

Lageland

Technical Specification for 110/33kV TR

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1. Purchase specification power transformer

This document is the Purchase Specification for two, two winding, oil-immersed power transformers with On Load Tap Changer, placed in HV side, for Lageland Project. In this document the technical requirements of the power transformer will be described.

Transformer and system data:

Voltage ratio primary / secondary side	110/33 kV
Maximum system voltage (Um) – HV SIDE = Primary side = grid side = inner winding Primary side not effectively earthed.	123 kV / 141,45 kV (for 20 minutes)
Maximum system voltage (Um) – LV SIDE = Secondary side = BESS side = outer winding	36kV
Rated voltage (Ur) - HV SIDE	110kV
On-load voltage regulation range on HV side	±10 x 1,5%
Rated voltage (Ur) - LV SIDE	33kV
Rated lightning impulse insulation level - HV SIDE incl. Neutral	550 kV
Rated lightning impulse insulation level - LV SIDE	170 kV
Rated power frequency withstand voltage HV SIDE incl. Neutral	230 kV
Rated power frequency withstand voltage LV SIDE	70kV
Rated frequency (fr)	50Hz
Frequency fluctuation	47,5Hz - 48,5Hz: for 30 minutes 48,5Hz - 49,0Hz: for 30 minutes 49,0Hz - 51,0Hz: for unlimited time 51,0Hz - 51,5Hz: for 30 minutes
Rated apparent power HV/LV	110MVA
Minimum required continuous secondary current at 90% of rated voltage	2140A
Initial symmetrical short circuit current (Ik") at transformer's primary side	40kA, 50kA
Rated peak withstand current (Ip) at transformer's primary side	96,44kA
Rated duration of short circuit (tk)	1s
The earth fault factor of primary and secondary system	√3
PEI (Peak Efficiency Index)	According to EU regulation 2019/1783
Short circuit impedance Uk% at rated power	14%
Short circuit impedance Uk% tolerance at rated power	+/-7.5% of Uk as per IEC 60076-1
Cooling	ONAN
Winding connection	YNd5
Winding hot spot windings temp. rise	73K
Temp. rise average winding	60K
Temp rise top oil	55K
Total sound power level LwA at 100% Ir and 100% Ur (at reted tap position)	< 80 dB(A)
Expected power factor for the load	0,9
Design lifetime	40 years
Colour	RAL 7033

Ambient conditions:

Installation	Outdoor	
Temperature	Min.	-25°C
	Max.	+40°C
	Annual	+20°C
Ice load	10mm	
Humidity	40-100%	
Air velocity	25m/s	
Wind load	770 N/m ²	
Altitude	≤1000m	
Pollution level according to IEC 60815	Class "e" (very heavy)	
Seismic qualification acc. IEEE 693, IEC 60068-2-57 and IEC TS 61463 (for the bushings)	Moderate seismic activity, 0,25g	

2. Standards

Unless stated otherwise in this specification the transformers shall fulfil all the requirements of the relevant national and international standards according to (in order of priority) NEN, EN, IEC, DIN, ISO. The most recent edition of any standard shall always apply.

Without excluding other standards special attention shall be given to NEN-EN-IEC 60076: Power transformers.

In cases in which any technical requirement or test deviates from standard or general manufacturer practice, this will be stated and explained in detail. Customer will have the final decision.

3. Mechanical requirements

3.1. Windings

Epoxy bonded Continuously Transposed Conductor (CTC) shall be used in main windings. Thermally upgraded paper for isolation shall be used.

3.2. Core

Made of high-quality cold rolled grain oriented low losses steel.

3.3. Bushings

Basic bushing requirements:

- Type of insulating body HV and HV-N: RIP or RIS
- Type of insulating body LV: Resin Silicon
- Capacitive graded insulator body: HV and HV-N mandatory, LV to be determined
- Voltage test tap: yes, on HV
- Material of sheds: Silicone
- Colour of sheds: light grey
- The bushings shall be equipped with an integrated sealing system preventing transformer oil to come out from the transformer main tank in case of any (mechanical) damage of the bushing.

Specific bushing requirements:

- The primary terminals shall be suitable for connection to lines.
- The secondary winding terminals shall be suitable for connection to a metal enclosed cable connection. Current rating of bushings must be adapted due to surrounding ambient temperatures.
- The applied clearances at outside bushings are sufficient, when at testing with lightning or switching impulse test no flashover occur.

The current rating of bushings shall be minimum (120% of) rated current (and in lowest/minimum tap position when applicable) and short circuit currents.

3.4. Current transformers

Only current transformers shall be installed for measuring winding temperature. Specifications to be determined by supplier.

3.5. Main tank

The tank shall be constructed with a flat bottom (water collection points will be avoided) suitable for placing the transformer on a concrete foundation. Vibration pads between transformer and concrete must be delivered by supplier, capable of solving roughness of concrete surface of 3mm. Tank cover must be bolted.

Transformer must be able to be placed by sliding, organised by the transformer company.

Transformer shall be equipped with separate air dryer breathers, one for main tank and one for OLTC. Air dryer breathers shall be of the automatic silica gel regenerating process and maintenance free type.

The power transformer tank, valves, radiators and oil piping shall withstand full vacuum. For vacuum treatment of the power transformer on the site after an inspection or reparation requiring partial draining of the oil, a flange with valve for a vacuum pump shall be fitted to the upper part of the power transformer tank.

All bolted parts including flanged connections, which are sealed with gaskets must be electrically connected with earthing strips. All bolts and nuts shall be of metrical thread and of galvanized and/or stainless steel.

The transformer tank shall be provided with:

- Two oil tapping points for collecting samples, **one from top and one from bottom oil.**
- Four jacking lugs at the corners of the tank suitable for lifting the total weight of the power transformer, distance to the ground: ≥ 400 mm. Each jacking lug must withstand half of the weight of the power transformer.
- Clear markings of mechanical center and the center of gravity
- Valves for filling, draining and purification of the oil, for taking oil samples (also when the power transformer is energized, from the tank top and bottom), and for removal of each of the radiators.
- Lifting eyes for the cover and conservator
- Towing eyes on all sides of the tank.
- Fall protection with a safety line on the cover of the transformer.
- Ladder brackets.
- Two ground terminals of stainless steel (RVS316L) at the bottom of the tank, minimal dimensions: 80 x 50mm
- Ground terminals to ground the bushings.

The power transformer shall be completely oil-tight for all parts.

3.6. Oil temperature indicator

A top-oil temperature indicator shall be provided. The power transformer shall be fitted with a weatherproof dial-type thermometer capable of withstanding power transformer vibration, for tank top-oil temperature measurement of the oil-filled power transformer. The thermometer shall be provided with an adjustable alarm contact and with a tripping contact, and, moreover, with a maximum indicating pointer with a resetting device. The scale and setting shall range up to at least $+120^{\circ}\text{C}$. Indicators must be readable from the ground level.

Temperature sensors (PT100) must be available for both top oil as winding temperature measurement.

3.7. Over pressure relief device plate

Over pressure relief devices to be provided on main tank and OLTC and shall be well drained and protected against corrosion. Possible oil stream following opening of over pressure valve shall be directed to a safe location.

3.8. Buchholz

The power transformer shall be protected by two Buchholz relay in an accessible (even when the power transformer is energized) place. One Buchholz for the main tank, one for the OLTC. The Buchholz relays shall be fitted with one alarm and with two tripping contacts. There shall be gas-collecting pipes for the cushion-like spaces, and the power transformer cover shall slope so that the smallest amounts of gas immediately flow to the Buchholz relays. External short circuits must not cause the Buchholz relays to operate.

The scope of supply includes for each power transformer a device for testing the Buchholz relay, equipment for collecting gas samples and the relevant instructions in Dutch or English.

3.9. Oil conservator

Two oil conservators are required, one for the main tank, one for the OLTC. The oil conservators shall be supported by transformer or cooling bank. The oil conservator shall be detachable from its stand. It shall have an adequate capacity to allow for the extreme changes in oil level when the power transformer is off-circuited at -25°C and when the power transformer is fully loaded at **$+40^{\circ}\text{C}$** ambient temperature.

The main oil conservator and the expansion space shall be fitted with filling openings and draining valves (NEN-EN 50216).

The oil in the conservator must be hermetically closed from the outside air, for example by means of an oil and ozone resistant rubber membrane.

3.10. Oil-level indicators for conservator

Dial-type oil level indicators shall be fitted for the main oil conservator and for the expansion space readable from the ground, provided with alarm contacts for low and high oil levels. The oil level indicators shall bear marks indicating, in addition to the maximum and minimum oil levels, the correct oil level at three different temperatures of average oil, e.g. -10°C, +25°C and +70°C. It must be possible to test the contacts without emptying the conservator.

3.11. Oil

The manufacturer shall take adequate provisions to eliminate the risk of corrosive sulfur compounds in the oil. The quality of the oil will be determined in accordance with the latest IEC and ASTM tests.

During the FAT and SAT tests the transformer shall be filled with the identical type of oil as intended for operation.

The transformer shall be filled with new oil and not regenerated used oil.

3.12. Cooling

The radiators shall be attached to the power transformer tank. Each radiator shall be connected to the tank through two valves, with an indication "open-closed" position.

Each radiator shall be provided with an air release valve and a draining valve according to NEN-EN 50216.

3.13. Temperature increases

Measurement of the temperature increase of winding and oil takes place at least at the highest rated power which leads to the largest temperature rise in the transformer.

Fiber optic temperature sensors shall be installed in the main winding of the middle phase for the hotspot temperature rise measurements during temperature rise test.

3.14. Valves and pipes

Valves shall be suitable for outdoor use, for application in the oil pipes of power transformers. Their purpose is filling, draining and purification of the oil, for taking oil samples (also when the power transformer is energized, from the tank top and bottom), and for removal of the radiators.

Main characteristics of valves are:

- ~~wedge type~~
- ~~cast iron valve body~~
- used in conservator pipes & cooler pipes
- fire-proof and resistant to transformer oil exchangeable when valve is shut
- operated manually by hand (on-site).

3.15. Earthing and EMC

All electrical equipment installed on the transformer shall fulfil the EMC requirements of IEC/TS 61000-6-5 for "Equipment installed in HV substations". Cable penetrations and cable glands shall be of EMC type where the cable shielding is connected to the wall of the housing.

The housing, the frames, demountable and swing frames, mounting plates, gland plates, etc. shall be equipped with a corrosion free M6 screw hole or a welded M6 bolt at least 15mm long. These connections shall be corrosion free, clean, and free of paint. All parts shall be earthed according to the standards and to achieve the prescribed EMC level.

Earth connections shall be flexible with yellow/green insulation and where applicable flat litze with minimal width of 20mm.

3.16. Short-circuit forces

The transformer must withstand the forces resulting from the assigned short-circuit power for the specified length of time. For the calculation of single-phase or three-phase short-circuit currents through the transformer, manufacturer must take into account the actual values of the supply voltages, such as those that can occur during normal operation, during overloads or sudden loss of load. The resulting short-circuits currents form the basis for assessing the thermal and dynamic short-circuit resistance of the transformer. The verification of the short-circuit resistance of the transformer is part of the design assessment.

3.17. Vibration

Three, 3-axis shock impact recorder shall be installed to monitor shock impacts during transportation and installation. The manufacturer shall inform the customer about the manufacturer's criteria before transport takes place and what additional inspections and tests the manufacturer will perform when criteria are not met. The logged data shall be analysed and shared with the customer.

3.18. Environmental requirements

The transformer, including all accessories, oil and other materials shall fulfil the national and international regulations and should not contain PCBs.

3.19. Corrosion protection

The power transformer tank and other weather-exposed parts shall be reliably protected against corrosion. The manufacturer shall specify the method of corrosive protection for approval by the customer.

The corrosion protection of the power transformer shall comply with as a minimum ISO12944 Category C5-VH (> 25years).

3.20. On-Load Tap Changer

The transformer shall be equipped with an on-load tap changing (OLTC) mechanism on the high-voltage side, designed for high reliability and ease of maintenance, meeting the following mechanical requirements:

- The OLTC diverter switch shall be housed in a dedicated, oil-tight compartment separate from the main transformer tank.
- Pressure relief devices to be provided and shall be well drained and protected against corrosion. Possible oil stream following bursting of a disc shall be directed to a safe location.
- Maintenance Access: The OLTC head shall feature a removable bolted cover, allowing for full access to the diverter switch for inspection and maintenance without the need to drain the main tank.
- Manual Operation: A manual hand-crank for emergency operation shall be provided. It must be electrically interlocked to automatically disable the motor drive during manual use.
- Automated operations: The OLTC should be able to be operated from a voltage control device. The actual tap level should be readable available by a BCD code.
- Secondary cabinet must apply to the requirements stated in chapter 4.
- Visual Indicators: The mechanism shall include a mechanical tap position indicator and a non-resettable operations counter, both visible from ground level through a weatherproof window.
- OLTC must be from MR, other suppliers can be offered as option and are only allowed after acceptance by customer.
- OLTC must have a vacuum type diverter switch.

4. Secondary systems

4.1. General

Components, instruments and materials shall be of standard available type, be suitable for the intended application, and the ambient circumstances of the application.

Special attention shall be given to touchable live parts. Additional to the relevant standards these parts have to be covered by transparent, easily removable cover plates. These cover plates shall be free from sharp rims and edges.

Auxiliary supply voltages made available by the Customer:

- 400/230Vac +/-15%

Auxiliary control voltages made available by the Customer:

- 110Vdc +/-15%

4.2. Control cabinet

- The control cabinet shall be fitted with insect protected ventilation holes and draining eyelets.
- The degree of protection shall be IP65 with closed doors and IP21 with open door.
- The minimum free space under control cabinet shall be 500 mm. In case of control cabinet with a swing frame the door will open to left with an open angle of at least 150°. The open position can be locked with robust provisions.
- The opening angle shall be achieved also with adjacent housing regardless the positions of the adjacent doors.
- Control cabinet without swing frames shall have doors with an opening angle of at least 115°.
- Components and instruments shall be easily accessible for maintenance, commissioning and fault investigation and replacement.
- The control cabinet shall be equipped with lighting and a power socket for maintenance. Lighting and socket shall be equipped with protecting relays for short circuit, overload and 30mA earth differential current. The protection of lighting and sockets may be combined.
- The live parts laying in the cabinet around a device to be handled when operated must be sufficiently protected against accidental touching.
- Control cabinet shall be installed with heating to prevent condensation. Touchable elements will have a maximum temperature of 60°C. The heating element will have a maximum temperature of 90°C. The hot air or radiation of the element may not have any negative effect on components, wiring etc.
- Collection of fluids on the inside and outside of the housing shall not occur.
- Cable penetrations and cable glands shall be equipped with mechanical strain relief. Cable penetrations will be in the bottom of housings. Unused cable penetrations and cable glands shall be covered according to the required IP class.
- Cable penetrations and cable glands shall be 30 minutes flame retardant and EMC prove.

4.3. Coding

Apparatus, components and cabinets shall be marked in a permanent way, durable and clearly readable for over 40 years with a unique code marking shall consist of synthetic white marking plates with black text.

Terminal strips and/or terminal blocks shall be marked with a unique number. Terminals shall be numbered consecutively in each terminal strip or block from left to right and from top to bottom. Terminals with the same number may not appear in the same block. The terminal shall be coded at the cable side. Terminal of supply circuits shall be provided with an additional code to indicate the supply circuit, for example: L1, L2, L3, N, GND, R, U, +, -, +110Vdc, 0Vdc, etc.

Each wire end shall be provided with one or more coded captive rings which correspond to the code of the terminal or connection to which the wire end is connected. Clamp rings are allowed when guaranteed for the lifetime and no damage to the wires occurs.

The use of self-adhesive stickers is not allowed.

4.4. Cable sizing

Unless otherwise specified, cables shall be sized for continuous service at full load and of a proven design. Sizing shall be based on International Electrotechnical Commission (IEC) standards and in particular the following:

- Current carrying capacities conform to IEC 60287
- Rating factors appropriate for the method of installation.
- Load factors.
- Allowable circuit voltage drop as specified in the list below
- Limitation of conductor temperature rise during short circuit to 250°C for XLPE insulated cables (for sizing see NEN 1010)
- Maximum cable length based on end of line faults.

Feeder cables to sub distribution systems shall be sized for 125% apparent power or the nameplate power whichever is the highest.

Maximum voltage drop:

- LV distribution system cables: 1%
- Cables to lighting and small power panels: 1%
- Cables to lighting fixtures and socket outlets: 4%
- Cables to tracing panels: 2%
- Cables to tracing circuits: 3%

Total voltage drop seen from LVDB should not exceed 5%.

Minimum conductor sizes for LV installations shall be as follows:

- main power supply circuits AC/DC from main terminal to mini circuit breaker 4 mm², 0.6/1 kV
- main power supply behind the mini circuit breaker to the terminal row 2,5mm², 0.6/1 kV
- for circuits of current transformers 4 mm², 0.6/1 kV
- for circuits of voltage transformers 4 mm², 0.6/1 kV
- for control circuits, signal circuits and other circuits 1,5 mm², 0.6/1 kV
- lighting circuits 2.5 mm², 0.6/1 kV

Cabling must also meet following requests:

- Power and control cables shall comply with NEN-EN-IEC 60502 with vertical flame spread characteristics in compliance with NEN-EN-IEC 60332-3-22 (Category A).
- Cable shall be heat resistant up to and including 90°C
- All cabling shall be of low smoke, halogen free type and oil resistant.
- All Low Voltage cables, except EMC cables shall be of the type YMZK as mbzh
- Instrumentation cabling shall be flexible and have a cross section of 0.75 mm² as a minimum. For Profibus and Profinet cabling, the right color shall be used (purple for Profibus and green for Profinet)
- In principle all cables shall be shielded.
- Minimum conductor sizing shall be determined by considering, permissive current, ambient temperature, grouping factor, installation method, voltage drop and short circuit rating
- Systems as Control system, fire alarm system etc. shall make use of the fiber optic cables
- Ethernet cabling shall be of Category 6 (CAT 6) or (STP).
- Only one voltage level per cable will be applied.
- For signals (4-20 mA / 0-10 mV) separate cables will be applied.

4.5. Cable ladders and trays

Following requests must be met:

- Cable ladders and trays, including all accessories shall be aluminum. Synthetic pipes are not allowed), minimum height 60 mm, with a rung spacing of 100mm Iron parts shall have a sealed zinc system primer coating
- All necessary auxiliary steel constructions, etc. are part of the Works. The cable tracks shall be fastened so that the construction is sufficiently rigid
- Cable tracks shall be connected to the earth /potential equalization at several places
- Cable tracks shall be provided with galvanic interconnections to ensure that the system will form a grounded conducting unit
- The cables shall be led from the cable ladders by cable guides and any supplementary protection to their final destination. This includes for example hot dip galvanized guide pipes from the cable ladders to the motors or extra cable ladders for multi core and control cables. The delivery and installation of adequate cable guides is part of the Works. The endings of cable guides shall be finished off with appropriate material so that there is no risk of damage to the cables
- Cable tracks shall have a minimum usable spare space of 40% after installation of the cables.

4.6. Erection cabling and wiring

Following requests must be met:

- Cable naming should be based on the standard NEN-EN-IEC 81346.
- The nameplates shall be fixed to the mounting plate, the mounting brackets or junction box. The design of the nameplates is subject of approval by the customer
- In particular, wiring within cubicles and panels shall be suitably supported and shall be segregated according to voltage level. Wiring carrying Alternating Current (AC) and Direct Current (DC) voltage shall also be segregated
- Cabling and wiring of intrinsically safe circuits (type of protection EEx i) shall be done as stipulated by the corresponding "ATEX"- regulations
- Spare cores shall be connected at terminal strips
- After commissioning 20% of the conductors of multi-core cables shall be available.

4.7. Cable installation

Following requests must be met:

- Wiring must be laid straight and clearly arranged, without loops, the wires can be visually followed, and no strain is put on the connection points or the cable penetrations wire, wire bundles, wire tubes, flat cables and suchlike shall be routed in such a way that no damage to the wires can occur by passing sharp edges, closing doors etc.
- Supply, routing and connection all of the, for a properly functioning system, necessary cables are within the scope of the manufacturer.
- The work of the manufacturer includes:
 - o The supply and installation of all cable trays and ladders
 - o The supply and installation of tubular structures for cable passage from cable trays/ladders to consumers
 - o All accessories such as brackets and supports are also the delivery of the manufacturer
 - o Control and signal cables shall be installed in a separate cable carrying system, isolated from strong current and control current cables (400/230V and higher).
- Storage and handling of cables before and during installation shall be carried out in accordance with manufacturer's instructions for handling, storage and installation.
- Open ends of cables shall immediately be sealed after cutting to prevent ingress of moisture. Seals shall be kept in place up till cables are terminated
- Cable routes for auxiliary cabling, such as lighting, tracing and communication, shall avoid high-risk areas such as potential fire and leakage sources
- Where cables are liable for mechanical damage or exposed to excessive sun radiation or deterioration may occur by possible liquid leakage, they shall be protected by means of metallic conduit or tray covers in case the cables are installed in open trays.
- At all times the utmost care shall be exercised to avoid damaging the protective sheathing of the cable, or of twisting which may result in damaging of the core insulation, sheaths, armor, etc.
- Cable joints are only permitted in case the required length exceeds the commercially available drum length
- Cables shall be pulled following the installation instructions of the manufacturer

- Generally non-metallic glands shall be used for non-metallic enclosures and metallic glands for metallic enclosures. When adequately mechanically protected and installed, fiber optic cables may be installed in electrical trenches or on tray systems.

The cable laying on the equipment shall be in such a way that:

- Energy cables and signal cables are separate
- As much bundled laying as possible
- Fixing of the cables in a durable way and resistant way (no plastic cable strap)
- No squeezing of cables
- No bending over sharp edges

The wiring between the fittings (such as protective devices) and control cabinet of the power transformer shall be mounted at the works. The cables shall be metal sheathed.

Coding with colours and / or numbers shall comply with NEN1010 table C51-1.

4.8. Jointing technology

The following connections are approved:

- screw connections:
 - at insulated crimped eyelet cable-lugs applied in measuring circuits
 - at insulated crimped fork or pin type cable lugs
- soldered connections:
 - shall only be applied in case of prescription by customer for the concerning connection.
- connectors:
 - shall only be applied in case of prescription by customer for the concerning connection
- pinch connectors:
 - spring pressure type.

For all techniques above the following rules apply:

- each connection shall reliable and guaranteed
- all terminal screws, including empty terminals, have to be tightened to the correct torque
- in case the connection point consists of two screws (for example relay sockets), both screws shall be used for connection maximum one cable-lug or pin may be secured under one screw connection
- flexible wire ends shall be provided with insulated crimped cable-lugs regardless the prescriptions of the terminal block. Both pin and ring cable terminations are allowed, whereas the ring type prevails.
- connections shall be equipped with provisions for anti-loosening by shock and/or vibrations. Cable lug terminations shall be made with the proper tools only, equipped with an automatic release device which guarantees proper connection.
- only one conductor per terminal will be connected.

4.9. Terminals

All wiring and cabling shall be connected on terminals that comply with the following requirements:

- For connecting and testing all auxiliary circuits, moisture-proof terminals of at least 10 mm² and 10 or more extra terminals shall be fitted in a cabinet attached to the power transformer tank. The terminals shall be breakable and provided with 4 mm plug holes.
- Type: spring pressure or screw terminal
- Flexible wire ends shall be provided with insulated crimped cable-lugs regardless the prescriptions of the manufacturer of the terminal block. Terminals of current transformer circuits cannot be opened
- For account measuring, the terminal block shall enable periodic checking and the connection of calibration and measuring instruments is possible, safe and simple. Measuring instruments can be connected into the current loops. The terminals shall be installed as close as possible to the measuring instrument
- Materials: thermoplastics, polyamide PA or better quality, halogen free and flame retardant
- End-plates shall be applied:
 - on the end of a terminal strip
 - between terminals of a different type
- Separation-plates shall be applied between groups:

- between terminals which belong to different voltages or phases
- between terminals of different circuits
- between terminals of different current transformer circuits
- between terminals of + and - of DC circuits
- between terminals of different functions
- behind each connection bridge

4.10. Test voltages

- The following AC-test voltages apply:
 - For motors of the cooling system: 1500 V, 50 Hz, 1 minute
 - For gas relays, remote controlled thermometers etc.: 1000 V, 50 Hz or 2000 V DC, 1 min
 - Other auxiliary wiring and components: 2000 V, 50 Hz, 1 minute

4.11. Monitoring equipment

At least three glass fiber sensors for measurement of the hot-spot and top oil temperature shall be applied.

4.12. Auxiliary voltages

All auxiliary contacts shall be suitable for:

- AC: 230 V, 5 A, $\cos\varphi = 0,85$
- DC : 110 V, 5 A, time constant ≤ 40 ms.

5. Nameplates

All parts and components shall be equipped with nameplates made of corrosion free material. The nameplates shall be readable for a minimum period of 40 years. Name plate will contain at least manufacture, type number, ratings and standards stated on it. This plate has to be fitted to the apparatus in a clearly visible place.

- Language of the name plate Dutch or English
- Language of the manuals Dutch or English
- Language of the control and service instruction Dutch or English
- Operating and safety devices shall be identified with a code plate that corresponds to the parts list from the maintenance instructions.
- The name plate, diagram plate and the piping diagram shall be attached to the transformer in a clearly visible place.

6. Documentation

All files and documents to be in Dutch (preferably) or in English (as minimum).

Following information shall be submitted to the customer:

- Electrical Design Documents
 - o Rating Plate Preliminary
 - o Connection Diagram Preliminary of power transformer
 - o Calculation of Inrush Current Curve with Harmonics
 - o Calculation of Thermal Damage Curve
 - o Calculation of Overexcitation Curve
 - o Fingerprint measurement as zero moment for management and maintenance phase
- Mechanical Design Documents
 - o As-Built Documentation
 - o Drawing of Outline Drawing
 - o Drawing of Parts List (Annex to Outline Drawing)
 - o Drawing of Valves Function and Location Plate
 - o Drawing of Loading Plan / Shipping Dimensions
 - o Drawing of Rating Plate
 - o Drawing of Connection Diagram
 - o Drawing of Schematics of Control Cabinet
 - o Drawing of Schematics of OLTC Control Cabinet
 - o 3D Model of transformer in Revit format
 - o Method statements / plans for lifting and erection on site by Supplier to be provided
- Quality Documents
 - o Inspection and Test Plan for Type Test
 - o Inspection and Test Plan for Routine Test
 - o FAT/SAT Electrical Test Protocols
 - o FAT/SAT Mechanical Test Protocols
 - o FAT reports
 - o SAT reports
- Manuals
 - o Installation manual
 - o Operation manual
 - o Maintenance manual
 - o Equipment documentation
- List of recommended spare parts

Note:

During basic design of the transformer, manufacturer must supply parasitic capacitances of the windings for the transient study to be able to make a dynamic model of the transformer.

All documents will be delivered as AS-BUILT after the SAT.

6.1. Datasheet

Data sheet (see Appendix 1) must be completed by the manufacturer and handed over to the client as part of the offer.
All data supplied are guaranteed values.

7. Quality assurance

7.1. General

The tests shall be performed in accordance with the applicable IEC standards, unless otherwise stated in this specification. All tests must be in the manufacturer's quality test and inspection plan and shall be approved by customer for delivery.

All tests at the factory are applicable to the fully installed transformer including bushings and other subsystems.

Under the supervision of customer or its representative the factory acceptance test (FAT) will be arranged as follows:

- The FAT will be announced at least six weeks prior.
- The required FAT program will be submitted to Customer for approval at least 8 weeks before the start of the FAT. The FAT program has to be approved by **Customer at least 2 weeks** before the start of the FAT.

For all bushing a full type test report shall be delivered **at least 8 weeks before the start of the FAT.**

7.2. Tests during design

Supplier shall organize a design review session at which the electrical and mechanical design of the transformer is discussed in detail between supplier and client. The proposed/draft FAT program is part of the EDR.

Supplier shall provide tank rupture calculation verifying tank is capable to withstand **over pressure shock.**

7.3. Tests during FAT

Purpose of the Factory Acceptance Test (FAT) is to prove and confirm that the transformers are meeting the technical specification. All terms and conditions for the FAT shall be as specified in IEC standard.

Routine tests: all routine tests mentioned in IEC 60076-1:2011 cl. 11.1.2, both cl.11.2.1 and cl.11.2.2 (i.e. ignoring the pre-condition of Um) shall be performed and in accordance with this clause. Additionally, the following checks on:

- Bushings
- Auxiliary wiring and equipment
- Fittings
- Nameplate
- Dimensions
- Corrosion protection / surface treatment.

Type tests: all type tests mentioned in IEC 60076-1:2011 cl. 11.1.3 shall be performed and in accordance with this clause including addition:

The following dielectric special tests shall be performed as Routine test (i.e. on each individual unit):

- **Chopped wave lightning impulse test for the line terminals (LIC)**
- **Lightning impulse test for the neutral terminals (LIN)**

Special tests: the following special tests of IEC 60076-1:2011 cl. 11.1.4 shall be performed:

- **IVPD test**
- Winding hotspot (Special test to be performed as Type test (during TRT-test))
- Measurement of zero-sequence impedance(s) on three-phase transformers (Special test to be performed as Type test)
- Measurement of frequency response (Frequency Response Analysis or FRA). (Special test to be performed as Routine test)
- Measurement of dissolved gas analysis: before and after temperature rise test. (Special test to be performed as Routine test)
- Measurement of dissolved gas analysis: before and after dielectric test. (Special test to be performed as Routine test)
- DGA analyzes during FAT and SAT for fingerprinting for maintenance phase.

Note:

- If more than one identical transformer is delivered, temperature rise test has only to be performed on one unit, to be appointed by customer. Photos should be captured by infra-red camera during temperature rise test in each cooling cycle and shall be reported.
- Performing type tests for components (e.g. bushings, CT's) within the FAT are excluded.
- Short circuit test as per IEC 60076 is excluded. Proof to withstand short circuit by calculation in full accordance with IEC 60076-5.
- The dielectric strength, and the particle and moisture contents of oil shall be determined by testing oil samples taken from the power transformer tank. Moreover, the results of tests made in accordance with NEN-EN-IEC 60296 on a sample taken from the oil shipment in question shall be appended to the test report.

7.4. Site tests SAT

All test reports must be submitted to customer for acceptance.

All tests shall be in accordance with IEC 60076 with the following modifications and / or additional tests:

- Check of shock recorders
- Visual inspection
- Functional tests of accessories
- Oil sample test including gas analysis.
- Measurement of winding resistance
- Ratio and polarization test on all integrated CT's if applicable.
- Check of core and frame insulation for liquid immersed transformers with core or frame insulation
- Determination of capacitances windings-to-earth and between windings
- Measurement of DC insulation resistance between each winding to earth and between windings
- Measurement of dissipation factor ($\tan \delta$) of the insulation system capacitances
- Leak testing by means of visual inspection with a pressure of at least 30 kPa over the normal liquid pressure for 24 h (tightness test)
- Measurement of frequency response (Frequency Response Analysis or FRA) with and without HV and LV connections made. Report of comparison of measurements between FAT and SAT has to be delivered to client.

7.5. Reports

The electric-magnetic design of the transformer shall be submitted to the customer. A detailed design review by the customer (or representative) with the designers of the transformer manufacturer shall be organized by the manufacturer. Besides all other technical topics, the magnetic stray field calculations, additional losses in windings (hot-spot factor) and structural parts shall be included in the design review. Load losses shall be split into winding losses, (ohmic and additional) and additional losses not in winding.

A tank rupture report based on Cigré TB537: Guide for Transformer Fire Safety Practices, Working Group A2.33, June 2013 shall be submitted to the Customer.

8. Packing, transport and unloading

The manufacturer is responsible for loading, transport, unloading and placing on side.

The products shall be packaged to prevent damage during transport. Packaging made of plastic should be avoided.

The manufacturer of the power transformer is responsible for the transport of the power transformer to the site. The transformer shall be suitable for road and overwater transportation. The manufacturer is responsible for repairing all damage caused by transport of the transformer.

The manufacturer shall indicate the exact route to the substation.

During transport and installation on the foundation vibrations shall be monitored with at least two shock-recorders (x,y,z-coordinates), the recordings shall be submitted to customer. After the transport the manufacturer shall submit an overview of the transport documentation.

On request, specific information requested by the user shall be noted on the delivery container or individual packaging.

9. Erection and commissioning

Manufacturer scope include erection and commissioning and this applies:

- The erection and commissioning shall include the provisioning of technical personnel, tools and lifting equipment. The customer shall have the necessary training to install the equipment on site.
- In the substation the transformer will be filled with the operating oil, assembled and tested according to this specification.
- The manufacturer shall submit a drawing stating the support of the transformer and the maximum load in kN per mm².

10. Performance guarantees

Previously mentioned and described tests may be witnessed by a third party.

Maximized performance requirements:

Test No.	Performance Values (PV)	Maximum allowed values
1	Total Sound Power Level of transformer:	80 dB(A)
2	No-load losses at 100% Ur:	55 kW
3	Load losses at rated power, rated tap position and 75°C:	450 kW

11. Service life, maintenance & warranty

The technical service life of the power transformer shall be at least 25 years. This means that spare parts shall be available for all equipment for this time period.

The Works shall be designed in a way that first line maintenance can be performed by Customer's personnel without special training other than agreed upon.

The manufacturer guarantees that all Parts meet at least the Customers requirements and have those properties that have been agreed upon or that can reasonably be expected from these Parts. The Parts shall be free of defects, suitable for the purpose for which they are intended and meet the legal requirements and other government regulations, as well as the requirements of safety and quality standards, all as they apply at the time of conclusion of this Agreement.

Warranty is according to the Contract.

The manufacturer guarantees that replacement (spare) parts must remain available during the design lifetime. If replacement (spare) parts are no longer available, the manufacturer will provide a suitable alternative with equal form, fit and function.

12. List of abbreviations

HV	High Voltage
MV	Medium Voltage
LV	Low Voltage
Um	Maximum Voltage
Ur	Rated Voltage
fr	Rated Frequency
Ik"	Initial symmetrical short circuit current
Ip	Rated peak withstand current
tk	Rated duration of short circuit
IPB	Insulated Power Bus
Pk	Load Losses
Po	No-Load Losses
Io	Current during No-Load test
Uk%	Short Circuit impedance
ONAN	Oile-Natural-Air-Natural
LAR, LT	Long term average over a period of 24h
TR	Power Transformer
PF	Power Factor
NEN	Nederlands Normalisatie-instituut
EN	European Norm
IEC	International Electrotechnical Commission
DIN	German Institute for Standardisation
ISO	International Organization for Standardization
ASTM	American Society for Testing and Materials
ATEX	European Directives for controlling explosive atmospheres
RIP	Resin Impregnated Paper
FAT	Factory Acceptance Test
SAT	Site Acceptance Test
EMC	Electromagnetic Compatibility
IP	Ingress Protection
PCBs	Polychlorinated Biphenyls
R	Resistance
DC	Direct Current
AC	Alternating Current
KKS	Kraftwerk-Kennzeichensystem
XLPE	Cross-linked polyethylene
PA	Polyamide
LVDB	Low Voltage Distribution Board
CAT6	Category 6
STP	Shielded Twisted Pair
IVPD	Induced overvoltage withstand test with partial discharge
TRT	Transformer Turn Ratio Test
FRA	Frequency Response Analysis
DGA	Dissolved Gas Analysis
CT	Current Transformer
PD	Performance Damage
PV	Performance Value
MAL	Minimal Acceptance Level

Appendix A - Data sheet

This data sheet must be completed by the manufacturer and handed over to the client as part of the offer. All data supplied are guaranteed values.

Rated voltages and frequency	
Voltage ratio primary / secondary side	
Voltage regulation range	
Maximum system voltage (Um) – HV SIDE	
Maximum system voltage (Um) – HV-N	
Maximum system voltage (Um) – LV SIDE	
Rated lightning impulse insulation level - HV SIDE	
Rated lightning impulse insulation level – HV-N	
Rated lightning impulse insulation level - LV SIDE	
BIL Chopped wave level - HV SIDE	
BIL Chopped wave level - LV SIDE	
Rated power frequency withstand voltage HV SIDE	
Rated power frequency withstand voltage LV SIDE	
Rated frequency (fr)	
Rated power	
Rated power at ONAN cooling	
Rated power at ONAF cooling	
Winding and temperature	
Winding configuration	
Hot spot windings temp rise	
Average windings temp rise	
Top oil temp rise	
The partial discharge level	
Total Sound Power Level at 100% Ur and 100% Ir - LwA(total) (Guaranteed value)	
Sound Power Level at 100% Ur - LwA(Ur) (for information)	
Sound Power Level at 100% Ir at rated tap - LwA(Ir) (for information)	
Short circuit losses and impedance for positive and zero sequence at 160MVA	
Transfer ratio at Maximum - Rated - Minimum tap position	
Short-circuit impedance (Uk) in % at 75 ° C (HV-LV)	
Short-circuit impedance (Uk) tolerance at 75 ° C (HV-LV)	
Load losses Pk @ 75°C	
Load losses Pk @ 75°C tolerance	
Winding losses I²R at 75°C (kW)	
Stray losses at 75°C (kW)	
No-load losses and current at assigned frequency and Ur	
Voltage in % of the rated voltage 90 /100 / 110	
No-load losses Po in [kW] at assigned frequency and Ur	
No-load current Po in % of the assigned flow at the highest allocated power for positive and zero sequence	
No-load losses Po tolerance	
Io in % of In	
Higher harmonic components in the no-load current in % of the allocated current at the highest rated power 3rd harmonic 5th harmonic 7th harmonic	

9th harmonic	
X/R	
Positive sequence X/R	
Zero sequence X/R	
Feed-through insulators	
Line connection terminal: HV LV - Brand - type - rated current A A - capacitance pF pF	
Isolation levels A. Low frequency voltage kV kV B. Lightning voltage kV kV	
Star point clamp: - Brand - type - rated current A A - capacitance pF pF - isolation levels - Low frequency voltage kV kV - Lightning voltage kV kV - Switching voltage kV kV	
Tap changer	
- Brand - type - assigned current A - number of positions - type of scheme	
Cooling - provide if applicable Number (= n), Brand, Type, Power (kW/pc or MW)	
Oil Radiators Assigned power for (n-1) radiators Calculated hot-spot temperature Applied hot-spot factor	*Specify conditions for the calculation
Dehydrating breather - provide if applicable Brand, Type, Weight (kg)	
Main conservator OLTC conservator	
Constructive details – provide core/shell type	
Position of the windings core - - - Type of winding Core	
Flux density in yoke T Flux density in core legs T	
Maximum withstand AC voltage	
in LV winding in case of an earth fault in the heart of the second windings kV	
Maximum withstand lightning voltage	
in LV winding due to a single or 3-phase impulse on one of the other windings kV	
Inrush current	
In kA for PRIMARY/SECONDARY side	
Zero sequence impedance (Ohms per phase)	

Primary side: Secondary side open Ω Ω Ω Secondary side shorted Ω Ω Ω	
Secondary side: Primary side open Ω Ω Ω Primary side shorted Ω Ω Ω	
Capacities (3 phase)	
3-winding transformers, including feed-through insulators: core and – LV pF LV – MV pF MV – HV pF HV tank and core pF MV tank and core pF	
2-winding transformers, including feed-through insulators: core and tank – LV pF LV – HV pF LV screen (if applicable) pF screen – HV (if applicable) pF HV tank and core pF	
Weights	
Total weight, including oil, conservator and radiators (if mounted on the transformers) t Weight of the radiators (if mounted separately) t Transport weight including oil t Transport weight excluding oil t Oil weight t Active part weight t	
Dimensions	
Height up to top of conservator.....mm Height up to top of cover.....mm Height up to top of HV bushings.....mm Length overall.....mm Length with radiators.....mm Width overall.....mm	
Dimensions for transport	
Length.....mm Width.....mm Height.....mm	
Surface treatment	
Specification of proposed surface treatment	