



Instruktion

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TS EN Power transformers above 2 MVA

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1. Scope

The technical specification concerns three phase 50 Hz oil-immersed power transformers above 2 MVA for power applications.

2. Standards

The following standards and regulations shall be used if not otherwise specified. If standards referred to have been revised, the ones in force at the ordering date shall be considered as valid. CENELEC (EN, HD or TS documents) are the ruling requirements and thereafter IEC or ISO.

IEC 60076 & EN 60076	Power transformers
EN 50216	Power transformers and reactor fittings
IEC 60616	Terminal and tapping markings for power Transformers
EN 61869	Instrument transformers
IEC 60137	Insulated bushings for alternating voltages above 1000 V
EN 50180	Bushings above 1 kV up to 36 kV and from 250 A to 3,15 kA for liquid filled transformers
EN 50243	Outdoor bushings for 24 kV and 36 kV and for 5 kA and 8 kA for liquid filled transformers
EN 50299	Oil-immersed cable connection assemblies for transformers and reactors having highest voltage for equipment U_m from 72,5 to 550 kV
EN 50386	Bushings up to 1 kV and from 250 A to 5 kA, for liquid filled transformers
IEC 60038	IEC Standard voltages
EN 60071	Insulation coordination; Part 1, 2 and 5.



IEC 60214-1	On-load tap-changers, (SS IEC 214)
IEC 60214-2	Application guide for on-load tap-changers, (SS IEC 542)
EN 60529	Degrees of protection by enclosures (IP code)
IEC TR 60815	Guide for the selection of insulators in respect of polluted conditions
IEC TS 60815	Selection and dimensioning of high-voltage insulators intended for use in polluted conditions
EN 61000	Electromagnetic compatibility; Part 1- 6 (IEC shall apply if no EN Standards are published)
EN 61140	Protection against electric shock - Common aspects for installation and equipment
IEC 61462	Composite insulators - Hollow insulators for use in outdoor and indoor electrical equipment - Definitions, test methods, acceptance criteria and design recommendations.
IEC 62155	Hollow pressurized and unpressurized ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000 V
IEC 60296	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear
EN 10088-3	Stainless steel - Part 3: Technical delivery conditions for semi finished products, bars, rods, wire, sections and bright products of corrosion resisting steels for general purpose.
EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods
EN ISO 9001	Quality systems - requirements
EN ISO 10684	Fasteners - Hot dip galvanized coatings
EN ISO 12944	Paints and varnishes - Corrosion protection of steel structures by protective paint systems



EN ISO 14001	Environmental systems - Requirements with guidance for use
ISO 6708	Pipe work components - Definition and selection of DN (nominal size)
ELSÄK-FS 2022:1	Regulations and general advice of the Swedish National Electrical Safety Board (Elsäkerhetsverket)
AFS 2023:4	Swedish Work Environment Authority Regulations (Arbetsmiljöverket)
SS-EN-61000-6-2	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
SS-EN-61000-6-4	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
SS-EN-61000-6-5	Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment
SS-EN 61131-3	Programmable control systems - Part 3: Programming languages
SS-EN-IEC 62443-3-2	IT Security in Industrial Automation Systems – vendor parts

3. Service conditions

3.1. Mode of operations

The transformers shall if not otherwise specified be designed for outdoor erection and continuous operation.

3.2. Ambient temperature

As a lower limit of ambient air temperature -40°C shall apply. (Deviation from IEC 60076-1, Cl. 4.2)

For all equipment due consideration shall be taken to the increased ambient temperature caused by the temperature of the transformer tank which is assumed to



reach 105 °C on the cover. The lower limit temperature shall be accounted for as well.

For built in bushing current transformers the following shall apply (if not other verified by the supplier):

- maximum ambient temperature 115°C
- maximum daily average temperature 105°C

4. Electrical data and other main characteristics

4.1. Connection voltages

If nothing else is specified in the technical specification, following voltages shall be used:

- OLTC motor:
Normally 400/230 V, AC 50 Hz
- OLTC motor drive control and indication:
230 V 50 Hz or station DC voltage according to specification
- Cooling equipment motors:
400/230 V A
- Cooling equipment control:
Operation voltage, 230 V AC, single phase

Signalling voltage, 110 V DC or 220 V DC
- Lighting and heater:
230 V AC, single phase

Maximum voltage variation (-15% to +10%) shall apply at the connection point of apparatuses.

The circuit-breaking capacity on contacts that are used externally shall at least be: 0,3 A at 110 VDC and L/R = 40 ms.

4.2. Insulation levels

If not otherwise specified, insulations levels shall fulfil the requirements in Appendix 2.

4.3. Sound levels

If not otherwise specified, the maximum allowable sound levels according to Appendix 1 shall apply.

4.4. Core design

The transformer core shall be of three limbed core type.

4.5. Stabilizing winding (delta connected)

If not otherwise specified, all transformers with the connection symbol Y/y or Y/y/y, as well as a secondary or tertiary winding of U_m up to 36 kV, shall be provided with a delta connected stabilizing winding.

Stabilizing winding (+d) shall be closed and earthed internally at normal operation; however it shall be possible to open the delta and earth externally by connecting two DIN-bushings (at FAT).

4.6. Loading capabilities

All transformers, even multi winding transformers, shall be capable of continuous operation with rated current in all windings without exceeding the allowable standardised temperature rises, including winding hot spot temperature rises.

For two winding transformers operating at rated power and 20°C ambient temperature the ageing rate must not exceed 1p.u.

With the fans out of operation transformers with cooling type ONAF must be capable of loading with 60 % of the ONAF rating power unless else is specified in the technical description.

Cooling type ONAN transformers shall be prepared for future assembly of fans for additional cooling. This additional cooling must allow a loading with 130 % of rated ONAN current without exceeding the temperature limits of SS EN 60076-2. The transformer rated power is not changed and is still referring to ONAN cooling conditions.

Bushings, on-load tap-changers and other accessories shall be selected in such way that they can carry currents above the corresponding winding rated current of at least the same amplitude and the same duration as the transformer itself can withstand. Bushing rated currents must, however, exceed the winding rated current by 20 % (30 % for cooling type ONAN). On-load tap-changer rated currents



must, however, exceed the winding rated current by 10 % for cooling type ONAN. For built in current transformers according to technical specification.

The neutral points of three-limbed auto-connected inter bus transformers (400/130kV and 220/130 kV) shall be capable of continuously carrying a DC current of 200 A for 10 minutes while the transformer operating at its worst loading and at maximum ambient temperature.

Non effectively earthed neutral points shall be capable of

- Continuously carrying an AC current amounting to 10% of the rated phase current and the transformer operating at its worst loading at maximum ambient temperature.
- Starting from steady state with continuously current of 10% of rated phase current the neutral shall be designed for carrying at least 30% of rated phase current for 15 minutes and the transformer operating at its worst loading at maximum ambient temperature.

The transformers shall withstand external short circuits on any voltage level. Built-in current limiting reactors shall not be used.

4.7. Terminal markings

Two winding transformers shall have terminal markings according to

HV: A, B, C

LV: a, b, c

Stabilizing: d1, d2

Auxiliary: sa, sb, sc

Three winding transformers shall have terminal markings according to

HV: A, B, C

MV: a1, b1, c1

LV: a2, b2, c2

Stabilizing: d1, d2

Auxiliary: sa, sb, sc

5. Design and construction

5.1. Control equipment design

The transformer shall have two cabinets as follows:

- Supervisory and cooling equipment
- On-load tap-changer motor drive

5.1.1. General requirements

- Boxes and cubicles shall have draining and ventilation. As protection for insects, openings shall be provided with e.g. nets having a mesh size of about 1 mm.
- Boxes and cubicles for the on-load tap-changer drive and for the cooling equipment shall be provided with lighting and also be provided with a heater to prevent condensation. Heaters shall be protected against unintentional contact.
- The control equipment shall be designed and assembled to withstand occurring transformer vibrations.
- In boxes and cubicles containing equipment which requires extra heating to secure its function at -40°C ambient temperature the heater shall be controlled by a thermostat.
- One side of the cubicles shall be reserved for external cables.
- The terminal blocks shall be located for easy access. For the connection of incoming conductors minimum 100 mm free space along the complete terminal row shall be provided.
- Terminal blocks in the cubicle for supervisory and cooling equipment shall be of type URTK/S (E 29 109 02) or equivalent. The type shall be approved by the purchaser.
- All terminal blocks shall be disconnectable and provided with a 4 mm test tap.
- Terminal blocks type Ben 10 must not be used in CT/VT circuits.
- 220 VDC blocks must be covered.
- Blocks for power supply shall be suitable for power supply circuits.
- All components shall be provided with individual markings for easy identification in the circuit diagram.
- No mercury thermometers or mercury switches allowed.
- Boxes and cubicles shall be lockable and located for easy access. Cables shall normally be connected from below why the underside shall be at least 600 mm above the erection plane.
- It shall be provided a possibility to feed the heating and lighting in the on-load tap-changer motor drive and control cabinet from the station local power supply.

Requirements for the supervisory and cooling equipment:

- The cabinet shall be equipped with an earthed 230 V AC, 10 A socket (double) with earth fault breaker. Socket and earth fault breaker in accordance with the Swedish standards (socket Type F, Shuko, CEE 7/3).

Terminal blocks for current transformers shall be placed in the control cabinet.

5.1.2. Thermometers and temperature gauges

- One temperature gauge for the oil, mounted in the cover.
- One temperature gauge for the warmest winding, mounted in the cover and showing the true winding hot spot temperature i.e. calibrated by means of the true hot spot factor.
- Always use resistance transmitters (pt100) for remote winding temperature indication. Transducers shall be located in the control cabinet, 4-20 mA, - 40 - 130 degrees C if not specified otherwise.
- Three winding transformers shall have one temperature gauge for each winding.
- The temperature gauges shall have four independently adjustable contacts closing when the temperature reaches the adjusted value. (Five in case of OFAF)
- The contacts shall be electrically separated. One contact of each of the gauges shall be used for signalling/tripping, the others will be used optionally e.g. for control of cooling.
- The temperature gauges shall be provided with a legible maximum pointer resettable from the outside.
- In addition to thermometer pockets for the above gauges there shall be two extra thermometer pockets.
- All temperature indicators shall be mounted at service level. To prevent water from dripping into the thermometers a drip protection or a protruded roof shall be provided.

5.1.3. Cooling equipment

- Normally the top oil temperature shall control the coolers, however, necessary number of terminal blocks shall be available for cooling control from winding temperature.
- Temperatures where fans and pumps start shall be approved by purchaser.
- Cooling equipment shall be mounted on the transformer.

- It shall be possible to control the oil pumps by an auxiliary contact of the transformer breaker.
- Each motor shall have its own motor protective switch with both manual and automatic operation.
- Each motor protection and each contactor (auxiliary relay) shall be provided with its own miniature circuit-breaker (MCB).
- The complete control circuit shall be protected by a circuit-breaker and be provided with voltage supervision.
- If more than one fan is required, they shall be divided into two independent groups.
- Transformers 63 MVA and above should have the cooling equipment divided in at least two groups.
- The control shall normally have three switches with a handle for operation mode selection. Two for the fan groups and one for the pumps. The switches shall be labelled:

Fan switches	Off	FRÅN
	On	TILL
	Gauge t2	VAKT t2
	Gauge t3	VAKT t3
Pump switch	Off	FRÅN
	On	TILL
	Gauge t1	VAKT t1
	Breaker auxiliary contact	HK

In case of sub-division of the cooling equipment, the number of switches will be a multiple of three.

- In case of separately mounted coolers, an oil flow gauge having adjustable contacts closing at too low oil flow shall be provided. Contact closing shall occur also in case of wrong oil flow direction.
-

5.2. Supervisory equipment

5.2.1. Buchholz relay

The Buchholz relay shall be provided with two electrically separate contacts:

- One closing for slow gas formation to be used for alarm.
- One closing for heavy gas formation, heavy oil flow and low oil level to be used for tripping.
- The Buchholz relay shall be provided with shut off valves as well as a by-pass with a shut-off possibility in order to facilitate Buchholz exchange when the transformer is in service.
- Gas sampling and functional testing shall be possible to carry out when the transformer is in service.

5.2.2. Oil level indicator

- The oil level indicator shall have making contacts closing at too high and too low oil level. The contacts will be used for signalling.
- The indicator shall be readable at service level.
- A plate showing the oil level as a function of top oil temperature shall be provided at service level. The design must be approved by Purchaser.

5.2.3. On load tap changer overpressure relay

- The diverter switch oil compartment shall be provided with an overpressure relay (alternatively an oil-flow relay) equipped with an adjustable contact, closing when reaching a pressure (an oil flow) as specified by the manufacturer. In case of more than one oil space, individual relays for each space shall be provided. It shall be possible to perform a function test of the overpressure relay (oil flow relay) without disassembly.

5.3. Auxiliary winding 400 V

If the transformer shall be equipped with an auxiliary winding (i.e. few turns around each core leg, connected in yn and feeding a small matching transformer), according to the technical specification, following shall be fulfilled:

- The main fuses are a short circuit protection for the transformer. The fuses are considered as a part of the transformer.
- The auxiliary winding terminals shall be fused outside the transformer tank in immediate vicinity of the terminals. The neutral terminal shall be earthed to a flat terminal welded to the transformer tank.

- Off load reconnectable matching transformer 0,42 kV, - 5%, 0%, +5%, shall be included.
- Dry type matching transformer shall be provided with an enclosure with a hinged and bolted front cover.
- Oil insulated matching transformer shall be hermetically sealed and be provided with contact protected terminals.

5.3.1. Auxiliary winding terminals. Main fuses.

Fuses and winding terminals shall be provided with a single-phase insulating enclosure of incombustible material which also must withstand arcing. The equipment shall be enclosed in a cubicle with a hinged and bolted front cover.

Fuses shall be of blade contact type (NH fuse system) and have size 1.

The terminal / fuse cubicle shall be provided with a legible plate reading "**Får endast öppnas i spänningslöst tillstånd**" (Only to be opened when off circuit).

5.3.2. Load switch

At service level there shall be an encapsulated load switch having the breaking capacity 1.25 times the auxiliary winding rated current at $\cos(\phi)=0.7(\text{ind.})$. The load switch cubicle shall be provided with a hinged and bolted front cover.

5.3.3. Local power supply connection box

On the fuse box for local power supply a separate connection box for the connection of cables shall be furnished. The underside of the cable box shall be at least 800 mm above the erection plan. There shall be a free space and a cable strain relief for the purchaser's cable.

5.4. Corrosion protection and surface treatment

- The whole process from blasting until painting must take place in controlled and pre-defined climatic conditions.
- The system for the transformer painting should be suggested by the supplier and approved by the purchaser. The painting system should be appropriate for the local climate conditions.
- The painting system shall be in accordance with ISO 12944 category C4 durability High.



- The system for interior surface treatment such as sand blasting and painting should also be suggested by the supplier and approved by the purchaser.
- The supplier shall on request show that suggested painting system fulfils specified ISO 12944 category.
- Paint colour as agreed together with the purchaser.
- Radiators shall be hot dip galvanized according to EN ISO 1461 except from the local coating thickness that shall be at least 70 μm .
- Touch up paint shall be included in the delivery.
- Boxes and cubicles shall be made of hot dip galvanized steel, stainless steel or aluminium.
- The cabinet for supervisory and cooling equipment shall be made of stainless steel. A protruded roof shall be provided to prevent water from dripping into the cabinet.
- Stainless steel cabinets shall not be painted.
- If a zinc rich primer is used, zinc content must be at least 80 %

5.5. Transformer tank and tank accessories

- The tank must not be equipped with pressure relief valves.
- The transformer ($U_m \geq 82,5 \text{ kV}$) shall have the cover welded to the tank.
- The transformer tank and valves shall withstand full internal vacuum. A vacuum proof tank shall have a marking indicating this.
- All welds shall be all welded and all welding works shall be performed by qualified welders.
- Welders must be qualified in accordance with applicable EN and ISO standards.
- Welding shall be performed in accordance with applicable EN and ISO standards.
- Bell type tanks are not permitted
- All screws, washers and nuts shall be made of stainless steel. Screws and nuts shall be waxed in order to prevent seizing.
- One shut-off valve shall be mounted on every radiator, so that dismantling can be performed without draining the oil.
- The downside of the bottom shall be flat and constructed for mounting on oak planks.
- Lifting points for jacking shall be of console type.

- Wheels shall only be used when specified in the technical specification.
- When an arrangement on wheels is used, it should be possible to adjust the direction of the wheels between lateral and longitudinal direction with constant track gauge. Track gauges shall be approved by the purchaser.
- Stops for the wheels shall be provided.
- Each individual accessory shall clearly and permanently be provided with a plate showing the purpose as well as clear identification.
- Plates shall be in Swedish.
- The transformer tank should be equipped with lifting lugs for lifting of the complete transformer with oil. The active part should be equipped with lifting lugs for lifting the active part out of the tank.
- Ball valves shall have oblong toggle grip.
- The transformer should at least be equipped with valves for oil sampling testing as follows:

$U_m \geq 82,5 \text{ kV}$:	One for sampling at the level of the cover and on at the bottom
Or else:	One for sampling at the bottom
- Valves shall be drawn down from the conservator to service level to easily be able to replenish oil.

5.6. Earthing

5.6.1. Current transformer

5.6.2. Transformer tank

For the protective earthing of the transformer tank two earthing terminals diagonally located close to the tank bottom shall be provided. The earthing cable comprises a few wire copper conductor, 95 mm^2 for highest voltage for equipment $U_m \leq 82 \text{ kV}$ and 185 or 240 mm^2 for higher voltages.

The terminals shall be flat with four holes, diameter 14 mm with a vertical center 40 mm distance and a horizontal one of 50 mm . The contact surface shall be protected in a way so as a good electrical contact will be obtained after assembly.

5.6.3. Other equipment

All metallic pieces not welded to the tank shall be earthed to the tank through a visible earthing link or equivalent device.

5.7. Oil

5.7.1. Oil quality requirements

- The oil must be of naftenic base and be solvent refined and / or severely hydro treated.
- The oil must fulfil the requirements for inhibited oil (group I in accordance with IEC 60296) and contain at least 0.3% (kg/kg) of an oxidation inhibitor of type di-tert-butyl-parakreosol (DBPC).
- The lowest cold start energising temperature (LCSET) shall be -40°C .
- The oil must not be added any pour point depressants.
- The oil must not be added any gas absorption additives.
- The detection limit to verify the PCB content must be below 2 ppm. If an oil sample withdrawn at the delivery contains 2 ppm or more the oil delivery will not be accepted.
- The total aromatic content must not be higher than 10% (v/v).
- **It should be noted that the kinematical viscosity at -30°C must not be higher than $800 \text{ mm}^2/\text{s}$ (deviation from IEC 60296).**
- In connection with the factory acceptance tests the manufacturer shall take at least one oil sample from the transformers for among others PCB check (even if the oil will not be shipped with the transformer).
- The manufacturer shall present an oil specification for approval. In the specification the type of base, country of origin and refining place shall be clearly stated, as well as corrosion test result according to the most effective test method available (the test method must be approved by the purchaser).

5.7.2. Oil system

- Conservator with dehydrating breather shall be included. Transformers shall be provided with a completely separate conservator with oil level indicator for the OLTC.
- Dehydrating breather shall be of maintenance-free type.
- The conservator (tank) shall be provided with a rubber sack. The aging properties of the rubber material shall be presented.
- At -40°C ambient temperature, off circuited transformer and at steady state condition the oil level must not drop to such a level that the oil level indicator no longer will show any level changes. Furthermore, the oil shall not overflow at $+40^{\circ}\text{C}$ ambient temperature and full load.
- The expansion tank shall have at least 12% of the total oil volume between the signalling for low and high voltage level in order to avoid oil level alarms (5.2.2) (13% if lower limit -50°C applies according to technical specification). The expansion tank shall be placed on the short side of the transformer housing. Shut off valves must be installed in the connection pipe between expansion tank and transformer.

5.8. Bushings

5.8.1. General

For highest voltage for equipment ≥ 12 kV condenser type bushings shall be used when suitable. Applicable standard is IEC 60137. The insulators shall be of polymeric type.

For highest voltage for equipment < 12 kV either condenser type or ceramic type bushings may be used. Applicable standard is IEC 60137.

Condenser type bushings may be of either oil impregnated paper (OIP) or resin impregnated paper (RIP).

Ceramic type bushing shall fulfil IEC 50180 or IEC 50386. Deviations may be made for connection details on the oil side but only after written approval from the purchaser.

All hollow silicone composite insulators shall comply with the requirements of the IEC publication IEC 61462 and the relevant parts of IEC 62217. The design of the composite insulators shall be tested and verified according to IEC 61462 (design test and type test). Each composite insulator shall undergo routine test according to IEC 61462.

5.8.2. Marking

Each bushing shall have a rating plate showing the identification i.e. type and catalogue No. On smaller bushings this can be stamped on the top bolt or the flange or on a separate plate on the transformer.

5.8.3. Apparatus terminals

- The transformer should, if nothing else is specified, be connected through normal bushings on the transformer, i.e. not cable connection, or SF6-connection or similar.
- Bushings for highest voltage for equipment ≥ 52 kV and above shall be provided with vertical aluminium studs with following diameters:
 - 630 - 1250 A 30 mm
 - 1600 A 40 mm
 - 2000 - 2500 A 60 mm
- Studs for voltages < 52 kV and currents up to 1250 A is made by CuSn flat terminals of a suitable dimension with four holes (diameter 14 mm) placed in two rows and two columns with c-c 40 mm. For higher currents (up to 3150 A) a suitable dimension with nine holes (diameter 14 mm) placed in

three rows and three columns with c-c 40 mm shall be used. The terminals shall be placed perpendicular to the centrelines.

- Bushings shall be placed on the cover.

5.8.4. Capacitive taps

Phase bushings for highest voltage for equipment $\geq 82,5$ kV shall be equipped with capacitive taps for measuring purposes. The measurement taps shall be connected to a common connection box at service level where they normally shall be short-circuited.

5.9. Built-in current transformers

For built-in current transformers the following shall apply, if not otherwise specified:

- The terminal block labelling shall begin on 1 within each group. The grouping is clarified in Appendix 3, Principal terminal block disposition.
- The cores shall be provided with a common 35 mm² single turn test conductor, by means of which current transformer testing can be carried out without energizing the transformer.

5.10. System voltage reconnection and Off Load Tap Changers

De-energized change of ratio (+x %, 0, -x %) and/or reconnection between system voltages (series-parallel, Y-D) shall be made with the transformer not in operation. The reconnection shall be made by means of reconnectable (bolted) links under cover, accessible through hatches in the cover.

Drawings showing how to reconnect between system voltages shall in case of bolted links be included in the Instruction manual.

5.11. On Load Tap Changer (OLTC)

5.11.1. General

Change of operation shall be made by high-speed on-load tap-changers.

- Type, manufacture and design shall be formulated in the offer.
- OLTC motor drive shall be mounted on the transformer.
- The drive mechanism shall be located for an easy operation in service.



- The operating mechanism shall be designed for both motor operation (local and remote) and hand operation (by means of a crank, which shall be included)
- Contacts for raise and lower shall be electrically and mechanically mutually blocked.
- One complete operation must not take more than 35 turns at hand operation. The required number of turns shall be indicated on a plate on the drive. The operation time at motor operation must not take more than 8 s.
- The drive mechanism shall be provided with legible and weatherproof labels with arrows for the hand operation labelled, at the arrow points:

ÖKA	(raise)
MINSKA	(lower)

Raise means that a higher tapping number is connected when making a clockwise operation i.e. lower voltage ratio.
- Change over switch for Local and Remote shall be labelled

LOKAL
FJÄRR
- The drive shall be provided with a legible position indicator, readable from the outside. The indicator shall be mechanically controlled by the tap changer. The tap positions shall be numbered from one and upwards. The highest ratio shall correspond to position No.1 i.e. in the normal case this will give a higher voltage on the low voltage side at a higher tap position.
- For electrically operated single phase tap-changers a zero-voltage in any motor circuit shall be signalled and operation of the other phases shall be prevented.
- If the tap changer has a limited operating temperature above the temperature stated in 3.2 Ambient temperature, the manufacturer shall designate after how long time and the transformer unloaded, the tap-changer could be operated at the required ambient temperature.
- The diverter switch shall whenever suitable use vacuum switching technology in order to minimize the maintenance requirements.

5.11.2. Functional requirements

- A change of the drive motor polarity must not imply a reversal of the rotation. When at stand still all phase conductors shall be disconnected.



- The motors shall be protected against overload by motor protective switches. In case of single-phase tap-changers the motor protective switches shall be of a design allowing for a common fusing of the three drive motors.
- It must be possible to operate the motor protective switches by hand.
- The motor protective switches shall be provided with an auxiliary contact, which is closed when the switch is open. This contact will be used for signalling at protective switch tripping.
- Circuits for motor, operation, position indication and heating shall be electrically completely separated.
- A started cycle of operation shall be completed, even if the operation pulse length is shorter than the time required for one step. The pulse length varies between 5- 100 ms.

The following auxiliary contacts shall be provided:

- One making contact, which closes just before the actual load switching and which remains closed until the operation cycle is completed. The time during which the contact is closed shall as close as possible correspond to the critical switching time. The contact is to be used together with over current relay contacts to indicate that the diverter switch has been subjected to over current during switching and consequently calls for an inspection of the diverter switch contacts.
- One making contact which closes as soon as the drive is leaving its rest position and which remains closed until the operations cycle is completed. This contact will indicate that a switching is immediately at hand or already under way.
- Contacts for analogue potentiometer transmitter tap position indication. The auxiliary voltage to the tap shall be station DC-voltage. Output signal 0/4 – 20 mA according to purchaser.
- The potentiometer transmitter shall have as many positions (N) as the number of tappings and N-1 subresistors. Each resistor shall be of about 10 or 50 ohms with an individual spread of maximum 0,5 %.
- The potentiometer transmitter shall withstand at least 0,3 A continuously.

5.12. Power and control cables

- Permanently laid cables shall be of screened type and preferable wire armoured cable.
- Cables must not be laid inside protective tubes or pipes.
- Cables shall be approved by the purchaser.



To prevent excessive heating, the cables must not come into contact with the transformer cover and they shall be laid in such a way that they do not become an obstacle for water drainage.

- Cables on the cover and other horizontally laid cables shall be provided with a treading protection. However, this is not required when using steel wire armouring.
- Clips and cable straps shall be of stainless steel.
- Cable sheath and possible protective earthing conductor shall be earthed in both ends of the cable.
- The cable-bending radius of any cable must not be below ten times its own diameter.
- All cables and cable cores shall be provided with an individual and durable marking for the identification in the circuit diagram. The cable markings outside cubicles and boxes shall be of stainless steel.
- Functional earthing conductors must not be yellow/green.

5.13. Winding design

The manufacturer shall state the depolymerisation number (DP) of the insulation paper used in the windings:

- new paper from the paper supplier (actual value)
- processed and tested transformer ready for shipping (expected value)

Thermally upgraded paper is to be used.

The windings shall be made of copper.

The transformer shall be designed in such a way that copper deposition will be prevented. Winding wires and bare conductors shall always be equipped with a high temperature varnish layer. The varnish layer shall be designed for hot spot temperatures according to IEC 60076-7.

6. Testing

Factory acceptance tests shall be performed in accordance with IEC 60076 if not specified otherwise below.

Bushings shall be tested in accordance with IEC if not specified otherwise below.



On-load tap-changers shall be tested in accordance with IEC 60076-1, IEC 60214-1 and IEC 60214-2 if not specified otherwise below.

Current transformers shall be tested in accordance with

IEC 61869 if not specified otherwise below.

At the acceptance tests the transformer shall be assembled as for service, i.e. complete with conservator, coolers, auxiliary transformer, supervisory equipment etc. Deviations from this requirement may be made, however, only after written approval from the purchaser.

A preliminary test report including copies of draft test reports shall be handed over to the purchaser's inspector immediately after completion of each test. The inspector shall have the right to receive a draft test result copy as soon as a part test is finished.

Routine test reports for bushings, on-load tap-changers, auxiliary transformer and current transformers shall be presented for the inspector without request. Type test reports for the other equipment shall be available at the test location.

The result from all routine, type and special tests shall be compiled in a document together with the test program as well as a possible non-conformance report.

At the latest three weeks after the factory acceptance tests three copies of the test report shall be available at the purchaser's office.

The routine test certificates for bushing current transformers shall include, in addition to the routine test results, the following information:

- A The date and reference No. of the type test certificate
- B Current transformer data
- C The parameters n and R_{ct} (from the type test) for each core for the determination of the over current factor at different burdens
- D The purchaser's reference number
- E The current transformer serial No.

All measuring equipment shall be of at least class 0.2. Analogue watt meters giving a full deflection for a power factor of 0.1 may be of class 0.5. The equipment shall be calibrated at least once a year at a measurement laboratory. The latest calibration curves shall be available at the test location. The equipment shall in addition be provided with visible markings showing the last calibration date.

6.1. Routine test

- In case of windings reconnectable between different system voltages loss measurement shall be performed for each voltage level.
- Measurement of no-load loss and no-load current shall be made at 80, 100, 105 and 110 % of rated voltage.
- Examination of the corrosive protection and the surface treatment requirements shall be performed.
- Inspections shall be carried out to assure that the transformer is equipped with all the accessories and equipment stipulated in contract documents and these guidelines and that they operate as intended.
- Each complete control equipment shall be voltage tested with 2 kV 50 Hz for 1 min. Motors for the on-load tap-changer motor drive shall be subjected to a test with at least 1,5 kV 50 Hz for 1 min.
- The insulation resistance between electrically separated circuits or between conductor and ground must exceed 2 MOhm measured with 500 V DC.
- Lightning impulse test (LI) shall be a routine test on all winding $U_m \geq 12$ kV.
- Lightning impulse test on neutral (LIN) shall be a routine test on all windings $U_m \geq 36$ kV.

6.1.1. Measurement of zero sequence impedance

This section applies only to three phase transformers and shall be performed as routine tests for all transformers having $U_m \geq 100$ kV.

The test shall be performed on all-star- and zigzag-connected windings.

For all auto connected transformers and if not otherwise stated for non-auto transformers the zero-sequence impedance shall also be measured for a short circuited high or low voltage winding in pairs.

The zero-sequence impedance shall, if applicable, be measured in the principal, middle (if deviant from the principal) and extreme tapplings.

For transformers without a delta connected winding the measurements in no-load shall be performed from a very low (+0 A) neutral current up to as high current as possible (approximately 30% of rated current), with a number of measurements points (minimum 10 points) in between. The positive curve slope for low currents must be recorded. In cases where a counteracting magnetic flux exists, the neutral point of the transformer can be loaded up to rated current.

For transformers with a delta connected winding the measurements in no-load shall be performed from a very low (+0 A) neutral current up to as high current as



possible (approximately 30% of rated current), with a number of measurements points (minimum 3 points) in between.

If a stabilizing winding is provided, measurements shall be performed both with the delta connected winding closed and open.

At all tests, neutral current, phase to ground voltage and active power consumption shall be measured. From these measurements the impedance and resistance shall be calculated in ohms per phase.

Measurement with a short-circuited winding (EN 60076-1) refers to short circuit between phases and neutral.

6.2. Type test

For the first transformer of a new design, the following tests have to be performed:

- Temperature rise test
- Sound level measurement
- Dielectric type tests
- Measurement of zero sequence impedance for all transformers having $U_m < 100$ kV, as well as a star- or zigzag-connected secondary or tertiary winding

If a transformer of the same design has been tested earlier the test protocol shall be enclosed to the offer and the similarity of design be approved by the purchaser.

Temperature rise test shall be performed with full total loss and with maximum rated current for each winding unless else is agreed with purchaser. The assumptions shall be reported in the test certificate.

Storage-type measuring equipment with an average device must not be used for determination of sound levels.

Measurement of zero sequence impedance shall be performed in accordance with section 6.1.1. In a type test, zero sequence impedance shall be measured in the principal tapping; the measurements in other tappings are optional.

6.3. Site tests

Minimum the following site tests shall be carried out before taking the transformer in operation



- Oil quality test for among others PCB check and breakdown voltage. A weatherproof plate with (date of test) shall be provided to put on the transformer, certifying that PCB content is below 2 ppm. Analysis in accordance with IEC standards and protocol. Plate and analysis protocol shall be in Swedish.
- Dissolved gas analysis
- Winding resistance measurement (if bushings have been removed during transport)
- Bushing CT ratio and no-load current characteristic check (if CT:s have been removed during transport)
- 400 V three phase no-load ratio measurement
- Operational tests on all accessories
- Operational test of OLTC using recording instrument to ensure operation without breaking the current

The result from the site test as well as the site test program shall be compiled in a document to be added to the instruction manual.

Dissolved gas analysis shall be made one month after the transformer has been energized and test result be sent to the purchaser.

7. Transport, delivery and installation

7.1. Local coordination manager

The supplier is responsible to appoint a local coordination manager which shall coordinate the delivery on site, offloading and erection of the transformer.

Mode of conveyance is decided by the manufacturer.

The local coordination manager, as well as any personnel visiting or performing installation work in the substation shall follow the relevant safety instructions according to ESA14 ⁽¹⁾ and "Ellevio kompletterande anvisningar till ESA". It is the

¹ ESA (Electrical Safety Advice): <http://www.svenskenergi.se/Vi-erbjuder/Webbshop/ElsakerhetForeskrifter/ESA---Elsakerhetsanvisningar/>



responsibility of the supplier to ensure that its personnel has sufficient electrical knowledge to perform safe work within the Ellevio substation.

7.2. Transport

Impact recorder shall be placed on the transformer during the whole transport. Registered data shall be delivered digitally and included in final documentation.

The manufacturer shall before the start of the transport state the maximum allowed accelerations in XYZ-directions. The operation of the impact recorders shall regularly be checked during transport.

7.3. Electrical installation

All companies working with electricity (electrical installation work) must have a self-audit scheme guaranteeing that the work is carried out correctly by a person with the correct skills.

Companies carrying out electrical installation work on equipment which is not their own must register the activity with the Swedish National Electrical Safety Board.

Electrical installation work can only be carried out by:

- Individuals who are authorised as electrical contractors.
- Individuals who are covered by an electrical installation company's self-audit scheme.

The National Electrical Safety Board decides whether to authorise electrical contractors on the basis of an application.

The rules have been consolidated into a new Electrical Safety Act (elsäkerhetslag) with corresponding ordinance (elsäkerhetsförordning).

8. Quality assurance

The quality management shall be based on and in relevant parts fulfill the requirements in ISO9001 and ISO14001.

The manufacturer is responsible for all its sub suppliers establishing and executing quality management systems on their own.



The manufacturer shall for each transformer establish a main inspection and test plan (ITP) containing a summary of all the inspections and tests which shall be performed during the manufacturing, factory acceptance testing, final assembly and commissioning.

The main inspection and test plan shall be approved by the purchaser before the beginning of the manufacturing.

The purchaser or his representative shall have the right to take part in any inspection or test and shall also be informed of the result as specified in the inspection documents.

Inspections and tests performed in the presence of the purchaser or his representative, will not imply any limitation of the manufacturer's responsibility.

9. Information in the bid

10. Documentation

10.1. General

All documentation shall be written in Swedish to the utmost possible extent. The documentation required for erection, assembly, operation and maintenance must be in Swedish. However, test reports, catalogues and pamphlets may be in English provided a written approval from the purchaser.

10.2. Documents for approval

The following documents shall be provided for approval:

1 month after order	Outline drawings with binding outer dimensions
	The first time-schedule
Before beginning of manufacturing	Main inspection and test plan (ITP).
3 months after order	Binding outline drawings, diagrams and rating plates



	Instruction manual list of contents
1 month before factory acceptance tests	The test plan with dates
	1 copy of final documentation
1 month before delivery	Test plan for function test after installation
	Maximum allowed accelerations in XYZ-directions.
At the delivery	Instruction manual

Computer-produced drawings (CAD) a set of CD with format AUTOCAD shall be submitted. The AUTOCAD drawings shall comply with version 2010 and later. The drawings shall also be submitted with the format PDF. Any manual or descriptions shall be submitted as format PDF. All documentation shall also be submitted as sets of paper copies.

Examination and approval of the drawings, diagrams and documentation by the purchaser does not lead to any limitation in the supplier's responsibility.

10.3. Instruction manual

The instruction manual shall be supplied in three copies and one CD. Document-size in accordance with ISO 216 (A-sizes). Cover A4 but drawings may also be A3.

Table of content shall be approved by the purchaser before assembly of the transformer.

The following documents shall at least be included:

- Technical data sheet for all delivered equipment.
- Dimension/outline drawing with equipment/accessory list
- Circuit diagram
- Control cabinet
- Current transformers
- On-Load Tap-Changers with motor drive



- Test reports.
- Bushings
- Cooling equipment
- Supervisory equipment and other accessories
- Painting program
- Transport
- Erection/assembly
- Oil specification
- Operation and maintenance instructions
- Photos from manufacturing, active part and the complete transformer
- Photos from heat run test
- Product and safety information for all included chemical products
- Copy of signed Main Inspection and Test Plan
- Copy of signed painting protocol

A summary of all included components (list of apparatuses/equipment list including ordering information) such as thermometers, on-load tap-changers, motor drive, pumps, fans etc. shall be provided.

For bushings and current transformers, it shall be apparent in final documentation on which phase or neutral each device (serial number) is placed. The same applies to single-phase on-load tap-changers.

In submitted catalogues and pamphlets the actual component shall be legibly marked.

Recommended oil and winding temperatures for signal and tripping.

In case of ONAN prepared for ONAF, drawings showing how to complement the transformer to ONAF shall be included in the Instruction manual.



Appendix 1 ALLOWABLE SOUND LEVELS

Maximum allowable sound power levels

If not otherwise specified the following sound power levels shall apply.

A positive tolerance of 0 dB(A) shall be valid.

Transformer size, (MVA)	Max allowable sound power level - L_{WA} , dB (A)
6,3	65
10	68
16	72
20	74
25	77
31,5	79
40	82
63	85
100	86
150	87

The sound power level L_{WA} shall be measured in accordance with IEC 60076-10 and shall apply both with and without cooling equipment (fans and pumps) in operation.

In case of separately erected cooling equipment maximum allowable sound level will specified in every single case.

The transformer size is equivalent to the high voltage winding rated power.

For intermediate sizes linear interpolation shall be used.

Factory measured sound power level shall be rounded off to the closest integer value before comparison with the guarantee level.



Appendix 2

HIGHEST VOLTAGE FOR EQUIPMENT

INSULATION LEVELS AIR CLEARANCES AND CREEPAGE DISTANCES

Highest voltage for equipment, insulation levels

Table 1: Highest voltage for equipment, insulation levels

Highest voltage for equipment (kV)	Insulation level according to IEC 60076-3 (kV)
1.1	AC3
3.6	LI40 AC10
7.2	LI60 AC20
12	LI75 AC28
24	LI125 AC50
36	LI170 AC70
52	LI250 AC95
60	LI280 AC115
72,5	LI325 AC140
82.5	LI380 AC150
123	LI550 AC230 – LI325 AC140
145	LI550 AC230 – LI325 AC140
170	LI650 AC275 – LI325 AC140
245	SI750 LI850 – LI325 AC140
420	SI1050 LI1300 – LI125 AC50



Note 1 For phase to phase insulation the following addition shall apply

145 kV	LI550	AC 275
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245 kV	SI750	LI850
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420 kV	SI1050	LI1300
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Note 2 For neutral point of autotransformers the following shall apply:

420/245 kV	LI250	AC95
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420/145 kV	LI250	AC95
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In some cases	LI550	AC230 may be required
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Air clearances

Table 2: Minimum air clearances

Highest voltage for equipment (kV)	Minimum free air clearance	
	phase - earth (mm)	phase - phase (mm)
3.6	60	60
7.2	90	90
12	110	110
24	220	220
36	320	320
52	480	480
60	520	520
72.5	630	630
82.5	750	750
123	1100	1100
145	1100	1100
170	1300	1300
245	1900	2250
420	3100	3500

Note 1 The air clearance is assumed to be measured from live bushing parts.

Note 2 In some cases the clearances have to be increased to account for the connector size

Creepage distances

Table 3: Unified specific creepage distances

	USCD	
	mm/kV	
Class c	34,7	Medium
Class d	43,3	Heavy
Class e	53,7	Very heavy

Note Classes in accordance with IEC TS 60815

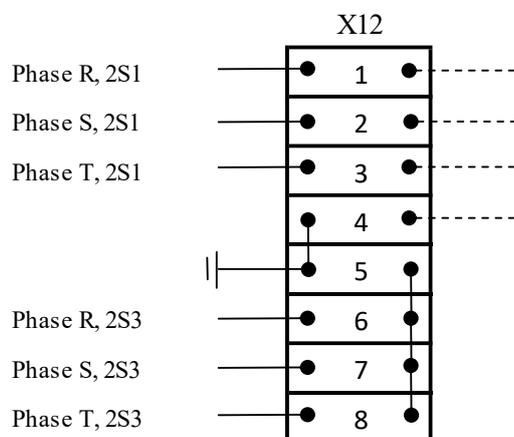
Safety distances

By safety distance is meant the phase - earth air clearance above increased by 6%.

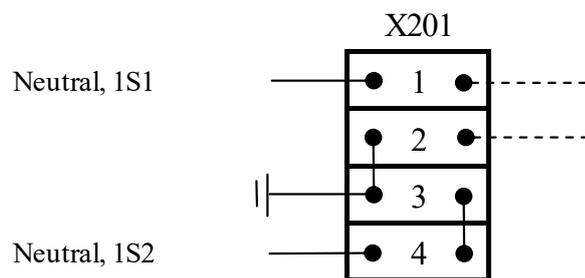
When applying this the distance from the neck to the finger tip is assumed to be 900 mm and the distance from the neck to the sole of the foot to be 1600 mm.

Appendix 3 PRINCIPAL TERMINAL BLOCK DISPOSITION

Disposition of terminal groups in the current transformer cubicle. Example Core No.2 of the highest voltage winding



Example: Core No.1 for the neutral of the next highest voltage winding





11. Omfattning (Ellevio internal)

Denna instruktion är en teknisk specifikation som omfattar krafttransformatorer över 2 MVA.

12. Giltighet och revision (Ellevio internal)

Instruktionen är godkänd av ordföranden för Nätkommittén, och granskas och revideras vid behov.

13. Syfte (Ellevio internal)

Syftet med instruktionen är att vara materialspecifikation för krafttransformatorer över 2 MVA.