated copper earthing conductor. The neutral current transformers shall be mounted on the transformer as per schedule of requirement.

3.1.2 33kV Connections (Not applicable for this project)

3.1.3 11kV Connections

Connections to 11kV switchgear shall be through XLPE cable terminations in a suitable cable box. The low voltage winding shall be terminated in an air filled cable box through oil/air bushings of suitable rating. The cable boxes shall be suitable for

Connecting six set of single core 630 mm^2 Cu. XLPE cable per phase and two single core 630 mm^2 Cu. XLPE cable for neutral. Adequate space shall be provided for the connection of the cables. Cable supports shall be provided at terminations. The cable box shall be equipped with a silica gel breather. Suitable non-magnetic type clamps shall be provided to support the cables. The stuffing glands for cable entry into the cable box shall be provided.

3.1.4 132kV Cable Box & Sealing End Chambers

The 132kV cable boxes shall meet the requirements of the relevant clause of the specification, and shall be suitable for the direct termination of the cables.

Cable boxes and sealing end chambers shall be designed for suitably insulated terminations, and shall accommodate all cable terminating fittings, heat shrink sleeves, stress cones, etc. as required by the particular type and size of cable being supplied.

To facilitate removal of the transformer without disturbing cables, the cable boxes shall be of detachable type.

3.1.5 Disconnecting arrangement

The transformer cable box shall be provided with disconnecting arrangement for 132kV terminations to facilitate testing of cables and/or transformers independently. It shall also facilitate removal of the transformer without disturbing cables. The disconnecting arrangement can consist of links in the cable boxes or in a separate disconnecting chamber.

The disconnecting arrangement shall be suitably insulated with provision of vermin proof breathing arrangement where applicable. The clearances between the cable terminals and transformer bushings shall be adequate and ample to subject each cable or transformer separately to high voltage tests.

The cable box and the disconnecting arrangement shall be capable of withstanding both at the time of the first test on cables and at any subsequent time as required the test voltages for a period of 15 minutes.

An earthing terminal shall be provided in each disconnecting or sealing end chamber to which the connections from the transformer winding can be earthed during cable testing.

3.1.6 General Requirement on Terminals and terminations

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

Transformer terminals are to be provided with phase markings to the requirements of the FEWA. Transformer terminals shall be silver/tin-plated copper and hardware shall be stainless steel.

Special care should be taken to prevent galvanic corrosion. For connections of copper conductors to aluminium conductors crimping or welded type copper/ aluminium cable sockets shall be used. Suitable non-magnetic clamps are to be provided for supporting the cables.

4.0 DUTY UNDER FAULT CONDITIONS

Except where modified below, it is to be assumed that the amount of generating plant simultaneously connected is such that normal voltage will be maintained on one side of any transformer when there is a short-circuit between phases or to earth on the other side. Any transformer may be directly connected to an underground or overhead transmission line and switched into and out of service together with its associated transmission line.

All transformers shall be capable of withstanding for three seconds without damage an external short-circuit between phases.

Transformers with tertiary windings shall be capable of withstanding for three seconds, without damage, any external short- circuit to earth with the neutral points on both H.V and L.V windings directly connected to earth.

5.0 FLUX DENSITY

Unless otherwise agreed, the magnetic circuit shall be of cold rolled grain oriented sheet steel and the maximum flux density shall not exceed at normal voltage and frequency. Tesla when the voltage applied to any tapping is not in excess of that for which the tapping was designed.

6.0 VIBRATION AND NOISE

Care shall be taken to ensure that the design and manufacture shall be such as to reduce noise and vibration to the level of that obtained in good modern practice. Noise levels shall not exceed the values given in the schedule of requirements. The transformers shall be erected on anti vibration pads of approved type, which shall be supplied by the manufacturer.

7.0 SUPPRESSION OF HARMONICS

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

8.0 TOLERANCES

The admissible tolerances for no load current, component and total losses, voltage ratio and impedance voltage shall be as given in Table XIV of IEC 60076. However, penalty will be applied if the measured losses exceed the guaranteed limits, as per schedule of requirements.

9.0 MAGNETIC CIRCUIT

The magnetic core and return paths shall be made of laminated non-ageing, cold rolled, grain orientated, silicon steel of high permeability without burrs.

The design of the magnetic circuit shall be such as to avoid static discharges, development of short-circuit paths within itself or to the earthed clamping structure and the production of flux components at right angles to the plane of the laminations which may cause local heating.

The design of the magnetic shielding, if required, shall be such as to minimise the effect of the return flux path penetrating the container wall without undue reduction in the overall reactance or increase in tank size.

Where the magnetic circuit is divided into packets by cooling ducts parallel to the plane of the laminations or by insulating material above 0.25 mm thick, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between packets.

The magnetic circuit shall be earthed through a link as specified below. With the link removed the magnetic circuit shall be insulated from all structural parts so as to withstand the tests specified and shall subsequently be earthed.

10.0 MECHANICAL CONSTRUCTION OF CORES

Care shall be exercised in the selection, treatment and handling of the core steel to ensure that as far as possible laminations are flat and the finally assembled core is free from distortion. Particular care shall be taken to secure even mechanical pressure over the

laminations, to prevent subsequent settling of the core and to reduce noise and vibration during operation.

All parts of the cores shall be of robust design capable of withstanding any shocks to which they may be subjected during lifting, transport, installation and service.

All structural members of the assembled cores shall be of steel. All castings shall be fettled and structural steel adequately cleaned and painted before being built into the structure. Any non-magnetic or high resistance alloy used shall be subject to approval.

Adequate fitments shall be provided to enable the core and windings to be lifted.

Suitable accommodation, attached to the transformers, shall be provided for the storage of any removable portions of the lifting arrangements.

Adequate provision shall be made to prevent movement of the transformer relative to the tank during transport and installation or while in service.

The supporting framework of the cores shall be so designed as to avoid the presence of pockets, which would prevent complete emptying of the tank through the drain valve, or cause trapping of air during filling.

11.0 WINDINGS - GENERAL

Electrolytic copper of high conductivity and insulating material of high quality shall be used.

Insulation shall be in accordance with IEC 60076. 132kV windings shall have graded insulation. For 33kV and below they shall have uniform insulation

Tapings shall be arranged at such positions on the windings as will preserve, as far as possible, the electromagnetic balance at all voltage ratios, but shall also be positioned with due regard to the impulse voltages which may be impressed on the windings.

Star connected windings shall consist of a course and fine regulation winding. Regulation windings for delta-connected windings shall be provided with a mid winding arrangement.

The insulation of windings and connection shall be free from insulating composition liable to soften, ooze out, shrink or collapse during service.

The stacks of windings shall receive adequate shrinkage treatment before final assembly.

The coil clamping arrangement and the finished dimensions of any oil ducts shall be such as will not impede the free circulation of oil through the ducts.

No strip conductor wound on edge shall have a width exceeding six times its thickness.

The coils shall be mounted in such a manner as to reduce any magnetic imbalance between each of the windings liable to induce circulating flux in the windings and surrounding metal work.

12.0 BRACING OF WINDINGS

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

Coil clamping rings, if provided, shall be of steel or of suitable insulating material built up from flat laminations. Axially laminated material other than Bakelite paper shall not be used. Where bakelite paper rings are used with the layers of paper lying in an axial direction, the rings shall only be relied upon to provide the major insulation between the windings and earth provided the creepage voltage stress obtained by dividing the full line voltage by the creepage distance to earth does not exceed 200 kV/m.

Any metal pieces in contact with laminated rings shall be so designed and secured that they do not weaken the electrical or the mechanical properties of the rings.

If the winding is built up of sections or disc coils, separated by spacers, the clamping arrangements shall be such that equal pressures are applied to all columns of spacers. All such spacers shall be securely located, shall be of suitable material and shall receive adequate shrinkage treatment before assembly.

13.0 TERTIARY WINDINGS

The tertiary winding shall be rated for 1/3rd capacity of the transformer. The common points of the Red and Blue phases are to be brought outside through separate bushings and closed using removable copper link with adequate capacity. This point shall be connected to earthing conductor through removable copper link. CT's for protection shall be accommodated in the earthing circuit.

14.0 INTERNAL EARTHING ARRANGEMENTS

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

The top main core clamping structure shall be connected to the tank body by a copper strap. One or more of the following methods shall earth the bottom clamping structure: -

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

(b) By direct metal-to-metal contact with the tank base, maintained by the weight of the core and windings.

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

The magnetic core and clamping structure shall be earthed at one point by connections brought to removable links in a closed terminal box, placed in an accessible position on the tank cover and which, by disconnecting, will enable the insulation between core and tank, clamp and tank to be tested at voltages up to 2.5 kV.

Magnetic circuits having an insulated sectional construction shall be provided with a separate link for each individual section and the arrangement of the connections shall be subject to approval. Where oil ducts or insulating barriers parallel to the plane of the laminations divide the magnetic circuit into two or more electrically separate parts the ducts or barriers shall be bridged and the magnetic circuit shall not be regarded as being of sectional construction.

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.

All the earthing connections with the exception of those from the individual coil clamping rings shall have a cross-sectional area of not less than 80 mm^2. Connections inserted between laminations may have the cross-sectional area reduced to 20 mm^2 where in close thermal contact with the core.

15.0 EARTHING OF TERTIARY WINDINGS

The open delta of stabilising windings shall be brought out by outdoor bushings and shorted to ground solidly by solid copper bars, which must be securely supported and fastened. A current transformer mounted on the transformer and in the earthing path shall be provided for use with an earth fault protection.

16.0 TANK CONSTRUCTION

The tanks shall be complete with all accessories and shall be designed so as to allow the complete unit in the tank and filled with oil, to be lifted by crane or jacks, transported by road, rail or water without over-straining any joints and without causing subsequent leakage of oil.

The main tank body excluding tap-changing compartments, radiators and coolers shall be capable of withstanding full vacuum when empty of oil.

A ladder with the hinged and lockable bottom section shall be provided and fixed permanently to allow access to the top of the transformer.

Unless otherwise approved, tanks shall be constructed of mild steel plate, the minimum thickness of which shall be 6 mm for the sides and l0 mm for the bottom or reinforced with heavy section steel beams. This applies where the longer sides have a horizontal length up to but not exceeding l.8 metres. For a horizontal length in excess of l.8 metres the minimum side plate thickness shall be l0 mm and the minimum bottom plate thickness l3 mm.

Where the design of the tank is such that the bottom plate will be in direct contact with the surface of the foundations the above minimum bottom plate thicknesses shall be increased to 30 mm and 40 mm respectively.

The base of each tank shall be so designed that it shall be possible to move the complete unit in any direction without injury when using rollers, plates or rails. A design, which necessitates slide rails being placed in a particular position shall not be used.

Unless specifically approved detachable under bases shall not be used.

Where the base is of a channel iron construction it shall be designed to prevent retention of water.

Tank stiffeners shall be continuously welded to the tank and designed to prevent retention of water.

Wherever possible the 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 l8 mm except for short branch pipes, which may be 6 mm minimum inside diameter.

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

The under surfaces of the bases shall be specially treated with an approved preservative composition before the transformers are finally lowered on to the concrete foundations.

The tank shall be of the upper flange type with bolted cover. Welded covers shall require the approval of the Authority.

17.0 TANK LIFTING AND HAULAGE FACILITIES

Each tank shall be provided with: -

(a) Lifting lugs suitable for lifting the equipment complete with oil.

(b) A minimum of four jacking lugs, in accessible positions to enable the equipment complete with oil to be raised or lowered using hydraulic or screw jacks. The minimum height of the lugs above the base shall be:-

(i) Up to and including l0 tonnes weight - 300 mm.

(ii) Above l0 tonnes weight - 500 mm.

(c) Horizontal plates with 50 mm diameter draw holes drilled therein shall be fitted adjacent to each corner of rectangular tanks at not more than 750 mm from the base to permit the tank to be hauled in any direction or slewed. On round-ended tanks the draw holes shall be located approximately on the diagonals of the rectangle formed by the overall boundaries of the tank. At least l00 mm free working space shall be provided above and below each draw hole.

As an alternative to draw holes, rope fairings may be provided at each corner at not more than 750 mm above the base to enable a hawser to be placed round the tank for haulage purposes.

18.0 TANK COVER

Each tank cover shall be of adequate strength, and shall not distort when lifted. Inspection openings shall be provided as necessary to give easy access to bushings, for changing ratio or winding connections or testing the earth connections at the link board. Each inspection opening shall be of ample size for the purpose for which it is provided, and at least two openings, one at each end of the tank, shall be not less than 450 mm by 360 mm.

The tank cover and inspection covers shall be provided with lifting arrangements. Unless otherwise approved inspection covers shall not weigh more than 25 kg each.

The bolt holes in all cover plates shall be provided with washers, which will prevent the collection of moisture in the bolt hole.

The tank cover shall be fitted with pockets for a thermometer and for the bulbs of the winding temperature indicators. Protection shall be provided where necessary for each capillary tube.

The thermometer pocket shall be fitted with a captive screwed cap to prevent the ingress of water.

The pockets shall be located in the position of maximum oil temperature at full rated power and it shall be possible to remove the instrument bulbs without lowering the oil in the tank.

19.0 CURRENT TRANSFORMER ACCOMMODATION

Provision shall be made for the mounting of external current transformers in the neutral earth connection of the high and low voltage windings of transformers.

Similarly current transformer shall be provided in HV or LV side of transformer on 'Y' phase for parallel operation of transformers. The current transformers' characteristics shall be suitable for the protection relays they are current connected for parallel operation for which it is intended.

20.0 CONSERVATOR VESSELS, OIL GAUGES AND BREATHERS

A conservator complete with sump and drain valve shall be provided in such a position as not to obstruct the electrical connections and having a capacity between highest and lowest visible levels of not less than 8 % of the total cold oil volume in the transformer and cooling equipment. The minimum indicated oil level shall be with the feed pipe to the main tank covered with not less than 50 mm depth of oil and the indicated range of oil levels shall correspond to average oil temperatures of from minus 10°C to plus 100°C.

If the sump is formed by extending the feed pipe inside the conservator vessel, this extension shall be for at least 50 mm. The conservator shall be designed so that it can be completely drained by means of the drain valve provided when mounted as in service.

One end of the conservator shall be bolted into position so that it can be removed for cleaning purposes and equipped with elastic dischargers of the air bag type.

Two oil gauges of approved type shall be provided, preferably one at each end of the conservator. Float operated oil gauges shall be of the magnetic type. Gauges shall be provided with low oil level alarm contacts for each alarm station.

The oil level mark on the gauges shall be to the approval of the Authority.

Taps or valves shall not be fitted to oil gauges.

The oil connection from the tank to the conservator vessel shall be arranged at a rising angle from 3 to 7 degrees to the horizontal and shall consist of pipes having inside diameters not less than 75 mm.

A valve shall be provided at the conservator to cut off the oil supply.

Each conservator vessel shall be fitted with a hydro compensator for separating oil and air. A dehydrating breather shall be used for the air intake of the hydro compensator. Alarm for leakage detection of the hydro compensator shall also be provided. A breather in which silica gel is the dehydrating agent shall be designed so that: -

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

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

(c) The moisture absorption indicated by a change in colour of the tinted crystals can be easily observed. At least 25 per cent of the total quantity of silica gel crystals shall be tinted.

(d) All breathers shall be mounted at approximately l.4 metres above ground level.

21.0 FILTER AND DRAIN VALVES, SAMPLING DEVICES AND AIR RELEASE PLUGS

Each unit shall be fitted with the following: -

(a) One valve at the top and one valve at the bottom of the tank mounted diagonally opposite to each other for connection to oil circulating equipment.

(b) A drain valve together with such arrangements as may be necessary within the tank to ensure that the tank can be drained of oil as far as practicable.

(c) A drain valve fitted to each conservator.

(d) A robust sampling device at top and bottom of the main tank. The sampling devices shall not be fitted on the filter valves specified under (a) above.

(e) Flanged type air release plugs.

All valves opening to atmosphere shall be fitted with blank flanges.

22.0 VALVES

All valves up to and including l00 mm shall be of gunmetal. Larger valves may be of gunmetal or may have cast iron bodies with gunmetal fittings. They shall be of the full way type with internal screw and shall be opened by turning counter-clockwise when facing the hand wheel.

Means shall be provided for padlocking the valves in the open and closed positions. Provision is not required for locking individual radiator valves.

Every valve shall be provided with an indicator to show clearly the position of the valve.

All valves shall be provided with flanges having machined faces.

Supply padlocks complete with duplicate keys for all lockable valves. A key cabinet will be provided suitably sized to accommodate all the valve padlock keys. The cabinet will be provided with padlocking and facilities and will be mounted on or adjacent to the transformer.

23.0 PRESSURE RELIEF DEVICE

A pressure relief device shall be provided of sufficient size for rapid release of any pressure that may be generated within the tank, and which might result in damage to the equipment. The device shall operate at a static pressure of less than the hydraulic test pressure for transformer tanks. Means shall be provided to prevent the ingress of rain or dust and dual-

operating springs shall be provided for proper seating and uniform pressure after the event of action.

Contacts for trip initiation shall be provided on operation of the device.

Unless otherwise approved the relief device shall be mounted on the main tank and if on the cover shall be fitted with a skirt projecting 25 mm inside the tank to prevent gas accumulation.

If a diaphragm is used, it shall be of approved design and material and situated above maximum oil level. If the device is mounted below top oil level it shall be of the resetting type.

Loss of oil on operation of the relief device shall be contained within the transformer oil retaining area by using proper guides bringing the spilled oil down to the bottom.

24.0 EARTHING TERMINALS & BONDING

Earthing terminals shall be adequately dimensioned to receive the subsidiary-earthing conductors. Provision shall be made at positions close to each of the bottoms four corners of the tank for bolting the earth terminals to the tank structure to suit local conditions. A similar terminal shall be fitted to the tank cover.

24.1 Bonding

Substantial bonding connection studs shall be provided to all parts of the transformer, ancillary equipment and housings not forming an integral part of the main transformer tank. Bonding straps shall be provided to form an adequate and substantial connector capable of carrying prospective earth fault currents to the main earth terminals provided with the transformer.

25.0 RATING, DIAGRAM AND PROPERTY PLATES

The following plates shall be fixed to the transformer tank at an average height, where possible, of l.5 metres above ground level: -

(a) A rating plate bearing the data specified in IEC 60076 or IEC 60289 as applicable. Ratings under site ambient conditions shall also be stated.

(b) A diagram plate showing the internal connections and also the voltage vector relationship of the several windings and in addition a plan view of the transformer giving the correct physical relationship of the terminals. When links are provided for changing the transformer group symbol and/or ratio, then means shall be provided for clearly indicating the group symbol and/or ratio for which the transformer is connected. The transformer ratio shall be indicated for each tap.

(c) A plate showing the location and function of all valves and air release cocks or plugs. This plate shall also warn operators to refer to the Maintenance instructions before applying vacuum treatment.

The above plates shall be of stainless steel or of other material capable of withstanding continuous outdoor service.

26.0 JOINTS AND GASKETS

Oil resisting synthetic rubber gaskets may be used, subject to approval, provided they are of the limited compression type.

27.0 COOLING PLANT - GENERAL

The transformers shall be provided with 2 Nos. 50% capacities cooler banks each 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 stages. The automatic operation of the cooling units shall be actuated from winding temperature indicator contacts under "Auto" condition of remote selector switch. All local control devices shall be mounted in the Marshalling Box.

The cooling units shall be so designed as to meet the following requirements without exceeding the specified temperature rise under continuous mode of operation.

a) When both cooling units in service

   1. All fans running - 100% ONAF capacity.
   2. All fans stopped - 100% ONAN capacity.

b) The transformers shall be able to deliver its rated output for at least 10 minutes in case of failure of complete cooling fan at a time when the transformer was operating at its 100% capacity with thermal stability. (Without exceeding the calculated hot spot temperature).

The radiators of the cooling units shall be detachable type and shall be provided with suitable isolation valves at the top and bottom so as 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. The radiators shall be provided with drain/air release plugs at bottom and top.

The fans shall be so arranged that they can be attended or replaced conveniently from the outside periphery of the cooling unit.

28.0 RADIATORS CONNECTED DIRECTLY TO THE TANK

Radiators connected directly to the tank shall be detachable and shall be provided with machined or ground inlet and outlet branches. Plugs shall be provided at the top and bottom of each radiator for draining and filling.

Valves shall be provided on the tank at each point of connection to the tank.

29.0 COOLERS

All radiators shall be suitable for mounting on the transformer.

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

(a) A butterfly valve at each point of connection to the tank.

(b) A butterfly valve in the main oil connection at the bottom of each cooler.

(c) Removable blanking plates to permit the blanking off of the main oil connection to the top of each cooler. The blanking plates, when not in use, shall be bolted to some suitable structure on the equipment.

(d) A drain valve at the lowest point of each cooler.

(e) A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each cooler.

(f) Machined flanges on all items.

(g) A 50 mm filter valve at the top and bottom of each cooler.

(h) Flanged air release plugs.

30.0 COOLER FANS

The cooler fans used for air-forced cooling, shall be motor driven and shall be suitable for continuous operation out door 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 from reputed manufactures.

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.

31.0 COOLER CONTROL

Power supply to the fan control cubicle shall be provided from two independent a.c. sources with delayed auto changeover incorporated.

Each motor 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 by hand and also automatically from the contacts on the winding and oil temperature indicating devices. Individual, variable overload and single-phasing protection with alarm contacts shall be provided but no-volt releases shall not be fitted. This equipment

shall be accommodated in a weatherproof cabinet (protection class IP55) mounted on the transformer.

The control arrangements shall be such that motors arranged in a minimum of two groups shall be started sequentially. MCB's shall be used for manual switching of each cooling group. Auto start and stop of fans shall be arranged such that all fans will be running in 2 stages during ONAF rating and stops during ONAN rating. Both WTI and OTI contacts shall be used in parallel for start/stop of cooler fans at stage 1 and stage 2. The differential temperature between makes and break of WTI and OTI contacts is to be used for cooling fan ON/OFF. The temperature setting for cooler start/stop shall be subject to approval of the Authority.

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, main and control supplies are interrupted.

32.0 TAP CHANGE CONTROL

Each transformer shall be provided with on load tap changers (OLTC) for varying its effective transformation ratio whilst the transformers are 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.

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

(a) It shall not be possible to operate the electric drive when the hand-operating gear is in use.

(b) It shall not be possible for any two electric control points to be in operation at the same time.

(c) Operation from the local, remote or supervisory control switch shall cause one tap movement only unless the control switch is returned to the off position between successive operations.

(d) All electrical control switches and the local operating gear shall be clearly labelled in an approved manner to indicate the direction of tap changing.

(e) The local control switches shall be mounted in the Tap Changer Motor Drive Unit.

In the above context "local" means at the transformer, "remote" means at the remote control panel and "supervisory" means via the SCADA system from the System Control Centre.

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 travel has not been reached.

Apparatus of approved type shall be provided for each transformer: -

(a) To give indication mechanically at the transformer and electrically at the remote and supervisory control points, of the number of the tapping in use on the transformer. The numbers shall range from l 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.

(b) To give an indication at the remote and supervisory control point that a "tap change is incomplete".

(c) Full supervisory control facilities are to be provided. A selector switch located at the local point is to 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 remote control panels, including the provision of auxiliary relays and indication units shall be included.

All indicating devices shall operate correctly at any voltage between the limits of 85 per cent and 110 per cent 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. "Drop down" tanks, which necessitate the provision of pits in the foundations, shall not be used.

Any enclosed compartment not oil-filled shall be adequately ventilated. A metal-clad heater shall be provided in the driving mechanism chamber and connected in parallel with the heater in the marshalling kiosk.

The oil in those compartments of the main tap changing apparatus which do not contain contacts used for making or breaking current shall be maintained under conservator head by means of a 50 mm inside diameter 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. This requirement shall not apply where mercury or vacuum switches are used to make and break current.

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 to each alarm station. 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 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., and 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".

The A.C control circuits shall operate at 110 V single phase to be supplied from a transformer having a secondary winding of 55-0-55 V with the centre point earthed through a removable link mounted in the marshalling kiosk. This supply shall be monitored and alarmed to provide "Tap Changer Control Supply Faulty" at the RCP.

The type of Tap Changer shall be preferably with vacuum type interrupter in the diverter switch (Vacutap - MR) and the OLTC /Drive Unit etc. are subject to the approval of the Authority.

Tripping contacts associated with any thermal devices used for the protection of tap changing equipment shall be suitable for making and breaking l50 VA between the limits of 30 volts and 250 volts a.c. and d.c. and for making 500 VA between the limits of 110 and 250 volts d.c.

The whole of the apparatus 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 with numbers corresponding to those on the leads attached thereto.

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 must also 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 is to be provided to allow easy removal of the tap changer for maintenance.

33.0 AUTOMATIC VOLTAGE CONTROL

Approved means shall be provided for automatically maintaining within adjustable limits a pre-determined voltage at the lower voltage busbars to which the transformer is connected. The AVR relay shall be TAPCON 240 (MR make) or equivalent in the technical features.

Unless otherwise specified, the equipment shall be suitable for control of up to three transformers and shall be so designed that where control of less than three transformers is initially required it shall be possible to extend the facilities to cover up to three transformers at a later date.

The method of voltage control to be provided shall be selectable from a two-position changeover switch having the following functions: -

Auto - Manual

When selected in Auto, the AVR is in service. When selected in Manual, OLTC operation is by means of push-button control. There shall be a common change over switch for the control panel having two selections - Supervisory/remote. When selected in Supervisory either the Auto or Manual modes can be selected from the 'Supervisory location' and, in the latter mode, raise/lower commands from System Control Centre shall initiate OLTC operation.

Logic shall be provided to automatically assign any one transformer as Master and the others as Follower, when they operate in parallel. Under such conditions, the Master transformer AVR or manual raise/lower commands alone (as determined by the selection of the Auto-Manual-System Control Centre switch) shall operate the Follower transformer OLTC. In case the master transformer trips, the follower transformers shall go to independent mode automatically. Necessary interlock wiring with LV side (33kV or 11kV) breaker shall be provided to achieve this requirement.

Local control shall be so arranged that it is necessary to have the remote selector on manual position and the Local/Remote changeover switch in the marshalling kiosk positioned on "Local" before operation is possible.

A static voltage regulating relay of an approved type designed to operate from a nominal energising voltage of 110 V shall be provided for each transformer. The no-load voltage level of the relay shall be adjustable between 90% and 110% of the nominal energising voltage independent of other adjustments. Unless otherwise specified the sensitivity of the relay shall be suitable for pre-determined adjustment at any value between the transformer tap step percentage and 1.5 times the transformer tap step percentage. The relay shall be insensitive to frequency variation within reasonable limits.

Associated with the voltage regulating relay shall be provided a time delay relay, the setting of which shall be adjustable between the limits of 10 and not less that 120 seconds.

Approved means shall be provided either at the remote control point or at a supervisory point, for selection of adjustment in the balancing voltage to give load shedding facilities, together with means for restoration. Unless otherwise specified three stages shall be provided, each stage representing a 5% reduction in load.

Provision shall be made on the tap changer for an additional set of tap position contacts to be provided for use in conjunction with the supervisory control scheme.

Compounding (line drop compensation) shall be an inherent feature of the regulating relay. Provision shall be made, within the tapping range, for voltage compounding to a maximum of 15% resistance and 15% reactance in suitable steps, with separate adjustment for each component. It shall be possible to reverse the reactive component by means of a changeover switch or links.

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

An out-of-step device shall be provided for each transformer, which shall be arranged to prevent further tap changing if after a definite time interval any transformer in one pair or group operating on "parallel control" is one tap out-of-step. The device shall not operate under any control arrangement other than parallel control.

A device shall also be provided for each transformer to render the automatic voltage control in operative if the control voltage falls below 80% of the nominal value with means of restoration of the automatic control with the application of at least 85% of the normal energising voltage. Unless otherwise specified the apparatus shall stay at the tap in use at the instant when the automatic voltage control is rendered in operative.

The following additional apparatus of an approved type shall be provided for each transformer.

(a) To give after a suitable interval an out-of-step alarm at the remote control point when the units of a pair or group of transformers arranged to operate in parallel are operating at different taps.

(b) A V.T. fail alarm at the remote point to give indication of a partial or complete failure of the voltage transformer supply to the voltage-regulating relay. The alarm shall be operative only when the transformer L.V. circuit breaker is closed and when the tap changer is on automatic control. The tap changer shall remain on the position at which it stands when the alarm is given, until such times as the control voltage is restored.

(b) LED/Digital meters suitably scaled to read secondary volts and to indicate tap position.

(c) All indication lamps shall be Neon/LED type.

A remote control panel shall be provided complete with all relays, voltage regulator, instruments, control switches and wiring. Unless otherwise agreed, a separate control panel shall be provided for each transformer. All the necessary repeat contacts for the supervisory system are to be provided.

33.1 Remote Tap Changer Control Panel

A remote tap changer control panel (RTCC) shall be provided with all accessories as indicated in the schedule of requirement. The control of transformer tap changer shall be arranged in local, remote or supervisory modes. The control switches shall be effective only when the control mode selector switches on both the local control cubicle and the remote control panel on in the remote position. The control switches on local kiosks and on the remote control panel shall be either lockable spade type or push button as required by the Authority.

It shall be possible to regulate both HV & LV voltages by selecting the respective secondary VT voltages. Means shall be provided in the RTCC Panels for selecting secondary voltage from either HV or LV Bus VTs by selector switch for regulating both HV or LV voltages depending on FEWA operational requirement.

Separate transducers (4 – 20mA) shall be provided for indication of Tap Position at Remote Tap Changer Panel and SCADA Control Centre.

Remote/supervisory selector switch shall be provided for tap change control panel. The panel shall be made of sheet steel of thickness not less than 2.5 mm. The panel and transformer shall be painted (light Grey – RAL 7032). Remote winding temperature indicator shall be supplied in RTCC panels.

The RTCC Panel dimension shall be 2300mm (height) x 800mm (width) x 600mm (depth). The RTCC indication lamps shall neon or LED type and shall be provided with lamp test facility.

34.0 TEMPERATURE INDICATING DEVICES AND ALARMS

All transformers shall be fitted with a dial type oil temperature thermometer with two maximum pointers and normally open switch contacts of micro switch type, which close at a predetermined setting, also initiating alarm/trip and cooler control.

Also, equipment shall be provided with a device for indication of winding temperature, (W.T.I), having a dial type indicator and a pointer to register the maximum temperature reached. These devices shall incorporate two normally open, electrically separate sets of switch contacts of the mercury bulb type which close at predetermined settings, one of which shall be used to initiate an alarm and the other to initiate tripping of a associated circuit- breaker.

Transformers having or being suitable for mixed or forced cooling, shall have additional 2 sets of normally open micro switch contacts on both oil and winding temperature indicators to control automatically the forced cooling plant.

The temperature indicators shall be housed in the marshalling kiosk, which shall be mounted in the transformer.

The electrically separate alarm and trip switch contacts of winding temperature indicators and oil temperature indicators shall be adjustable to close between 60°C and l50°C and re-open when the temperature has fallen by not more than 7°C.

The electrically separate switch contacts used to control cooling plant motors of mixed cooled transformers shall be adjustable to close between 50°C and l00°C and re-open when the temperature has fallen by l0°C. The electrically separate cooler control switch contacts shall be connected in parallel with corresponding contacts on other indicators.

All contacts shall be adjustable to a scale and shall be accessible on removal of the cover. Alarm and trip circuit contacts shall be suitable for making or breaking l50 VA between the limits of 30 volts and 250 volts A.C. or D.C. and of making 500 VA between the limits of 110 and 250 volts D.C. Cooler motor control contacts shall be suitable for operating the cooler motor contactors direct, or, if necessary, through an interposing relay.

The winding temperature indicators shall have their corresponding switch contacts paralleled.

The temperature indicators 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. It shall not be possible to operate the trip contacts without removing the temperature indicator cover.

The working parts of the instrument shall be made visible by the provision of cutaway dials and glass-fronted covers.

Connections shall be brought from the devices to terminal boards placed inside the marshalling kiosk.

35.0 GAS AND OIL ACTUATED RELAYS

Each unit shall be fitted with gas and oil actuated relay equipment having alarm contacts, which close on collection of gas, and tripping contacts, which close following oil surge or low oil level conditions.

Each gas and oil actuated relay shall be provided with shut off valve at both sides.

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

To allow gas to be collected at ground level, a pipe approximately 5 mm inside diameter shall be connected to the gas release cock of the gas and oil actuated relay and brought down to a point approximately l.35 metres above ground level, where it shall be terminated by a cock.

A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay.

A straight run of pipe work shall be provided for a length of five times the internal diameter of the pipe on the tank side of the gas and oil actuated relay and three times the internal diameter of the pipe on the conservator side of the gas and oil actuated relay.

The surge float contacts shall close at a rate of steady oil flow between the following limits. As far as possible the limits shall also be met when the relay is subjected to oil surge conditions produced by rapid opening of a lever operated gate valve.

The relays shall be so located as to be easy accessible from the top of the tank.

Oil Pipe Connection Relay Internal Diameter Steady Oil Flow	Operational Limits for Rising angles of l° to 9°
mm	(mm/s)
25	700 - 1,300
50	750 - l, 400
75	900 - l, 600

The gas collection contacts shall operate within the angle limits specified for tests.

The design of the relay mounting arrangements, the associated pipe work and the cooling plant shall be such that mal-operation of the relays shall not take place under normal service conditions.

The pipe work shall be so arranged that all gas arising from the unit shall pass into the gas and oil actuated relay. The oil circuit through the relay shall not form a delivery path in parallel with any circulating oil pipe, nor shall it be teed into or connected through the pressure relief vent. Sharp bends in the pipe work shall be avoided.

When a transformer is provided with two conservators the gas and oil actuated relays shall be arranged as follows: -

(a) If the two conservators are connected to the transformer by a common oil pipe, one relay shall be installed in the common pipe.

(b) If the two conservators are piped separately to the transformer two relays shall be installed, one in each pipes connection.

Connections shall be brought from the relay to terminal boards inside the marshalling kiosk.

36.0 DRYING OUT

All equipment shall be dried out at the Manufacturer's Works and the transport and method of erection thereof so arranged that unless otherwise approved they may be put into service without further drying out on Site. The method of drying out and the arrangements for transport and erection shall be subject to approval. Any subsequent drying out which may be necessary after taking over will generally be carried out on Site, and the Contractor shall submit to the Authority for their approval details of the method, which he recommends. These details shall be incorporated into the Maintenance Instruction Manual.

37.0 TRANSPORT

Shipping arrangements shall be subject to approval.

Irrespective of the actual method approved for transport to the individual sites, all equipment shall be suitable for transport with oil unless otherwise approved.

The transformer main body shall be transported with oil above the winding and nitrogen shall be filled above the oil and make up bottles of nitrogen shall be provided along with provision for monitoring and regulating gas pressure during transportation shall be provided.

All bushings, insulators, conservator vessels and breathers, radiators, wheels or other external parts may be removed for this purpose provided that they can be replaced on Site without necessitating drying out.

The Contractor shall be responsible for ascertaining the methods and limitations of transport to Site and designs affected by these factors shall be subject to agreement.

Impact recorder(s), capable of indicating all horizontal and vertical impacts, shall be rigidly attached to each power transformer.

Provisions must be made to ensure that these indicators are sealed, that they will be completely functional without interruption of indicated records during the entire period of shipment, including loading and unloading, and to ensure that the Authority will receive

clearly indicated data by breaking the seal. Instructions for interpretation of the recorded data shall be provided prior to shipment.

38.0 ERECTION

The completely assembled equipment shall be designed to withstand any of the following vacuum treatments: -

(a) Vacuum of 50 kN/m^2 applied to tank and cooling equipment when empty of oil.

(b) Vacuum of 70 kN/m^2 applied above oil level to tank and cooling equipment when full of oil.

(c) Vacuum of 70 kN/m^2 applied to tank only when empty of oil.

(d) Erection and testing of all 132/33kV and 132/11kV transformers shall be supervised by manufacturer's specialist, for which the cost shall be quoted separately as per B.O.Q. The erection and testing of the transformers shall be carried out at site under separate erection contract and erection contractor's Engineers/Technicians will assist manufacturer's specialist

Clear instructions shall be included in the Maintenance Instructions regarding any special precautionary measures (e.g. strutting of tap changer barrier or tank cover), which must be taken before the specified vacuum treatments can be carried out. Any special equipment necessary to enable the equipment to withstand the treatment is to be provided with each unit. The maximum vacuum, which the complete equipment filled with oil can safely withstand without any special precautionary measures being taken shall also be stated in the Maintenance Instructions.

After the equipment has been erected and completely filled with oil at Site adequate steps shall be taken in order to exhaust, as far as possible, all air, which may be trapped within the tank and pipe work.

Special care shall be taken not to injure galvanised or other specially treated surfaces during erection and also to prevent or remove any rust streaks or foreign matter deposited on galvanised surfaces during storage or transport or after erection.

39.0 TERMINAL BOARDS

Terminal Boards shall be Klippon type or similar.

Terminal Boards used in CT's circuits shall have shorting/disconnecting links to allow testing with circuit on load.

Terminal Boards used in trip and alarm circuits shall have an isolating link, which can be removed with circuit on load. 20% spare terminals shall be supplied for each type.

40.0 INSTRUMENT CABLES AND ACCESSORIES

Instrument cables mounted on the transformer are to be stood off from the transformer tank mounted on cable tray and well supported mechanically and protected from obvious possible damage. Cables are to be of MICS or Heat & Fire Resistant armoured types routed to the marshalling kiosk. PVC will not be accepted.

Glands are to be of brass compression types or MICS type fully weatherproofed and giving long life (rubber grommets will not be accepted).

All cables and accessories provided by the transformer manufacturer and fitted on to the transformer at the transformer works are subject to these requirements. The cabling and terminations from transformer accessories, cooling fans etc. up to local marshalling panel is included in the scope of the supply contract.

41.0 MARSHALLING KIOSKS

Where specified a marshalling kiosk shall be provided for transformer ancillary apparatus. Alternatively where specified the transformer ancillary apparatus shall be mounted in heated and ventilated chambers. Such chambers shall comply with the requirements relating to marshalling kiosks in so far as they are applicable.

Kiosks shall be divided into separate compartments for the accommodation of the following equipment: -

(a) Temperature indicators, cooler control "auto-hand" changeover switch and test links and ammeter for the winding temperature indicator circuits.

(b) Control and protection equipment for the tap change gear including an isolating switch in the incoming circuit capable of carrying and breaking the full load current of the motor and of being locked in the open position and interposing relays for supervisory control equipment etc.

(c) Control and protection equipment for the cooling plant including an isolating switch in the incoming circuit capable of carrying and breaking the full load current of all cooling plant motors and of being locked in the open position, together with means for isolating each motor circuit or group of motor circuits when a multi-fan arrangement is adopted.

(d) Terminal boards and gland plates for incoming and outgoing cables, except for the auxiliary supply cables to the tap change and cooler motors, which shall terminate at the base of compartments in which the supply is required.

Each compartment shall be provided with access doors at front and rear. All doors shall have "lift off" type hinges.

The temperature indicators shall be so mounted that the dials are not more than 1.6 metres from ground level and the door(s) of the compartment shall be provided with glazed windows of adequate size.

Facilities shall be provided to permit the temperature indicators to be removed from the kiosk without the necessity of passing the capillary tubing and bulbs through the various compartments. Mechanical protection shall be provided and sharp bends avoided where the capillary tubes enter the kiosk.

A metal-clad heater shall be provided controlled by a watertight single pole metal-clad rotary switch mounted on the outside of the kiosk and a fuse and neutral link inside the kiosk.

All three-phase relays, contactors, isolating switches and thermal devices shall be marked with the appropriate phase identification.

The kiosk shall be fitted with the following switch plug units mounted externally.

1 - Watertight 13 Amp 3-pin interlocked switch-plug, for an auxiliary single-phase A.C. supply. This switch-plug is to be connected to the kiosk heater supply circuit through a 16-amp fuse in the "live" lead and a link in the neutral lead.

2 - Watertight 4 pin interlocked switch-socket and plug unit for a 3-phase and neutral A.C. supply. This switch-socket is to be connected to the auxiliary supply through separate fuses and links and is to be of the current rating specified.

42.0 TRANSFORMER OIL

The transformers shall be supplied with first filling oil and 10% spare oil in separate non-returnable containers. The transformer oil shall be as per IEC 60296 (inhibited oil).

43.0 TESTS AT FACTORY

43.1 Routine Tests

General

All tests as per IEC 60076 standard shall be carried out at factory in the presence of FEWA Engineers.

(a) Dielectric Routine Tests - The windings and all connections of each transformer with its voltage control apparatus when completely assembled including bushing insulators or cable boxes, shall be subjected to all dielectric tests in accordance with the provisions of IEC 60076-3 except where these are varied by the following requirements: -

(i) Where single-phase induced voltage tests are used, the tests shall be applied to each phase in succession.

(ii) Insulation resistance tests on the windings shall be carried out by an approved method both before and after the high voltage tests. The average oil temperature shall be recorded.

(iii) A partial discharge measurement test shall be carried out before and after the HV test for the 132kV Transformers.

(b) Where the normal specified voltage ratio is adjusted to take account of anticipated voltage regulation, the value of test voltage selected shall be based on the tap appropriate to the highest system voltage.

(c) Other Tests - Each transformer shall be tested in accordance with IEC 60076 to prove compliance with the guarantees in respect of the following: -

- No-load Loss and Current
- Short Circuit Impedance and Load Loss
- Regulation
- Voltage Ratio and Phase displacement

- Vector group reference
- Winding resistance

(d) Oil samples to be taken before and after testing

(e) Magnetic circuit, associated insulation applied voltage test.

Immediately prior to the despatch of the equipment from the Contractor's Works the magnetic circuit shall be voltage tested for one minute at 2,000 volts A.C. between the core and earth. Alternatively the test may be a made with a 2,500-volt megger and the transformer considered to be satisfactory providing a reading in excess of 5 mega ohms is obtained.

(f) Calibration of hot spot indicator.

(g) Functional test of on load tap changer/motor drive unit.

(h) Functional test on parallel operation of transformers

43.2 Type Tests

The following tests are to be carried out on one transformer of each type and rating in the presence of FEWA Engineers:

(a) Temperature Rise Test - One transformer of each rating and voltage ratio with its own tank, voltage control apparatus and cooling apparatus shall be tested in accordance with the provisions of IEC 60076. Transformers with combined natural and forced cooling shall be tested at each specified rating and during these tests the accuracy of the oil and winding temperature indicators shall be determined. Unless otherwise agreed with the Authority, the temperature rise test shall be carried out with the transformer on normal ratio.

(b) Analysis of dissolved gases in oil before and after temperature rise test

(c) Dielectric type tests as per IEC 60076-3.

(d) Type test certificates for all other accessories are to be submitted for the approval of the Authority.

43.3 Special Tests

The following tests are to be carried out on one transformer of each type and rating:

(i) Dielectric special tests as per IEC 60076-3

(ii) Ability to withstand short circuit as per IEC 60076-5 (2000-07).

The ability to withstand the dynamic effects of short circuit shall be demonstrated by calculation and design considerations as per IEC 60076-5 clause No. 4.2.1. The validation of calculation and design consideration shall be made by comparison with a similar transformer or tests on representative

model as per guide line given in Annexure–A of the IEC for the identification of similar transformer shall be submitted.

(iii) Capacitance Test - The capacitance between windings and to earth shall be measured by an approved method.

(iv) Measurement of zero sequence impedance - One transformer of each rating and voltage ratio with its own tank, voltage control apparatus and cooling equipment shall be tested in accordance with the provisions of IEC 60076.

(v) Measurement of harmonics of the no load current.

(vi) Power consumption of auxiliary cooling plant.

(vii) Measurement of power factor.

(viii) Noise levels with and without force cooling operating (as per IEC 60551)

43.4 Tests on Voltage Control Equipment

43.4.1 Routine Tests

(a) Duty Cycle - Mechanical Test. All switching apparatus, when completely assembled, shall be operated ten times in the normal manner through the complete cycle with the transformer unexcited. This shall be followed by one operation in the normal manner through the complete cycle when the transformer is energised at normal volts on open circuit.

(b) Dielectric Tests - Auxiliary circuits shall withstand the dielectric tests specified in IEC 60214.

(c) Operational Tests - The correct functioning of all control devices including limit switches and mechanical end stops shall be demonstrated.

43.4.2 Type Tests on Voltage Control Equipment

In accordance with the requirements of IEC 60214. The power frequency withstand voltage test to be applied between electrically adjacent contacts and connections shall be proposed by the Contractor depending on the design of tap changer proposed and shall be subject to approved by the Authority.

43.5 Routine Tests on Magnetic Circuits

After assembly each core shall be pressure tested for one minute at 2,000 volts A.C. between all bolts, side-plates, structural steelwork and the core.

43.6 Routine Tests on Cable Boxes and Disconnecting Chambers

(a) Oil Leakage - All cable boxes and disconnecting chambers shall be tested with oil with a viscosity not greater than that of the appropriate grade of insulating oil when at a temperature of l5°C at a pressure of 70 kN/m^2 for l2

hours during which time no leakage shall occur nor shall there be any permanent set when the pressure is released.

(b) High Voltage - Cable boxes and disconnecting or sealing end chambers shall withstand the following voltages for l5 minutes:-

2E kV D.C or 4E / 3 kV A.C

Where E is the rated nominal rated system voltage between phases.

43.7 Routine Tests on Tanks

(a) Oil Leakage Test - All tanks and oil-filled compartments shall be tested for oil tightness by being completely filled with oil of a viscosity not greater than that of the appropriate grade of insulating oil at a temperature of l5°C and subjected to a pressure equal to the normal pressure plus 35 kN/m^2. This pressure shall be maintained for a period of not less than 24 hours, during which time no leakage shall occur.

43.8 Type Tests on Tanks

(a) Vacuum Test - One transformer tank of each unit shall be subjected when empty of oil to a vacuum of 70 kN/m^2 below atmospheric pressure. The permanent deflection of flat plates after the vacuum has been released shall not exceed the value specified below.

Horizontal Length of Flat Plate mm	Permanent Deflection mm
Up to 750	5

Horizontal Length of Flat Plate mm	Permanent Deflection mm
Over 750 to 1250	6.5
Over 1,250 to 1,800	8
Over 1,800 to 2,000	9.5
Over 2,000 to 2,300	11
Over 2,300 to 2,500	12.5
Over 2,500 to 3,000	16
Over 3,000	l9

(b) Pressure Test – one transformer of each unit together with its radiators, conservator vessel and other fittings shall be subjected to a pressure corresponding to twice the normal head of oil or to the normal pressure plus 35 kN/m^2 whichever is the lower. The permanent deflection of flat plates after the excess pressure has been released shall not exceed the figure specified in the Vacuum Test.

(c) Pressure Relief Device Test - Where required by the Authority one pressure relief device of each size shall be subjected to increasing oil pressure and

shall operate before reaching the test pressure specified. The operating pressure shall be recorded on the test certificate.

43.9 Routine Tests on Gas and Oil Actuated Relays

The following tests shall be made on relays when completely assembled and ready for mounting as in service. Where oil is referred to it shall have a viscosity not greater than that of the appropriate grade of insulating oil at 15°C.

(a) Oil Leakage - The relay when filled with oil shall be subjected to an internal pressure of 140 kN/m^2 for 15 minutes. No leakage shall occur either from the casing or into normally oil-free spaces, such as floats, within the casing.

(b) Gas Collection

(i) The relay shall be mounted in a straight run of pipe work such that the provisions of the Specification are satisfied with regard to length and size on both the tank and conservator sides. 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 reading at the time of contact closing shall be stated in the test certificate. The low oil level/surge 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 free of oil.

(ii) 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 l3 degrees to the horizontal.

(iii) With the relay mounted at a falling angle of l6 degrees to the horizontal and full of oil, the gas collection contacts shall be open.

(c) Oil Surge - With the same mounting condition as in test (b) (i) and with the relay full of oil at approximately 15°C, the surge contacts shall close within the steady oil flow limits specified in the Specification. This operation shall not be adversely affected when the gas collection contacts have already closed and gas is escaping freely.

(d) Dielectric Test - 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.

43.10 Sample Tests on Gas and Oil Actuated Relays

At the discretion of the Authority any part or the whole of the following tests shall be made:

With the mounting conditions prescribed in test (b) (i) the mounting angle shall be varied within the rising angle limits of 1° and 9° and tests made in accordance with those prescribed in tests (b) (i) and (c). It is permissible for this test to be combined with tests (b) (i) and (c).

44.0 SUBMISSION OF DRAWINGS/DOCUMENTS

The following drawings shall be submitted for review/approval.

1) General outline arrangement drawing with dimension and details of accessories/components/panels.

2) Rating and connection diagram plate

3) Drawings of valve schedule plate

4) Schematic diagram of cooler controls

5) Schematic diagram of tap changer controls

6) Protection and annunciation schemes

7) Drawing to internal assembly with part identification and dimensions and clearances.

8) Drawings of cable boxes and termination arrangement

9) Drawings of foundation details

10) Drawings of earthing of magnetic circuits

11) Drawings of transportation dimensions

Six (6) sets of “As Built” drawings (Hard copies) shall be submitted. Soft copies in 6 CD’s shall be submitted (ie. 6 sets)

45.0 APPLICABLE STANDARDS

Except where modified by this specification, the transformers/accessories shall be designed, manufactured and tested in accordance with following international and British Standards/equivalent.

IEC	BS	
60076		Power Transformers
60551	6056	Methods of measurement of transformer and reactor sound levels.
64360		Weldable structural steel
60061		Threads for light gauge copper tube and fittings
63600		Steel pipes and tubes for pressure purposes

64504		Flanges for pipes, valves and fittings
60529	EN60529	Enclosures for electrical apparatus
60214	4571	On-load tap changers
60137	233	Bushings for alternating voltages above 1000 V.
60233	4963	Tests on hollow insulators.
60296	148	Insulating oils for transformers and switchgear
60422		Maintenance guide for insulating oils in service
60542		Application guide for on-load tap changers
60354	CP1010	loading guide for transformers
60606		Application guide for power transformers..