Appendix A0

Main transformers - Common specifications

CONTENTS:

1. SCOPE

These provisions cover oil-insulated power transformers with two or more main windings. They concern the technical execution of transformers with or without voltage regulation, including standard fittings, testing, commissioning and documentation.

They apply to all invitations to tender and orders for transformers over 2 MVA and voltages over 3 kV. To the extent that they can be used, the provisions also apply to reactors.

1.1 Standards

In general, a transformer shall meet the requirements of current IEC standards for power transformers, with the additions made in these provisions, unless special exemption is given. Exemption may be granted from the following standards in the individual invitation to tender.

Reference is made to the following standards:

Ecodesign Tier 2

IEC 60076, 1	Power Transformers – General
IEC 60076, 2	Temperature rise
IEC 60076, 3	Insulation levels, dielectric tests and external clearances in air
IEC 60076, 4	Guide to lightning impulse and switching impulse testing
IEC 60076, 5	Ability to withstand short circuit
IEC 60076, 7	Loading guide for oil-immersed power transformers
IEC 60076, 8	Application guide
IEC 60076, 10	Determination of sound levels
IEC 60137	Bushings for alternating voltages above 1000 volt
IEC 60354	Loading guide for oil-immersed transformers
IEC 60551	Measurement of transformer and reactor sound levels.
IEC 60616	Terminal and tapping markings for power transformers.

Oil

IEC 60296	Specification of unused mineral insulating oils for transformers and switchgear.
IEC 60422	Supervision and maintenance guide for mineral insulating oils in electrical equipment.
IEC 60567	Guide for the sampling of oil and gases from oil-filled equipment and for the analysis of free and dissolved gases.

IEC 60599	Mineral oil impregnated electrical equipment in service – Guide to the interpretation of dissolved and free gases analysis.

Supplements (if relevant):

IEC 60289	Reactors
IEC 60076, 6	On-load tap-changers
IEC 60542	Application guide for on-load tap-changers

2. TECHNICAL DATA

The technical for each specific transformer is listed in Appendixes A1-A6.

3. OPERATING CONDITIONS

3.1 Erection

Transformers made for erection outdoors must function reliably in the Norwegian outdoor climate with temperatures of between -40 °C and +40 °C.

Particularly unfavourable local climatic conditions such as air pollution or cooling water and special temperatures will be notified from time to time.

3.2 Operating voltage

3.2.1 Transformers

The transformers shall be capable of operating with the rated output at **±5%** primary voltage without the core or other parts being damaged by overheating or abnormal vibration. Requirements beyond this will be stated.

Similarly they shall withstand continuous no-load operation with the primary voltage increased by 10%. The no-load current with the primary voltage increased by 10% shall be stated.

3.2.2 Network connection transformers

For network connection transformers with a tertiary winding used in connection with phase compensation account must be taken of the voltage increase that occurs in the tertiary winding when reactive output is given off to one or both of the connected networks and the rated voltage is maintained.

If a rotating phase compensator is to be used the client will state its rated voltage so that the correct rated voltage can be calculated for the transformer's tertiary winding.

3.3 Insulation level at neutral

The transformer shall be designed for shock testing with insulation levels in accordance with the above-mentioned standards.

Networks with a system voltage of 145 kV or lower shall be able to operate with an insulated neutral. Transformer windings for these system voltages are therefore executed with full insulation.

3.4 Load capacity

3.4.1 Network connection transformer

Network connection transformers will usually be rated for mixed regulation. The client will specify the desired full load – and any no-load voltages at both ends of the range of full rated output. For lower voltages (e.g. -10%) the performance is reduced in proportion to the voltage. The desired step size is usually between 1% and 2%.

3.4.2 Multiple-winding transformer

Multiple-winding transformers shall be capable of being loaded with full current in all windings simultaneously without the permitted overtemperature being exceeded. Exceptions from this rule will be stated from time to time.

If the client has stated a number of determining load cases the permitted overtemperature shall be maintained in all these cases and the rated output of the individual windings shall be calculated from the design currents.

3.4.3 Overload capacity

For assessment of overload capacity state, the calculated winding/oil temperature differences for each individual winding at specified currents, as well as the average oil temperature at a specified load state, total loss and type of cooling.

To avoid restrictions on the overload capacity, conductive parts other than the actual winding – such as bushings, connectors, tap changers and integrated current transformers – shall be designed for a current **40 %** higher than the rated current.

3.5 Short-circuit strength

When designing the transformers, it may be assumed that the short-circuit and earthing currents are of the duration specified in the standards and that the asymmetrical peak value is 2.55 times the stationary effective value.

The transformers shall be guaranteed to withstand – without degradation – the short-circuit and earthing currents that may arise in the windings under these circumstances.

3.6 Noise

Requirements of the upper limit for noise beyond the standard will be specified in the individual case.

3.7 Losses

The Contractor shall pay for the share of the losses that exceeds the guaranteed values. This penalty will vary from case to case.

4. EXECUTION OF THE WORK

4.1 In general

The transformers shall be oil-insulated with an oil conservator and air-dryer. The materials used shall be those deemed best for the purpose for which the equipment is being used.

4.2 Oil

Inhibited naphthenic oil made by Nynas Nytro 10XN or similar be used unless specified otherwise.

4.3 Core

The sheet quality and induction shall be selected such that there is no troublesome hum or excessive overtemperatures that could be damaging to the sheet insulation or to neighbouring oil and insulating materials. It shall have a fixed mechanical structure, scarf joints and an adequate number of cooling channels. The structure shall not be degraded as a result of the temperature fluctuations that can occur during operation.

Press beams, core bandages and bolts shall be insulated against the core sheet for a test voltage of 2 kV and shall not be capable of forming closed current paths.

The individual sheet packages shall have a secure electrical connection without forming closed current paths, as shall the press parts. They shall be earthed so that no unearthed part can cause discharge.

The core shall be removable from the tank for inspections/service and shall have suitable lifting lugs for this purpose.

4.4 Windings

Information on the insulation level of the individual transformers' windings shall be stated in the tender.

The conductor material shall be electrolytic copper and the insulation material shall be high quality paper and pressboard. If the insulation class and test voltage are not stated in the invitation to tender, the winding shall be insulated in accordance with the relevant standards.

The cooling channels of the winding shall be executed so as to allow oil to flow though freely and no pockets shall form in which oil or gas could accumulate.

The windings shall be carefully dried and pre-shrunk so that they cannot settle during operation or as a result of short circuits. Supports and winding taps shall be designed for the short-circuit forces occurring.

All the CTC conductor in the windings shall be enamel covered.

4.5 Transformer tank

The transformer tank is made of easily weldable steel plate. The tank and cover shall withstand 100% vacuum and all other stresses that may arise during transport and lifting, as well as pressures that can occur if there is a fault in the transformer.

It shall be absolutely oiltight in respect of hot transformer oil. Leaking welds shall be chiselled off and rewelded. Sealing shall not be approved.

The tank shall be equipped with the necessary grips for transport, lifting straps, towing eyelets and equipment for jacking up the complete transformer. The jacking devices (8 pcs) shall be located 400 mm above the tank bottom.

There shall be two earthing points in the bottom of the tank, placed diagonally opposite each other. The size of the earth connections will be specified in the individual case.

The transformer tank shall be designed such that gas cannot accumulate in undesirable locations and prevent the gas from passing to the gas relay.

All gaskets used on the transformer must be of oil-resistant material.

All lifting/jacking points must be marked.

4.6 Cover

The cover shall be designed such that any gas can pass freely to the gas relay without accumulating in pockets on the underside. The cover shall have a visible fall away from the centre line of the longitudinal axis: approx. 10-15 mm per linear metre.

All bushings and stubs in the cover shall be built up above the surface of the cover to avoid water lying on the cover. All oil pipes and cable bridges on the cover and tank shall be fitted a minimum of 10 cm above the base.

Bushing devices shall be equipped with suitable air lines to the gas relay.

The cover shall have the necessary inspection and connection hatches so that the bushings can be replaced without having to lift off the cover.

Transformers shall be fitted with runners for mounting guard rails. Removable rails shall be included in the Deliverables.

4.7 Conservator

The oil conservator shall have an expansion volume at least taking into account the temperature range specified in the section on operating conditions.

The conservator shall have a hatch for inspection and cleaning as well as lifting lugs.

If the transformer has oil-filled cable boxes (bushings) the conservator shall have sufficient clearance relative to these.

A rubber bladder for the conservator shall be offered as an option for all transformers. The lifetime of these shall be stated. The tightness of the rubber bladder should be verified, either through factory tests or by mounting and pressurizing the rubber bladder with an overpressure of approximately 0.1 bar before shipment and checking the pressure to still be intact after arrival on site.

The conservator shall be removable.

4.8 Underbody

The transformer shall be equipped with an underbody with flanged wheels or bogeys for travelling longitudinally and transversely. The underbody shall be strong enough for the transformer to be transported on its own wheels.

The track width will be specified in the individual case if desired.

4.9 Surface treatment, corrosion protection

The transformer tank, cover, conservator and other iron parts shall be sandblasted internally and externally.

The inside shall be painted with a coat of oil-resistant lacquer or paint immediately after sandblasting.

The outside shall be primed with a zinc chromate-based primer and at least 2 coats of weatherproof topcoat shall be applied.

The colour shall be approved by the client in advance.

The total thickness of the layers of primer and topcoat shall be at least 200 µm measured with a device such as an Elcometer. If erected outdoors 240 µm shall be required.

Sharp edges shall be rounded off with a radius of 2 mm.

Cover screws and other external screws, washers and nuts shall be in acid-proof or stainless materials. Galvanised surfaces, apart from radiators/coolers, shall be painted with topcoat.

4.10 Bushings

Unless stated otherwise, the bushings shall be executed to the same insulation class and test voltages as the associated winding taps.

With a view to stocks of spare parts the fewest possible number of bushing variants shall be used for each voltage class. To allow the client to check this, bushing types and their data shall be stated in the tender and included in all dimensioned drawings.

The bushings shall be phase-marked using raised letters which are welded or screwed permanently to the cover and which are not also removed when the bushings are dismantled. Marking shall be carried out in accordance with IEC standards.

The bushings top shall be of fine threads type.

4.10.1 Oil/air bushings

Oil/air bushings for voltages over 36 kV shall be terminated with a smooth cylindrical bolt in copper. Bolt dimensions:

Ø30 x 125 for up to 1250 A

Ø60 x 125 for 1250 A - 5000 A.

For test voltages over 170 kV the bolts shall be Ø60 x 125 for all currents.

The temperature at taps with associated connection parts shall not exceed 85 ºC at an ambient temperature of max. +40 ºC even at the highest permitted operating current (taking into consideration overload in accordance with 0).

4.10.2 HV-Connex pluggable connection system (72,5-170kV)

If applicable, the size for the HV-Connex socket should be:

Up to 145kV: size 6
170kV: size 6

The type and size of connection socket shall be controlled by the vendor to ensure correspondence with the transformer design and ratings. This is a mandatory part of the design review meeting.

Equipment for draining water should be delivered if the plug also is in the delivery.

4.10.3 MV-Connex pluggable connection system (10-52kV)

If applicable, the size for the MV-Connex socket should be stated. The type and size of connection socket shall be controlled by the vendor to ensure correspondence with the transformer design and ratings. This is a mandatory part of the design review meeting.

Equipment for draining water should be delivered if the plug also is in the delivery.

4.10.4 Oil-SF_6 bushings – not allowed

Oil-SF_6 bushings must have a connection to suit the SF_6 equipment supplier. The SF_6 equipment generally requires narrower tolerances for the connecting flanges and must be checked carefully.

4.10.5 Cable connection

In the case of cable connection with direct cable entry into the transformer: in view of the conductor temperature in the cable the temperature of the oil surrounding the cable termination must be lower than that required by the standards.

If the cable is to be tested with alternating voltage, full line voltage to earth for 15 min., the transformer's neutral must be insulated to withstand phase voltage to earth for 3 x 7.5 min.

4.11 Tap changer

The tap changer and driving mechanism must meet the requirements set out in IEC 214, on-load tap-changers. A type testing report for the tap changer shall be forwarded in good time prior to delivery of the transformer. The transformer supplier shall select the tap changer such that it withstands all the stresses to which it may be exposed during testing and operation of the transformer. This requirement may be reduced or waived if the tap changer manufacturer is able to document that the limits for temperature rise given in IEC 214 section 8.1 are not exceeded at a current equal to the rated current of the tap changer.

The tap changer and driving mechanism must undergo the routine testing specified in IEC 60076-1 together with the transformer.

4.11.1 Voltage regulation

Unless agreed otherwise, equipment for automatic voltage regulation with active co-compounding and reactive counter-compounding shall also be supplied. In addition, a remote control reversing switch shall be supplied as well as one electric indicator instrument for mounting in a board. The instrument shall normally be 96 x 96 mm for recessed fitting, type Centrax with a grey frame.

4.11.2 Equipment

The tap changer shall be capable of being controlled by push buttons or manually using a handle on the driving mechanism, as well as automatically from the control room. The driving mechanism shall be placed such that it can be used by the personnel during operation.

In addition, the tap changer shall be supplied with a counter for the number of changes and a measured value converter for settings -N to +N (4-20 mA).

The tap changer shall be equipped with a rapid pressure relay and separate conservator tank with its own breather.

4.12 Cooling system

4.12.1 ONAN cooling

The radiators shall be hot-galvanised or in stainless material. They shall be capable of being dismantled and equipped with radiator valves that allow them to be used with an oil-filled transformer. During transport the radiators must be fitted with tight-sealing blank flanges to prevent any dirt or moisture penetrating.

4.12.2 ONAN/ONAF cooling

Fans fitted on the radiators to provide additional cooling must be shielded from accidental contact with rotating parts.

The fans shall be controlled from a control cabinet as described in section 4.12.6.

4.12.3 OFAF cooling

Heat exchangers for forced oil/air shall normally be mounted on the transformer tank for vertical air flow. Each transformer shall have at least two independent cooling assemblies so that it can be operated with at least 70% output if one cooling assembly is temporarily unavailable. Permitted overtemperatures according to IEC standards must not be exceeded.

Each cooling assembly shall have shut-off valves towards the tank, an oil flow indicator that gives a signal when the oil flow in the cooling assembly gets too low and cocks at the highest and lowest point for oil replenishment, emptying, flushing and venting.

The heat exchangers shall be controlled from a control cabinet as described in section 4.12.6.

4.12.4 Oil pumps

The oil pumps used for forced oil-cooled transformers shall be of the assembled glandless type.

There shall be circulation relays for oil. A simple electronic type is acceptable.

In those cases where the coolers are placed separately from the transformer, steel expansion joints must be inserted in the connecting pipes between the transformer and the cooling system. Rubber compensators are not permitted.

4.12.5 Control cabinet

Transformers with ONAF, OFAF and OFWF cooling shall as a general rule have 2 separate control cabinets for controlling cooling. One cabinet may be acceptable by agreement. If erected outdoors the cabinets shall be rainproof (IP 55) and shall be fitted on the transformer with vibration dampers. The cabinet shall be protected by a bent sloping roof with a drip lip to prevent ice forming on the cabinet when water runs off the transformer cover.

In occasional cases separate erection of the cabinets on their own stands or in their own room will be required. To ease access the cabinets should then have doors on both the front and back.

All cable entries shall be located in the underside of the cabinet.

Each cabinet shall contain:

- Main fuses for the total alternating current supply to the cabinet.
- Fuses, contacts, motor protection and operating indicator lamps for each pump or fan motor that is controlled from the cabinet.
- Elapsed hours counter for operating time of fans in the case of air-cooled transformers and for pumps in the case of water-cooled transformers.
- Control current circuits, the necessary relays and equipment for automatic control of pumps, fans and valves.
- One operating mode switch per cooling assembly: on or off or automatic start/stop using thermometer contacts.
- One switch for selecting whether the pump motors are controlled automatically or in operation continuously (summer/winter mode). Applies to cooling type OFAF only.
- Thermostatically controlled heating element to prevent condensation in the cabinet plus cabinet lighting with a door switch.
- Double socket outlet.
- The necessary connection terminals of the Weidemüller or Phoenix type.
- There shall be only one conductor connected to each terminal.

4.13 Equipment for monitoring and protection

The transformer shall be supplied with the following equipment for monitoring and protection.

4.13.1 Gas relay

A gas relay shall be fitted in the connecting pipe between the transformer and oil conservator. It shall have contacts for a signal for slow gas generation and for responding to a rapid flow of oil or gas.

The gas relay shall have shut-off valves on both sides so that the relay can be removed for maintenance.

The gas relay shall be placed in a location where it is accessible for inspection while the transformer is being under loading.

4.13.2 Oil level indicator

The oil conservator shall be equipped with an oil level indicator for high and low oil levels. The oil level shall be able to be read from the cell floor, ideally using a separate indicator instrument placed in an easily accessible place on the transformer tank, or by angling the oil level indicator on the conservator.

4.13.3 Dryer

The oil conservator shall be provided with an air-dryer with an oil lock. The device shall be filled with the necessary drying agent that can easily be inspected.

Self-dehydrating breather shall be offered as an option for all transformers.

4.13.4 Pressure Relief Device

The transformer tank shall be supplied with one pressure relief device with pipe down to oil pit.

4.13.5 Temperature monitoring

The transformer shall have the following temperature monitoring equipment placed in pockets on the cover.

- 1 indicator thermometer with signal contacts for measuring peak oil temperature. A thermometer made by Kihlstrøm, or similar shall be used. Self-cooled transformers require 2 signal contacts, while transformers with thermostatically controlled cooling require 4 signal contacts.

- 1 resistance thermometer for remote measurement of the peak oil temperature (Pt–100).

To indicate the winding temperature in the hottest winding the transformers shall be equipped with one or more current transformer and compensated thermometer pockets.

- 1 compensated pocket containing an indicator thermometer to indicate the winding temperature. A minimum of 2 contacts are required.

- 1 compensated pocket containing a resistance thermometer for remote measurement of the winding temperature.

In the case of regulating transformers and in particular in the case of multiple-winding transformers the winding with the highest temperature may vary depending on the load state. In such cases more current transformers with compensated pockets shall be installed by agreement.

The thermometers shall be fixed on fixing plates protected by a bent sloping roof with a drip lip to prevent ice forming on the thermometer when meltwater runs off the transformer cover.

Optical fibres for direct winding temperature measurement shall be offered as an option for all transformers. Solution should contain at least two measures for hot-spot temperature (one on each side of the warmest place). Optical fibres shall be terminated in the control cabinet for future connection of measurement unit.

4.13.6 Protection of tap changer

The protection recommended by the tap changer supplier shall be used to provide protection from gas development and pressure increases in tap changers and as oil level relays.

4.13.7 Earthing

There shall be an earthing terminal on each side of the bottom of the tank for earthing purposes. These shall have at least one clamping insert and two clamping screws, with clean contact surfaces. Rating of earth connections to be specified in the individual case.

4.13.8 Cabinet for signal lines

Lines for the transformers monitoring devices shall lead to a separate cabinet with terminals for forwarding to the control room.

The insulation of the signal cables and contacts must withstand a 1-minute voltage test at 2 kV eff, 50 Hz. The conductor cross-section shall not be less than 2.5 mm^2

Cu. For current transformers 4 mm² Cu shall be used. Series terminals to be used for current measurement shall be of type SAKT 2 KrG (Weidemüller) or equivalent with approved joining and short-circuiting facilities.

4.14 Other equipment

4.14.1 Valves

Ball valves are preferred, but butterfly valves can be used at the radiators. The valves must be of non-corrosive material (e.g. acid resistant, stainless steel or bronze). All valves shall be easily accessible when the transformer is de-energized. The valves shall be clearly marked “Olje inn” (oil in) and “Olje ut” (oil out) and should be placed in an easily accessible place where there will be no problems with regeneration of the oil.

- 1 valve with a dimension of 1½” at the bottom of the transformer tank for connection of oil filter, for oil replenishment and draining.
- 1 sampling valve suitable for the purpose located slightly above the bottom of the tank to avoid bottom sludge/water in the oil sample.
- 1 valve with a dimension of 1½” on the cover, located diagonally opposite the first valve mentioned, for connection of oil filter.
- 1 valve with a dimension of 1½” in the bottom of the oil conservator for oil replenishment and draining and for oil samples.
- 1 shut-off valve in the pipe connection between the transformer tank and oil conservator.
- shut-off valves to the transformer tank for each individual cooling circuit or for each individual radiator, and valves at the highest and lowest point of each separate cooling circuit for filling, venting and flushing though.
- necessary valves on the tap changer and cable boxes for filling, emptying, venting, and for sampling.
- valves for oil/gas monitoring/analysing should be placed where maximum flow of oil in the transformer occurs. Ideal locations could be on cooling radiator pipelines or somewhere on the mid-section of the main tank wall, at least 1,0 m above the bottom of the tank. The size of valves should be 1½” NPT or larger and without any pipe between the tank wall and the valve. The valves should be of ball type that allows sensor head to be shoved through the valve into the flowing oil. This is to prepare the transformer for solutions typically provided by sub-vendors such as Vaisala, ABB, GE or similar.

4.14.2 Ladder

If required, each transformer shall be supplied with a permanently fitted ladder for checking the gas relay and oil level indicator. These checks shall be able to be carried out during operation at no risk to the personnel. The same ladder, or an another solution, should give access to the transformer top.

The ladder shall be fitted with a locking access barrier to the cover. The ladder shall be placed so as to allow the gas relay to be checked during operation without risk and without unlocking the barrier.

4.14.3 Tools

If operation and maintenance of the transformer or its fittings require special tools or auxiliary equipment (e.g. gas relay testing device) this shall be supplied if such equipment is not already present at the station concerned from earlier deliveries.

4.14.4 Spare parts

To be specified as necessary.

4.15 Marking of transformer

All rating plates and marking of fitted equipment shall be in Norwegian and the text shall be approved by the client. The plates shall be of the engraved or stamped type and shall be securely fixed.

In addition to the transformer and OLTC rating plate, a location plate of the transformer’s valves should be mounted on the transformer.

4.16 Cable

All internal signal and power cables used on transformer should be of halogen -free type.

5. INFORMATION WHEN TENDERING / GUARANTEES AND TOLERANCES

In addition to the transformer's main data, tenders for transformers shall contain information on no-load losses, load losses and reactances. In addition, dimensioned drawings shall be provided stating dimensions and information on weights.

Where a financial penalty for losses is specified the tolerances of this shall be ±0%. Otherwise the tolerances specified in IEC 60076-1 chapter 9 –Tolerances shall apply. The Contractor shall pay a penalty for the share of the losses that exceed the guaranteed values.

5.1 Guaranteed values

The following values shall be guaranteed in the transformer tender:

5.1.1 No-load loss

The no-load loss/exciting current shall be guaranteed at the printed nominal voltage.

5.1.2 Load loss, short-circuit voltage

Load losses shall be guaranteed.

Short-circuit voltages shall be stated.

5.1.3 Pumps and fans

The power consumption of the cooling system's pumps and fans shall be stated and guaranteed.

5.1.4 Noise level

If requested in the invitation to tender the noise level of the transformer and cooling system shall be stated and guaranteed with reference to a measurement method in IEC 60551.

5.2 Information about weights

The transformer tender shall contain the following information regarding weights:

- Weight of complete transformer
- Transport weights
- Weight of oil
- Weight of active part
- Weight of active core sheet
- Weight of active conductor material

5.3 Information about dimensions

Each transformer tender shall be accompanied by dimensioned drawings of the complete transformer including the cooling system and fittings. The following dimensions shall be stated in the drawing:

- Main dimensions of complete transformer. If the client supplied cell drawings it must be able to be documented that the transformer offered can be placed in the cell and that it can be transported along transport routes and door openings.
- Position of any wheeled underbody relative to the centre line of the transformer, and track width longitudinally and transversely.
- Itemised list of the transformer's equipment.
- Transport dimensions.
- Required height (to crane hook) for lifting the core out of the tank.

5.4 Information about the transformer's fittings

The following information is required concerning any fittings on the transformer:

5.4.1 Tap changer

Tap changer; make, model, insulation level and current. A description shall accompany the tender.

5.4.2 Bushings

Bushings; make, model, insulation level, creep current path and current.

5.4.3 Cooling system

For cooling type OFAF state air requirement, and for cooling type OFWF quantity of cooling water, as well as the dynamic counterpressure of the water coolers on the water side.

5.4.4 Monitoring equipment

The tender shall include a list of the transformer's monitoring equipment.

5.5 Other information

5.5.1 Windings

Description of the windings, type and sequence starting from the cores outwards, current densities in the individual windings at nominal current, as well as location of taps.

5.5.2 Insulation

Description of the insulating material, wire insulation and impregnation for the individual windings.

The transformer shall have equipment to take samples of the insulation.

5.5.3 Oil

Statement of oil type and quality. Addition of oxidation inhibitor.

5.5.4 Tank

Description of the transformer tank stating the plate thickness of the sides, bottom and cover.

5.5.5 Oil conservator

Description of oil conservator.

5.5.6 Corrosion protection

Description of surface treatment/corrosion protection.

5.5.7 Other

Information on the individual windings' overtemperature over mean oil, and overtemperature in top oil and middle oil over cooling medium (air or water) at

nominal load. For cooling type OFAF state also the same temperatures in the event of loss of a cooling assembly with continued nominal load.

6. DESIGN REVIEW AND TESTING

6.1 In general

Prior to delivery the transformer shall undergo acceptance testing, mainly in accordance with the relevant IEC standards. The testing shall be carried out in the Contractor's workshop and in the presence of a representative of the client unless the client has expressly renounced this right. The Contractor shall therefore give notice of the date of testing in good time.

All testing and measurements shall be documented in reports which shall be signed by the representative, who shall immediately be given a copy of the report. Identification numbers for the instruments used and their constants shall be stated in the provisional report so that a later final report can be checked.

The Contractor shall be able to document that the instruments and measuring transformers used were recently calibrated against the standard and that there are established routines for checking the instruments.

Before acceptance testing is carried out the Contractor shall have checked, adjusted and function-tested all fittings, cooling systems, relays, etc. Any core bandages and bolts shall be tested momentarily at 2 kV. Provisional tests and checks shall also be carried out and documented (as a minimum, control of transformation and connection group) so that faults and shortcomings are discovered and remedied.

6.2 Design review

Before the design and layout of the transformers is finally decided, a design review meeting shall be arranged. As a result of the meeting, and among other things, a list of materials selected for use in the transformers shall be set up, including its accessories, with make and type designations. The design review meeting shall be included in the transformer price.

6.3 Acceptance testing

The following checks and tests shall be performed during acceptance testing in the presence of the client's representative:

6.3.1 Routine testing in accordance with IEC 60076.

6.3.2 Dimension checks

Checking of the transformer data, dimensions, bushings, fittings, positioning and that it conforms to the contract and dimensioned drawings.

6.3.3 Pressure check

Check that the tank, oil conservator, bushings, cooling systems, cocks and gaskets are tightly sealed in respect of hot transformer oil at 0.25 atm. pressure over the cover. Prior to the inspection the transformer shall have been kept under this pressure for a minimum of 24 hours. The pressure must not be removed until the inspection has taken place.

6.3.4 Resistance and temperature measurement

Measurement of winding resistance for all windings and in all possible tap changer or switch positions. Simultaneously with resistance measurement the temperature of the bottom oil and top oil shall also be measured. The winding temperature shall be determined as the mean temperature of these two.

6.3.5 Measurement of short-circuit voltage and load loss

The losses shall be measured according to the three wattmeter method. Precision wattmeters shall be used, where cos ø = 0.05 or cos ø = 0.1. Readings shall be taken at three different currents between 100% and 25% of the rated current.

For regulating transformers load loss and short-circuit voltage shall be guaranteed in the main position and at both extreme positions of the regulating range. For multiple-winding transformers the guarantees shall apply in the main regulating position for all combinations of 2 windings, and for split-winding transformers also for the main winding versus the split windings collectively.

6.3.6 Voltage testing

Voltage testing shall be performed in accordance with IEC 60076-3 and IEC 60076-4 for the following voltage stresses:

- Lightning impulse

6.3.7 Insulation resistance

Measurement of the windings' insulation resistance to each other and to earth.

6.3.8 Measurement of zero sequence impedance

The zero sequence impedance shall be measured at a minimum of 4 different currents up to at least 50% of the rated current through the neutral. Transformers with two star-connected windings should be measured with voltage applied to each individual star-connected winding with the other open, also with the other closed for zero sequence current and measurement of this.

6.3.9 Oil

Measurement of the insulation strength of the transformer oil. An analysis result from a recognised laboratory is acceptable.

6.3.10 Sound level measurement

6.3.11 Temperature Rise test

6.3.12 Measurement of no-load currents at 400V or 230V, 50Hz

7. TRANSPORT, ASSEMBLY AT THE STATION, TESTING AND COMMISSIONING

Assembly of transformers at the erection site, including cooling systems and fittings, oil filling and control shall be carried out by the Contractor unless specified otherwise.

7.1 Transport

The Contractor shall include transport from the factory right to the place of erection. The Contactor must therefore familiarise himself with the limitations and challenges associated with transport. The Contractor shall be responsible for any calculations associated with transport such as roads, bridges, etc. Local circumstances, dimensions and drawings of the erection site will be provided on enquiry. The

transformer is to be carried with either oil, dry air or nitrogen at a slight pressure, and must be suitably covered during the transport.

During transport, at least two shock recorders fitted on opposite sides of the transformer tank exterior should be used. This provides either confirmation of recorded data or redundancy of shock recorders. Optionally, a third shock recorder could be mounted on the active part. It would allow for more advanced analysis if this third shock recorder is connected in a master-slave configuration with one of the recorders in the tank exterior.

7.2 Assembly

As soon as possible after arrival at the erection site the transformer must be fully assembled and filled with dry and filtered oil. The Contractor shall bring the necessary equipment for this purpose. Prior to assembly it must be checked that the drying agent is still active. In the case of nitrogen filling it shall be checked that this is still pressurised after arrival at the erection site.

Otherwise assembly shall be carried out in accordance with dimensioned drawings and sketches.

7.3 Filling with oil

All transformers with a maximum operating voltage ≥ 100 kV shall be filled with oil under vacuum.

Once evacuation has started and the residual pressure has reduced to around 2 torr or after max. 4 hours' evacuation checks shall be made that the transformer tank and all its gaskets, cocks and all vacuum equipment is sufficiently vacuum-tight. Any leaks must be located and remedied.

If the residual pressure remains high, water must be tapped to check the residual humidity of the transformer's insulating material.

The evacuation shall continue until the residual pressure is less than 20 torr for voltages of below 220 kV and less than 1 torr for voltages from 220 kV upwards.

Prior to filling with oil the oil shall be preheated, degassed and filtered. The oil shall be circulated through the filter at a temperature of at least 50 °C. The residual pressure in the filter's degassing tank shall be less than 50 torr for voltages of less than 220 kV and less than 1 torr for voltages ≥ 220 kV.

Oil filling shall take place under continued evacuation and if possible without interruption.

Cooling circuits for forced oil circulation shall be closed immediately after filling with oil. Each cooling circuit shall then be flushed with hot, degassed oil. The oil shall be circulated through the filter at least twice. After the filter has been disconnected the valves shall be opened and the cooling circuit vented.

After being filled with oil, oil and gas samples shall be taken and analysed. The imperviousness and insulation resistance within the winding and between each winding and earth shall be checked using a megger.

7.4 Pre-commissioning checks

The Contractor is responsible for the following checks being carried out. The client will make the necessary personnel available for these checks.

The following checks must be carried out prior to commissioning:

7.4.1 Earthing

Check that the transformer tank, neutral for windings intended for direct earthing and stabilisation winding are properly earthed. Check also that any current transformers and the bushings' capacitive voltage tap are earthed.

7.4.2 Filling with oil, venting

Check that the transformer is filled with oil to the correct level and that all cooling circuits, bushing fittings, cable boxes, etc. are vented. Make sure that all valves to coolers, radiators and the oil conservator are open.

7.4.3 Cooling system

Check that the pumps and fans of the cooling system have the correct direction of rotation and that they run without vibrating and without causing abnormal noise. Signal contacts for pressure gauges and liquid flow relays are to be checked and adjusted and the motor protection of the motors is to be tested for proper functioning. The functioning of the cooling system shall be tested and the cooling system shall be checked in accordance with approved forms.

7.4.4 Tap changer and voltage regulation

Check that driving mechanism and tap changer are correctly connected together. Test the functioning of the driving mechanism both locally and by remote control. Check the position indicator. Check and adjust automatic voltage regulation and any parallel operating equipment.

7.4.5 Monitoring devices

Check all monitoring devices. Test both the signal and the triggering functions right up until the circuit breakers respond. Check and adjust the signal contacts of the thermometers. Check that the secondary circuits for all the current transformers are closed.

7.5 Commissioning

Representatives of the Contractor and client shall normally be present when voltage is applied. If the Contractor waives this right he shall not be released from liability for faults in the equipment delivered or for shortcomings in assembly.

Before the transformer is placed under voltage ensure that the bushings are clean, that the transformer cover and the cell have been cleared of tools, ladders and other objects that might cause a nuisance or risk and that earthings of the transformer's line outlets are removed.

After voltage has been applied the transformer is to be carefully observed in respect of suspected vibrations and noise phenomena as well as reactions by gas relays or thermometers.

8. DOCUMENTATION

All documentation for maintenance and operation of the transformer shall be supplied in electronic format and shall be in Norwegian. All drawings shall be supplied in the file format dwg. Other text files shall be supplied in Microsoft Word. The drawing list, drawings and equipment/maintenance list shall bear function codes (equipment numbering) in accordance with the EBL code plan.

The documentation shall be divided into the following main groups:

A. Drawings with drawing list.

B. Test reports and certificates.

C. List of equipment including technical data.

D. Operation and maintenance documentation.

Unless another date is agreed, the Contractor shall forward 2 copies of binding dimensioned drawings and 2 copies of diagrammatic documentation for the transformer, cooling system and monitoring equipment within 4 weeks of the order being placed. The client shall notify his comments within 3 weeks of receipt of this documentation. After this, new revised copies shall be forwarded within 2 weeks. The procedure shall continue until the client has no comments on the documents and final approval of dimensioned drawings and forms shall be notified to the Contractor.

Before supply is deemed complete the client shall be sent 2 copies, one printed and one electronic, of folders containing the transformer's test reports, dimensioned drawings and circuit diagrams, as well as descriptions and instructions for use for all protective devices and fittings. At the front of the folder shall be placed a sheet containing the transformer's rated data, as well as – for assessment of the overload capacity – the calculated temperature differences for each winding and mean oil temperature, the calculated top oil and middle oil temperature, as well as the rated current for all parts that may influence the load capacity, such as bushings, switches and tap changers. Also the weight of the transformer, oil and all removable parts, power consumption of pump and fan motors and the cooling water and air requirement. It should also contain the Contractor's recommendation for the frequency of oil checks and other inspections, as well as the requirement of the result of these samples before oil treatment or other revisions are required.

8.1 Requirements of dimensioned drawings

Dimensioned drawings forming part of the order shall be required to meet the requirements mentioned below. Regarding dimensioned drawings in the tender please take into account the requirements as far as possible.

The dimensioned drawings shall be in 3 projections and preferably to scale. They shall be clearly marked with the transformer's rated data, with the station name with which the invitation to tender and/or order are marked, as well as with the Contractor's production number or order number. The transformer's transport weight, total weight and oil weight shall be stated.

The dimensioned drawing shall show all fittings, all cocks, all manholes and hatches. The required crane hook height for lifting the complete transformer shall be stated, and for lifting the active part out of the tank. The dimensioned drawing shall clearly show the connecting parts of the bushings.

Fittings and removable parts, including bushings, shall be marked with a number referring to an explanatory key.

The aim is to enable transport dimensions and the dimensions of the extreme points relative to the centre line of the tracks to be found easily. If any measurement is out of scale and the dimensioned drawing is otherwise drawn to scale, these dimensions shall be highlighted.

The itemised list shall state data for the fitting parts. (This applies in particular to bushings, thermometers, coolers and flow indicators. State dimensions for cocks.)

Jacking points and towing lugs shall be stated and dimensions given. The transformer should be equipped with two jacking points at all four sides.

For parts that are to be assembled at the erection site the weight, lifting points and any requirements of pulley hooks in the cell ceiling shall be given.

The dimensioned drawing shall show the centre of gravity.

Documentation/dimensioned drawings are required for all gaskets.

8.2 Requirements of diagrammatic documentation

The diagrammatic documentation shall include:

- Circuit diagram for the transformer's main circuits
- Diagram of monitoring system
- Diagram of the cooling system
- Diagram of the tap changer's driving mechanism
- Diagram of any auxiliary power system if the transformer has its own auxiliary power winding.

All the diagrammatic documentation shall be uniform in appearance and its presentation should as far as possible be based on IEC standards.

The first page of the transformer's main diagram should include the type designation, output, voltage transformation, frequency, connection group, vector diagram and a tap diagram (cover drawing) showing the position of the taps and stating the associated windings.

The transformer's main diagram shall show all external and internal taps, including built-in current transformers and measuring taps for capacitor bushings.

The diagram shall provide a table of special information about the individual taps such as the nominal voltage in all possible tap changer positions and switching options.

The diagram shall also contain a table of any built-in current transformers with their tap marking, possible connections, transformation, output and class.

A diagram of monitoring devices shall show all the monitoring devices' contacts and tap markings, as well as the conductor's route to cabinets and terminal markings in the cabinet.

A circuit diagram for the cooling system shall show all fan and pump motors and control cabinets. Motors belonging to the same cooling assembly should be drawn on the same diagram page along with the associated fuses, contactors, motor protection and contacts for protection and control.