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General ABB specification for HiDry Power Transformers

Table of Contents

1	SCOPE	4
2	GENERAL.....	4
2.1	Reference laws, standards and codes.....	4
2.2	Laws.....	4
2.3	International standards.....	4
3	SERVICE CONDITIONS	5
3.1	General	5
3.2	Standard conditions.....	5
3.3	Seismic qualification levels.....	6
3.4	Installation	6
4	TECHNICAL ASPECTS.....	6
4.1	Types of transformers	6
4.2	Number of windings.....	6
4.3	Number of phases	6
4.4	Cooling system.....	7
4.5	Rated power.....	7
4.6	Temperature – Rise limit	7
4.6.1	Transformers designed for high cooling medium temperatures	8
4.6.2	Transformers designed for operation at altitudes greater than 1000 m.....	8
4.7	Rated voltages	8
4.7.1	High Voltages	8
4.7.2	Medium/Low Voltages.....	8
4.8	Rated frequency	8
4.9	High voltage tapplings.....	9
4.9.1	Off-load circuit tapplings.....	9
4.9.2	On-load circuit tapplings.....	9
4.10	Insulation levels and minimum air clearances.....	9
4.10.1	Bushings.....	10
4.10.2	HV and MV neutral.....	10
4.11	Losses and short circuit impedances.....	10
4.12	Over-excitation conditions	11
4.13	No load current.....	11
4.14	Inrush current	12
4.15	Over temperature of the core.....	12
4.16	Capability of withstand short-circuit	12
4.17	Sound levels.....	12
4.18	Overall dimensions.....	12
4.19	Climatic, environmental and fire behavior classes	13
5	DESIGN REQUIREMENTS.....	13

5.1	Core and frame	13
5.1.1	Lifting lugs and pulling Points	13
5.1.2	Core earthing	13
5.1.3	Wheels and wheel frame	14
5.1.4	Core assembly	14
5.2	Windings	15
5.2.1	HV and LV windings assembly	15
5.3	Windings connections	16
5.3.1	High / Medium Voltage connections	16
5.3.2	Low Voltage connections	16
5.4	Epoxy resin insulation	16
6	ACCESSORIES AND AUXILIARIES	16
6.1	Temperature monitoring	16
6.1.1	Windings	16
6.1.2	Core	17
6.2	Fans	17
6.3	Rating plates	17
6.4	Terminal markings	18
6.5	Warning plates	18
6.6	Lifting devices	18
6.7	Wheels	18
6.8	Grounding terminals	19
6.9	Protections	19
6.10	Security devices	19
6.11	Marshalling boxes	19
7	MAIN COMPONENTS	20
7.1	Terminal connections	20
7.2	On-load tap changer (OLTC)	21
7.2.1	Ratings	21
7.2.2	Design Requirements	21
7.2.3	Tests	22
7.3	Enclosures	23
7.3.1	Standard enclosure for indoors	23
7.3.2	Standard enclosure for outdoors	29
7.3.3	Insulators / wall-bushings for outdoors	33
8	PROTECTIVE PAINTING	33
9	TESTS	36
9.1	List and classification of tests	36
9.1.1	Routine tests	36
9.1.2	Type tests	36
9.1.3	Special tests	36
9.1.4	Inspection at factory	37
9.1.5	General statements for the tests	37
9.2	Test description	38
9.2.1	Routine tests	38
9.2.2	Type tests	39
9.2.3	Special tests	40
9.3	Commissioning	40

9.3.1	Test on field	40
10	SUPPLY REQUIREMENTS.....	41
10.1	Transport and storage	41
10.2	Package	41
10.3	Documentation	42
10.3.1	Documentation for the offer	42
10.3.2	Documentation for homologation, certification and approval	42
11	FIGURES.....	43
11.1	Layout diagrams.....	43
12	REVISION	44

1 Scope

The scope of this document is to provide technical requirements for the supply of the dry-type large power transformers to be used in the distribution networks / sub-transmission lines and generation.

2 General

2.1 Reference laws, standards and codes

The lists of some reference laws and standards, relevant for this document, are reported here below.

The equipment will be designed, manufactured and tested in compliance with the IEC, CENELEC, ISO, IEEE, codes and standards and the following codes and standards in particular shown latter.

Preference of codes and standards:

In case of conflict between this specification and any of the referenced codes and standards, the following order of preference shall apply:

- This specification
- Referenced codes and standards
- Acceptable alternative codes and standards

2.2 Laws

For the European countries, the performance efficiency of the transformers shall comply with the related European Commission Regulation (EU) No 548/2014 on Implementing Directive 2009/125/C regarding small, medium and large power transformers (in force from July 2015).

For other countries, national laws will have to be into consideration. For instance in Spain will be as follows:

- REAL DECRETO 614/2001, de 8 de junio, sobre disposiciones mínimas para la protección de la salud y seguridad de los trabajadores frente al riesgo eléctrico.
- Reglamento Sobre Condiciones Técnicas y Garantías De Seguridad en Centrales Eléctricas, Subestaciones y Centros De Transformación.
- Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances.
- Council Directive 1999/13/EC, of 11 March 1999, on the limitation of emissions of volatile organic compounds due to the use of organic solvents in certain activities and installations.

2.3 International standards

For America destinations the reference standard are the IEC/IEEE/ISO and for Europe destinations the reference standard are the correspondent European standards (EN).

EN 50629 Energy performance of large power transformers ($U_m > 36$ kV or $S_r \geq 40$ MVA)

IEC 60076-1	Power transformers – Part 1: General
IEC 60076-2	Power transformers – Part 2: Temperature rise
IEC 60076-3	Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-5	Power transformers – Part 5: Ability to withstand short circuit
IEC 60076-10	Determination of sound levels
IEC 60076-11	Power transformers – Part 11: Dry-type transformers
IEC 60076-12	Power transformers – Part 12: Loading guide for dry-type power transformers
IEC 60076-18	Power transformers – Part 18: Measurement of frequency response
IEC 60068-3-3	Environmental testing - Part 3-3: Guidance - Seismic test methods for equipment
IEC 60085	Thermal evaluation and classification of electrical insulation
IEC 60214-1	Tap-Changers – Part 1: Performance requirements and test methods
IEC 60214-2	Tap-Changers – Part 2: Application guide
IEC 60529	Degree of protections provided by enclosures (IP Code)
ISO 12944	Paints and varnishes – Corrosion protection of steel structures by protective paint systems

And all the standards referred in those listed above.

When the date of issue is not mentioned in the list above, the date to be taken as reference is that of the standard in force when the present document has been issued.

3 Service conditions

3.1 General

Unless otherwise specified the normal service conditions of Clause 4 of IEC 60076-11 apply. Transformers are generally used for step-down voltage purpose but they can also be used as step-up. In the network, they could occasionally be subjected to frequent energizations, over voltages and short-circuits.

3.2 Standard conditions

Standard service conditions are as follows:

- Altitude: Maximum 1000 meters above sea level (it must prevail the buyer's site conditions).
- Maximum ambient temperature: Never over 40° C and never below - 5° C (it must prevail the buyer's site conditions).

In addition, an ambient air temperature never exceeding:

- 30°C average in any one day (it must prevail the buyer's site conditions).
- 20°C average in any one year (it must prevail the buyer's site conditions).

(Note: other environmental conditions under customer request may be accepted).

3.3 Seismic qualification levels

The seismic qualification level must be in accordance with the final site installation.
As default, all designs shall be prepared in order to withstand zones 1, 2A and 2B, it means:

- Seismic horizontal acceleration: 0,2 g
- Seismic vertical acceleration: 0,1 g

For other higher seismic demands (i.e. zone 3, 4, u others) the Manufacturer may produce a report to demonstrate the seismic qualification level if required.

3.4 Installation

The type of installation will be preferably indoor.
In case customer requires an outdoors installation, the transformer needs to be protected mechanically with a metal or civil housing, in order to guarantee the IP degree depending on the environmental conditions.

4 Technical aspects

The transformer shall be designed so that they can deliver continuously its rated current under steady loading conditions without exceeding the temperature rise, assuming that the applied voltage is equal to the rated voltage and that the supply is at rated frequency.
For the definitions IEC 60076-11 applies.

4.1 Types of transformers

This document is applicable for dry-type large power three phase transformers, step-up (for GSU) or step-down and refers from the following type: separate windings transformer (TR).

Separate windings transformers are usually HV/LV, but they can also be HV/HV or MV/MV, in such cases they are conventionally indicated as HV/MV in the present standard.

Autotransformers or single-phase transformers can be also considered under customer request.

4.2 Number of windings

Number of windings should be preferably two (2).
Tertiary winding can be considered under customer request

4.3 Number of phases

Number of phases should be preferably three (3).
Also one-phase transformers are available (1)

4.4 Cooling system

Cooling system for dry-type large power transformers shall be natural air ventilation (AN) up to specified rating or/and with forced cooling (AF) to a higher rating.

Other cooling systems can be considered under customer request.

4.5 Rated power

Rated power should be preferably 1 MVA, 2 MVA, 5 MVA, 10 MVA, 12.5 MVA, 16 MVA, 20 MVA, 25 MVA, 30 MVA, 40 MVA and 63 MVA.

Other ratings can be also considered.

4.6 Temperature – Rise limit

The temperature rise of each winding of the transformer, designed for operation at normal service conditions, shall not exceed the corresponding limit specified in the Table 1 when tested in accordance with Clause 23 of IEC 60076-11.

Table 1

Insulation system temperature (see Note 1) °C	Average winding temperature rise limits at rated current (see Note 2) K
180 (H)	125
NOTE 1 Letters refer to the temperature classifications given in IEC 60085.	
NOTE 2 Temperature rise measured in accordance with Clause 23 of IEC 60076-11.	

The temperature rise of the winding is defined as the average temperature of the winding minus yearly average of the temperature of the external cooling medium.

The maximum temperature occurring in any part of the winding insulation system is called the hot-spot temperature. The hot spot temperature shall not exceed the rated value of the hotspot winding temperature specified in the Table 2.

Table 2

Insulation system Temperature °C	Rated hot spot winding Temperature °C	Maximum hot-spot winding Temperature °C
180 (H)	170	205

Components used as insulating material may be used separately or in combination providing that their temperature does not exceed the values given for the appropriate insulation system temperature in accordance with the requirements as prescribed in the left hand column of Table 2.

The temperature of the core, metallic parts and adjacent materials shall not reach a value that will cause damage to any part of the transformer.

4.6.1 Transformers designed for high cooling medium temperatures

During continuous service at the rated frequency and rated power, at any of the taps, for operation with AN cooling or AF cooling, the allowed heating will be the following:

For 40°C ambient temperature:

- Rated average winding heating 125K
- Rated heating of hottest winding point: 150K

In areas with special temperatures (50°C):

- Rated average winding heating 115K
- Rated heating of hottest winding point: 140K

The resulting maximum absolute temperature being (on both cases):

- For the windings 165°C
- For the hottest winding point 190°C

4.6.2 Transformers designed for operation at altitudes greater than 1000 m

According to IEC 60076-11 section 11.3, for transformers designed for operation at an altitude greater than 1,000 m but tested at normal altitudes, the limits of temperature rise given in Table 1 shall be reduced by the following amounts for each 500 m by which the intended working altitude exceeds 1 000 m:

- Natural-air-cooled transformers: 2,5 %
- Forced-air-cooled transformers: 5 %

Any altitude correction shall be rounded to the nearest whole number of K.

4.7 Rated voltages

4.7.1 High Voltages

Nominal rated voltages will be depending on each installation, with BIL according to table 3.

4.7.2 Medium/Low Voltages

Nominal rated voltages will be depending on each installation, with BIL according to table 3.

When requested, the parameters for double voltage connection (i.e. 20-10 kV) or delta/star connection shall be indicated in data-sheets.

4.8 Rated frequency

The rated frequency shall be 50 or 60 Hz.

4.9 High voltage tapplings

4.9.1 Off-load circuit tapplings

In this case, the transformer shall be provided with tapping links on the HV windings. Their position can be selected whilst the transformer is off circuit. Taping selection shall be by means of bolted links. The standard tapping range shall be:

- Plus 2.5% and 5%
- Minus 2.5% and 5%

Other combinations (number of steps as well as their magnitude) can be considered Depending on the case, tapplings with connection cables could be accepted.

4.9.2 On-load circuit tapplings

In case this is required, the transformer shall be provided with tapping links on the HV windings The high voltage windings will be provided with a device for changing the tapplings. The following types are preferred:

OLTC: On-load tap-changer: Voltage tapplings +8x1.25% -8x1.25%

OLTC: On-load tap-changer: Voltage tapplings +8x1% -8x1%

The OLTC will be based on oil-free technology (vacuum contacts), and with a proper linear configuration to be interconnected with the HV windings.

When required, it will be provided, with so many tapplings as needed, with a maximum by 17 positions, and covering a minimum ($\pm 10\%$) tapping range, and with at least the following limitations:

- Max voltage step 900 V
- Max current 500 A

It will be ready for a maintenance after at least >100000 operations.

The OLTC must be ready for indoors application, however, it could be also considered for outdoors, in an appropriate enclosure degree.

The OLTC will be interconnected to the windings tapplings point, by using insulated cable.

4.10 Insulation levels and minimum air clearances

The insulation levels and the corresponding minimum air clearances to assure electrical protection shall be those given in Table 3

Table 3

Rated voltage U_r (r.m.s.) (kV)	Highest voltage for equipment U_m (r.m.s.) (kV)	Rated short duration separate source AC withstand voltage (r.m.s.) (kV)	Rated lightning impulse withstand voltage (peak value) (kV)	Minimum air clearances. Line to earth Phase to phase (mm)
< 24	24	50	125	220
< 36	36	70	170	320
< 52	52	95	250	480
< 72.5	72.5	140	325	630

Other insulation levels could be required based on international standards (ANSI / IEEE).

4.10.1 Bushings

Dry-type large power transformers can be installed on indoor or outdoor locations.

- For indoor locations the HV and MV connections will be done directly through flexible outdoor cable terminations.
- For outdoor locations, if the connections are done with HV/MV cable, flexible outdoor cable terminations must be used.
- In the case the connections to the network are done by aerial cables, the use of wall bushing outdoor-outdoor will be installed in the top of the enclosure. These air to air bushings will have enough creepage distance according to the insulation class level.

4.10.2 HV and MV neutral

Windings with Star (Y) connection will have their neutral point accessible. The neutral connection shall be capable of carrying full phase rated current.

The connection to ground of the neutral point shall be defined in the data-sheets.

4.11 Losses and short circuit impedances

The impedance values of the transformer shall refer to the temperature defined in Table 4 (based on IEC 60076-11 Clause 17) to the base power indicated respectively. The loss values shall refer to the same temperature as the impedance values.

Table 4

Insulation system temperature (°C)	Reference temperature (°C)
180 (H)	145

- a) Short circuit impedances shall be given in the data-sheets.
- b) Losses can be prescribed by giving maximum values, peak efficiency index and/or capitalized values.

For the European distribution companies the EU Directive related to the efficiency of the transformer and the relevant losses shall be fulfilled.

- When maximum losses values are prescribed, they are given in data-sheets.
- When peak efficiency index are prescribed, the minimum values defined in the European Commission Regulation (EU) No 548/2014 and standardized in EN 50629 the must be used.

Table 5

Sr (MVA)	PEI(%) from jul 2017	PEI(%) from jul 2021
≤ 4	99,158	99,225
5	99,200	99,265
6,3	99,242	99,303
8	99,298	99,356
10	99,330	99,385
12,5	99,370	99,422
16	99,416	99,464
20	99,468	99,513
25	99,521	99,564
31,5	99,551	99,892
40	99,567	99,607
50	99,585	99,623
≥63	99,590	99,626

Losses exceeding the prescribed values and/or declared by the manufacturer can be penalized.

- When the capitalization of losses applies, the related capitalization factors must be specified in the offer request. The capitalization of losses is given by:

$$C_c = C + A \times P_v + B \times P_j$$

Where:

- C_c is the capitalized cost of the transformer (expressed in local currency)
- C is the cost declared by the manufacturer in the offer (expressed in local currency)
- A is the no-load loss factor (expressed in local currency per kW); B is the load loss factor (expressed in local currency per kW)
- P_v is the no-load loss declared by the manufacturer (expressed in kW) P_j is the load loss declared by the Manufacturer (expressed in kW)

4.12 Over-excitation conditions

In compliance with IEC 60076-1.

The transformer shall be able to operate at no-load with a magnetic flux in the core increased by the 5% of the nominal magnetic flux (therefore, the prescriptions relevant to the off-load current and the over-temperature of the core shall take into account such an over-excitation condition).

When required other over-excitation conditions, this must be taken into consideration by the manufacturer.

4.13 No load current

This value depends quite a lot from transformer size.

For big ratings (i.e. 20 MVA) the no-load current at the rated voltage shall be $\leq 0,5 \%$ of the rated current.

For smaller ratings (i.e. 2 MVA) the above values can be higher.

4.14 Inrush current

Transformer inrush current peak shall be limited to 10-12 times nominal current. Other inrush current limitations (maximum value, duration) defined by the customer could be considered.

4.15 Over temperature of the core

The surface over-temperature of the core shall not exceed 190 °C.

4.16 Capability of withstand short-circuit

The transformers shall be able to withstand the short circuit test in compliance with IEC 60076-5.

4.17 Sound levels

In compliance with IEC 60076-10.

The sound level of the transformers operating off-load and at rated voltage shall not be higher than the value prescribed in the data-sheet.

If required a reduced sound level, due to some restrictions in a specific installation, the manufacturer will check the feasibility of that lower sound level.

4.18 Overall dimensions

Designs are Maximum overall dimensions for dry-type large power transformers must be as defined in Table 6 and clause 11.1 "Layout diagrams".

Table 6

Rated Power (MVA)	Length (m)	Width (m)	Height (m)
12,5	5250	4500	4250
16	5400	4550	4700
20	5550	4600	4775
25	5800	4700	4850
31,5	6250	4850	4900
40	6300	4900	4950
63	7150	5150	5100

4.19 Climatic, environmental and fire behavior classes

Dry-type power transformers will comply at least with the following climatic, environmental and fire behavior classes defined in the Clause 13 of the IEC 60076-11:

- Class C1: The transformer is suitable for operation at ambient temperature not below -5°C but may be exposed during transport and storage to ambient temperatures down to -25°C .
- Class E2: Frequent condensation or light pollution or combination of both.
- Class F1: Transformers subject to a fire hazard. Restricted flammability is required. The emission of toxic substances and opaque smokes shall be minimized.

Also, as option, it can be considered:

- Class C2: The transformer is suitable for operation at ambient temperature not below -25°C but may be exposed during transport and storage to ambient temperatures down to -25°C .

5 Design requirements

Unless otherwise specified, the transformers shall comply with IEC 60076-11 standard; the single parts of the transformers shall comply with the relevant standards.

5.1 Core and frame

Core assembly shall allow disassembling the coils on site if necessary.

Complete set of magnetic steel core will be protected with a coating of high temperature paint that prevent corrosion.

The core and yoke tightening elements should be made of steel.

The tightening bolts should be made of steel. This elements must be insulated properly and connected to ground in only one point.

The magnetic circuit should be insulated from its tightening parts by fiberglass insulating material or something similar. Bolts will be insulated with this same material.

Another option would be that the magnetic circuit and the wheels frame kept the same potential.

In order to reduce losses, junctions between sheets will be step-lap at 45° minimizing gaps ($<2\text{mm}$).

5.1.1 Lifting lugs and pulling Points

Upper frame beams shall provide 4 hoisting points adequate to lift the complete active part.

These hoisting points will have holes of 65 mm diameter.

Lower frame beams shall provide holes of 40 mm diameter to facilitate pull the complete active part on site.

5.1.2 Core earthing

The core shall be connected to ground in one accessible point of the lower frame. The connection shall be done in the frame with a ground terminal of at least M12 thread. The lead shall be made with insulated copper strips of the proper section (taking into account the value of the short circuit current and in any case not less than 50 mm^2).

This system shall permit the disconnection of the core ground and measure the proper insulation resistance of the magnetic core. The disconnection point shall be properly and clearly marked.

5.1.3 Wheels and wheel frame

The wheels will be cast steel, flat or with one flange, and can be positioned in two directions at 90°.

Wheels will comply with EN 50216-4 “Power transformer and reactor fittings - Part 4: basic accessories (earthing terminal, drain and filling devices, thermometer pocket and wheel assembly)”.

The distance between the rollers may be defined either as the pitch between the wheels middle axis or as the rail gauge, the difference being given by the rail width.



Preferred rail gauge is 1435 mm, but other distances can be defined in the transformer data-sheet (1674 mm).

When required, locking devices will be placed on two wheels.

The frame will have four support plates for hoisting with jacks, making it possible to change wheel direction. The relative location of these supports will be indicated by the manufacturer. The wheels will have a fastening system preventing them from falling to the ground when the transformer is raised.

Wheel frame shall admit the substitution of the wheels by antivibration pads.

5.1.4 Core assembly

The core shall be constructed of the best quality, low loss, cold rolled, grain oriented steel laminations insulated on both sides.

Laminations shall be “step lap” overlapped to minimize core losses and noise.

The assembled core shall be braced in suitable steel frames that make up the base-frame and lifting facilities for complete transformer.

The core assembly shall enable the removal of the coils in the field, if this should become necessary.

The entire core assembly shall be covered with a resin-based lacquer for corrosion protection before the coils are mounted.

5.2 Windings

The windings shall be made with electrolytic copper and/or aluminium conductors properly disposed (foil disk, full width foil or transposed cable) and insulated to assure the better voltage distribution on the winding. The assembly shall be totally casted under vacuum with epoxy resin for high voltage components.

The following characteristics will be taken into account:

- Windings shall be vacuum casted 180°C (class H).
- Winding design shall be adequate to allow for full encapsulation with filled resin under vacuum. The resin system shall be two components epoxy filled with a mixture of inorganic fillers improving its thermal, mechanical and fire behavior properties. The single resin components and filler will be carefully stirred and degassed under vacuum in order to eliminate all air bubbles and then mixed together throughout a static mixer just before to pour them, under vacuum, into the mould that contains the coil (winding). In HV windings, where usually foil-disk or transposed cable are used as conductors formats, the position of this mould shall be horizontal or vertical respectively during the casting process that shall assure the total elimination of air bubbles that could create air cavities and critical points of partial discharges. In LV windings (where usually full width foil is used as conductor format), the position of the mould can be vertical, since the air bubble existence is quite rare.
- The surface of the encapsulated winding shall be smooth and completely closed and impervious to moisture and common industrial contaminants.
- Windings will be cylindrical.
- Windings composed by axial sections connected in series or parallel may have more than two sections.
- All support blocks and separation insulations used in constructing the windings will be fixed in such a way that their position is maintained, even under hypothetical loosening.
- All transpositions and connections between disks, both interior and exterior, will be performed by reinforcing insulation of an appropriate width.
- The main insulation between HV and MV will be sufficiently long so that they protrude over the windings. Supports that assures the firmly and equally holding shall be provided.
- Supports and insulating supports over which the windings are settled will be wide and robust enough to ensure that deformations will not exist over time. They shall provide an elastic compensator to absorb the thermal dilatation of the coils.
- Encapsulated winding surface will be smooth, fully closed and impermeable to moisture and to the usual industrial pollutants.

5.2.1 HV and LV windings assembly

Depending on the connection group, the position of the LV terminals shall be either at the opposite side of the HV terminals at the top or at the bottom of the transformer. The neutral bar terminal, if any, shall be at the same side as the LV phase terminal.

The design of the complete assembly should be in a way that if necessary, an exchange of separate high and low voltage coils can be done.

5.3 Windings connections

5.3.1 High / Medium Voltage connections

High or medium voltage connections will be Delta (D) or Star (Y) with the neutral point accessible.

The HV cable terminals will be made in copper material, located above the top or bottom of the connection bars, depending on how cables, bushings attack the HV terminals in the windings. Each terminal will be drilled with so many holes as needed depending on the size and number of cables. This information must be provided in the beginning of the project.

The HV star/delta connection will be made through copper or aluminum bars protected by HV cable without shield.

For transformer with double voltage level of the MV windings (i.e. 20-10 kV), the voltage changing shall be made by a bar connection between the MV terminals and taps.

5.3.2 Low Voltage connections

The LV cable terminals will be made in copper material, located above the top or bottom of the connection bars, depending on how cables, bushings attack the LV terminals in the windings. Each terminal will be drilled with so many holes as needed depending on the size and number of cables. This information must be provided in the beginning of the project.

The LV star/delta connection will be made through copper or aluminum bars protected by HV cable without shield.

5.4 Epoxy resin insulation

Epoxy resin used for winding insulation shall be two component system for liquid moulding. The epoxy resin is mixed with inorganic filler to improve the thermic, mechanical and fire behaviour. The following characteristics from the complete system are required:

- Minimum thermal class H (180°C)
- Minimum tensile strength of 60MPa (according to ISO 527)
- Minimum elongation at break of 1% (according to ISO 527)
- Minimum transition glass (tg) temperature of 80°C (according to ISO 11357-2)
- Minimum breakdown strength of 20kV/mm (according to IEC 60243-1)

6 Accessories and auxiliaries

6.1 Temperature monitoring

6.1.1 Windings

Transformer shall be provided with three infrared thermal sensor devices pointing at the upper part of the MV winding of each phase (one per phase as minimum).

These sensors will be connected to a control unit devices installed in the marshalling box. The control units provide three contacts, two for winding temperature control and another one for the fan control. Temperatures of alarm signal, trip signal, fan connection and disconnection, must be programmed to 120°C, 135°C, 100°C and 90°C.

Control units shall have an extra contact to indicate an internal fault of this device.

6.1.2 Core

At least, onothermal resistances for the surface core temperature measurement, of platinum of 100 ohms at 0° C, with the temperature coefficient $3,85 \times 10^{-3} \text{ } ^\circ\text{C}^{-1}$, and with shielded terminals (PT100), will be installed.

It shall be mounted at the central column in correspondence to the cross with the top yoke, or on the cover of the top yoke, in correspondence to the central column and inserted into a cooling channel of the core, if existing.

The relevant wires shall be brought to the marshalling box (for possible core over-temperature monitoring).

Additional Pt100 sensors can be installed under customer request.

6.2 Fans

The number of fans and the total volume cooling flow will be defined by the manufacturer, but in any case, it will never be less than two per phase, one in each side of the core frame.

The rated voltage and frequency value will depend on the place of installation. The definitive supply voltage will be defined when the order is awarded.

The cooling equipment control circuit will be provided to operate in automatic and manual mode, which may be selected with a control (IC) switch located in the transformer cabinet.

In manual-local mode, it may be controlled from the transformer cabinet with the selector.

Fan start-up and stop should be controlled by the transformer temperature, with the winding infrared sensors. When the IR sensor reaches a temperature of 100°C, the motor fans will start up automatically and will continue to operate until the temperature has lowered to 90°C, at which time they will stop.

The motor fan electrical circuits should be protected with motor protector relays, provided with thermal and electromagnetic protections with signalling contacts, without the fuses overlapping. Fans will be consolidated on supports fixed directly on the core frame. The fans should be situated in the transformer bottom part, and as such, the airflow has the same direction than the natural convection.

The blades will have a grill preventing involuntary hand contact.

6.3 Rating plates

In compliance with IEC 60076-1.

Two rating plates shall be provided, according to the following indications, and shall be fixed on appropriate supports on the longer sides of the transformers, on exactly opposite positions.

If the supports are removable from the core frame, the surface parts where they are fixed shall be painted in the same manner and shall comply with the same prescriptions of the whole core frame.

The rating plates shall be in the language agreed with the customer, they shall be of weatherproof stainless steel material placed in a clear position.

Nameplate information as called for by IEC standards shall be provided. This shall include as:

- Type of transformer
- IEC codes must be stated
- Manufacturer's name
- Serial number
- Year of manufacture
- Insulation Level
- Number of phases
- Rated power
- Rated frequency
- Rated voltage
- Rated currents
- Vector group
- Impedance voltage at rated current (measured at test room)
- Type of cooling
- Total mass
- Temperature rise of windings
- Non-load losses
- Load losses
- Efficiency peak index

6.4 Terminal markings

Terminal markings should preferably be in accordance with IEC 60616, unless otherwise covered in national standards.

Terminal markings shall be made with letters of 25 mm height approximately, engraved over a corrosion resistant surface.

6.5 Warning plates

Transformer shall have advice marks, easily readable in the four sides of the transformer, warning of voltage and temperature hazards.

This marks shall follow EN-ISO 7010 standard.

6.6 Lifting devices

See clause 5.1.1

6.7 Wheels

See clause 5.1.3

6.8 Grounding terminals

Two grounding terminals on the core frame, each of which consisting of a cylinder of dimensions $\text{Ø}40 \times 35$ mm with one threaded hole M16, positioned at the base of the core frame (on the right of the longest sides) and shall be marked with two name plates with the grounding symbol (black symbol on a yellow background).

6.9 Protections

Unusually, when required, an arc detector relay could be installed with a fast response ($<100\text{ms}$) tripping to open the feeder breaker. The unit should have at least two optical detectors, one per long side of transformer.

In case the transformer will be under direct sunlight or other highly intensive light reaching the sensors frequently, the relay shall have current inputs to discriminate undesirable trips.

6.10 Security devices

When required, transformer shall have two specific fall arrest system for the operator. These anchor points should be fixed in the upper side of the core frame in the space between coils.

6.11 Marshalling boxes

In case of on-load tap changer, the transformer will have two cabinets: one for actuating the tap-changer and another to control fans, other protections and terminals ends.

When off-load tap changer, the transformer will have only one cabinet: to control fans, other protections and terminals ends.

The common conditions to these cabinets will be:

- All the international and local laws, standards and documents referenced in clause 2 of this document must be observed.
- They will be protected against dust and water spurts with an IP54 protection level, according to standard EN 60529:1991.
- They will have illumination protected by magneto-thermal protection. This illumination will connect when doors open.
- They will have heating with thermostat to avoid condensation. A single-phase tap will also be placed for eventually works, with an earth electrode.
- Each cabinet and its door should be earthed through a flexible copper braid with a minimum cross-section of 60 mm^2 .
- It shall be installed at an appropriate height above the base level for a standing operator.
- The cabinets will be mounted on rubber pieces or silent blocks, not subjected to lateral forces.
- The two cabinets will be protected, inside and out, with a kind of paint identical to the rest of the transformer.
- The interconnection between cabinets and different transformer fittings will be done with independent multicore cables, these cables must fulfilling the local standards defined.
- It will not be accepted that the cables go through the inside of channels or tubes, and its route over the transformer top side will be the minimum necessary.
- Circuit outlet will be through the bottom part of the cabinet with compression glands so that they are protected from the rain.

- All devices installed in the control cabinet must be conveniently identified by acrylic plates printed indelibly in accordance with the wiring plans. The control cabinet itself must also have an identification plate in local language, as applicable.
- The channeling inside the cabinets must be implemented preferably using plastic conduit pipes. The conductors shall be grouped and attached with non-metallic fasteners, suitable for protecting its insulation and to support the weight of the cables.

7 Main components

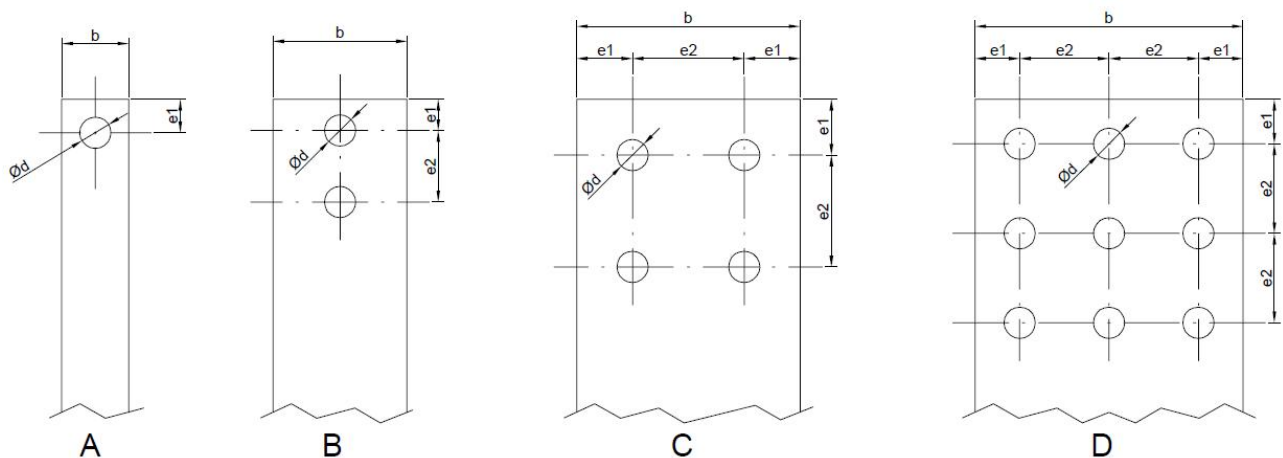
7.1 Terminal connections

The bushings on dry-type transformers are united and included on the windings. Copper or brass terminals are used as connection point for the HV and MV feeding cables. The terminals will be robust to sustain the cables connected to them without any deformation.

The holes disposition shall be in accordance with the technical report IEC/TR 62271-301 “High-voltage switchgear and control-gear – Part 301: dimensional standardisation of high-voltage terminals.”

Table 7

Current (A)	Terminal type	Width (b) (mm)	e1 (mm)	e2 (mm)	Number of holes	Hole diameter (mm)
< 400	A	30	15	-	1	14
< 800	B	60	14	32	2	14
< 1600	C	80	20	40	4	14
< 2000	C	100	25	50	4	14
< 3600	D	120	40	40	9	14



Insulation distances between terminals and terminals to ground defined in present document table 3 must be assured.

Depending on the installation, the cable access to these terminals is facilitated by insulators installed on the transformer core frame.

Other types of terminals can be installed upon customer request.

7.2 On-load tap changer (OLTC)

The scope of the present chapter is to define the technical-functional parameters, the design requirements and the tests definitions of the on-load tap changers to be used for the voltage regulation.

7.2.1 Ratings

The on-load tap changer shall be vacuum type.

The regulating positions shall be in accordance with the transformer ratings.

The on-load tap changer shall be in accordance with the transformer characteristics.

7.2.2 Design Requirements

The on load tap changer shall be dry-type.

OLTC shall have three single-phase modules, one per phase, and a common motor drive to manage the three modules.

Each module combines the functions of a diverter switch and a tap selector and must be clearly identified with their serial number and their type.

The three single phase modules and the motor drive unit will be assembled over a steel frame forming one single device. The frame shall have facilities to lift it and transport it.

7.2.2.1 Diverter switch

The diverter switch contains an energy storage device, a set of vacuum breakers and the commutation resistances.

The diverter switch shall allow the maintenance operations and/or replacement without requiring the disassembly of the modules from transformer active part.

Tap-selector and change-over selector.

The tap-selector and the change-over selector shall be also oil-free type.

7.2.2.2 OLTC driving mechanism

The commutation of the diverter switch shall be activated by an energy store device. The energy charge shall be achievable both through a motor drive and manually.

The motor drive commutation shall be achievable both remotely and locally through electric signals.

When the crank-handle is inserted, the electric/motorized commutation shall be inhibited through the interruption of both the supply circuit and the electric signalling circuit.

7.2.2.3 Cabinet

The box shall be manufactured with hot painted or galvanized steel sheets or with metal not susceptible to corrosion.

The box shall be IP55 - IEC 60529 provided with an appropriate door, laterally hinged and lockable.

On the door, a window, protected with transparent material withstanding the atmospheric agents and UV radiations, which allow the visualization of the position indicator of the OLTC, shall be fitted.

Inside the cabinet the following devices shall be located:

- 1) Push buttons or crank for the on-site electric commutation provided with the labels "increase MV" and "decrease MV".
- 2) Motor gear and the electrical devices for its command.
- 3) Automatic circuit breaker on the motor circuit, provided with NC contacts wires in the marshalling.
- 4) Heating anti-moisture resistance (always on) and additional heating resistance controlled by a thermostat and protected with automatic circuit breaker, provided with NC contacts wire in the marshalling, or with an equivalent system preventing the moisture generation.
- 5) Ground terminal for of all the metallic parts of the box.
- 6) Lamp and one single-phase.
- 7) Socket 230 V, 10 A, supply by the heating circuit.
- 8) The protection and signalling devices.
- 9) One marshalling for the interface with the marshalling box of the transformer.

7.2.2.4 Painting

The external paint of the motor drive box shall comply the same requirements of the external painting of the transformer, except colour.

7.2.2.5 Maintenance

The OLTC shall be able to work without any maintenance before **300.000** commutations. This prescription shall not limit the normal service conditions and the lifetime (the OLTC Supplier shall give evidence of the compliance with this requirement).

7.2.2.6 Functional requirements

The main functional requirements are the following:

- 1) The execution of the commutation shall be inhibited or interrupted when the over-current arrest relays (I max) installed outside the diverter switch activates.
- 2) A device that allows the completion of a tap commutation already started, regardless of the control activation time.
- 3) A device that prevents the execution of more than one commutation in case of control button pushed longer than time necessary to activate the commutation.
- 4) An electrical and/or mechanical device for the motor drive re-starting after an interruption of the supply voltage, in order to complete a commutation already started.
- 5) An electrical and a mechanical block that prevents commutations beyond the extreme positions.
- 6) An electrical device that prevents the activation of an increasing commutation while a decreasing commutation is in operation and vice versa.
- 7) A mechanical indicator of the position.
- 8) Electrical contacts for the indication of the tap positions.
- 9) Counter with 6 digits for the indication of the commutations number.

7.2.3 Tests

According to IEC 60214-1.

7.3 Enclosures

Standard transformers are supplied without enclosures, protection class IP00. Additional protection may be added, using an enclosure with protection degree IP21 to IP33, which provide safety barrier against accidental live contact.

Other IP degrees can be analyzed under request.

7.3.1 Standard enclosure for indoors

The enclosure is made of bolt-on type sheets of steel of the bolt-on type with removable panels and supported from the transformer framework. Its removable base can be installed without having to lift the transformer.

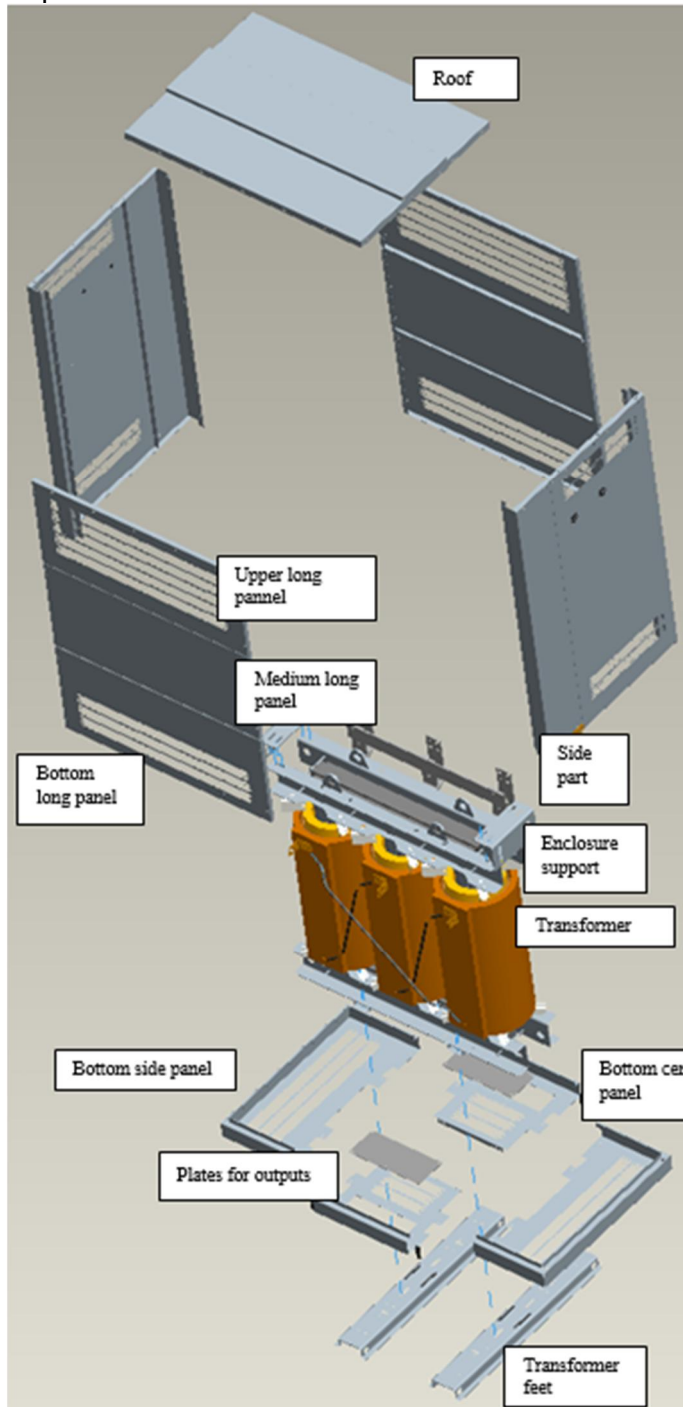
Central front and rear handle panels will be provided for access to the tap changer.

Inlet-outlet of cables is situated at the bottom of the enclosure through aluminum gland plates to be machined by the customer.

For indoor applications the sheet steel will be painted in grey color, RAL7035; for outdoors applications will be galvanized with painting.

Other solutions can be considered under customer request

Exploded view of the enclosure:

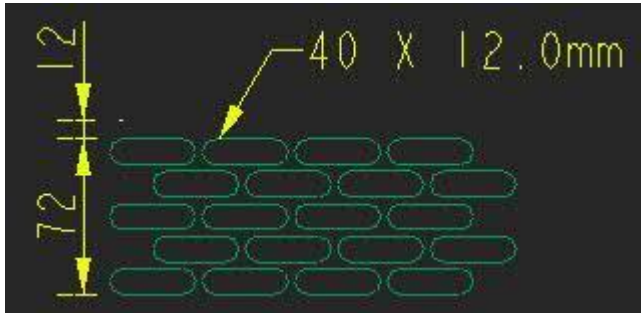


Design according to IP21/31:

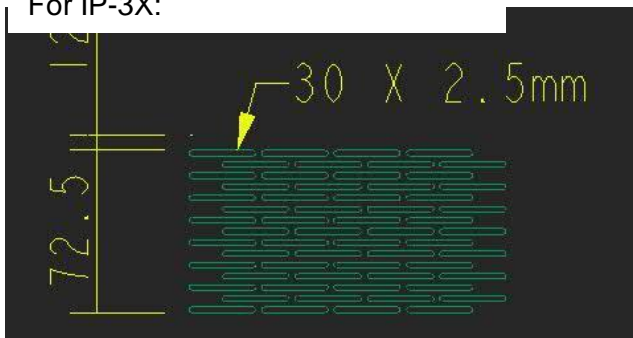


Hole punching detail:

For IP-2X:



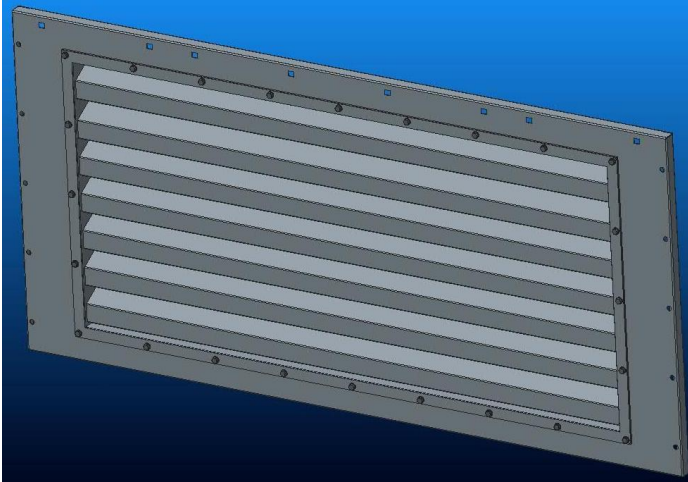
For IP-3X:



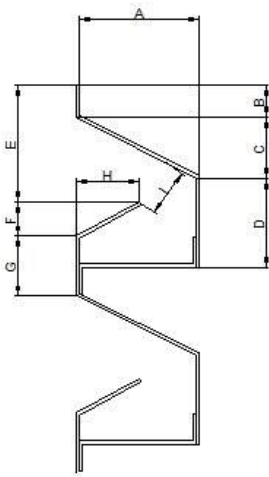
Design according to IP23/33/24/34/25/35:



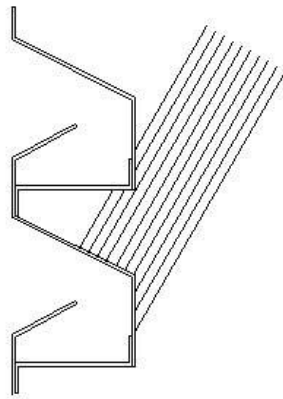
Louver detail:



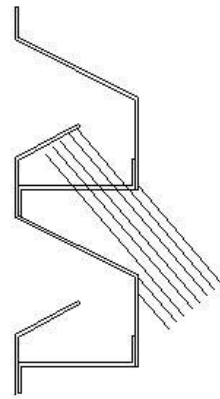
Rain protection detail:



LLUVIA 60°



LLUVIA EN TODAS DIRECCIONES



7.3.2 Standard enclosure for outdoors

In special cases, dry-type large power transformers could be installed outdoors. Dry-type large power transformers for outdoor applications shall have a cubicle to protect the active part and the OLTC from the environmental and climatic conditions. This cubicle could be metal or civil housing.

In case of metal enclosure, depending on the size, it shall be:

- Directly ground mounted. So, the cubicle is fixed to a concrete platform floor, and it will be delivered and transport individually to be assembled on site.
- Mounted on the transformer framework.

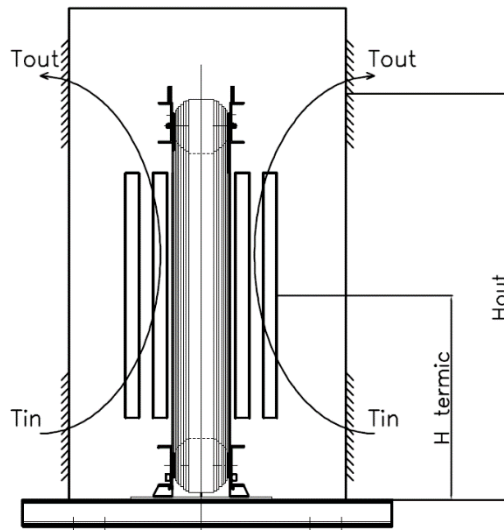
The enclosure must be dimensioned to permit the free access of a worker around the transformer and OLTC. It will have a door for access to the inside of the cubicle.

Minimum degree of protection for the cubicle according to IEC 60529 shall be according to the Table 8:

Table 8

Protection degree	Where	Type of transformer cooling allowed	Cooling system		Recommended for weather conditions
Protection degree	Where	Type of transformer cooling allowed	Cooling system		Recommended for weather conditions
IPX1	Protected outdoors area	a. AN b. AN/AF	a. Air natural convection b. Fans use often	Less conductivity (caused by the condensation)	Normal condensation
IPX3	Protected outdoors area	a. AN b. AN/AF	a. Air natural convection b. Fans use often	Less conductivity (caused by the condensation)	Normal condensation Rain
IPX4D IPX5	Protected outdoors area	a. AN b. AN/AF	a. Air natural convection b. Fans use often	Less conductivity (caused by the condensation)	Normal condensation Rain Snow Ice Fog

The enclosure could be manufactured with galvanized steel painted panels, with prefabricated concrete or similar panels. The cubicle must have ventilation windows with fans that assures the proper air interchange and the IP54 protection index.



Airflow necessary to dissipate the total transformer losses inside the enclosure is defined by the following formula:

$$\text{Vol (m}^3/\text{hour)} = (P_k + P_0 + P_{AF}) \times 3000 / (T_{out} - T_{in})$$

Where

T_{in} = Ambient outside temperature or in the inlet of the enclosure (lower part)

T_{out} = Temperature of the air in the outside of the enclosure (upper part)

P_k = Load losses

P_0 = No load losses

P_{AF} = Losses from the refrigeration system.

When only natural convection is used to move the air inside the enclosure, the area of the inlet and outlet windows are defined by the following formulas:

$$A_{in} \text{ (m}^2\text{)} = (P_k + P_0 + P_{AF}) \times 12'43 / \sqrt{(H \times (T_{out} - T_{in})^3)}$$

Where

$$H = H_{out} - H_{termic}$$

Height between center of the transformer coils and the center of the outlet window.

These formulas shown an estimated calculation method. A second and more accurate analysis is recommend to be evaluated by the customer/consultant.

Transformer feeding cable access is preferable from the bottom part of the cubicle, however it can be also by installing wall bushings on the roof of the enclosure.

The enclosure shall not limit in any way the rating power of the transformer unit. Transformer active part shall be designed to operate at full rated power inside the enclosure.

The connection box is fixed on the outside surface of the enclosure in the front or in the side panels.

The enclosure shall be manufactured such that to not allow the water accumulation on the external surface.

All the materials of the enclosure shall be chosen to prevent corrosion processes. All the screws included on the enclosure shall be made by either hot-dip galvanized steel or by stainless steel; for diameters \leq M10 they shall be made of stainless steel.

Enclosure protective painting shall comply the requirements described on this document.

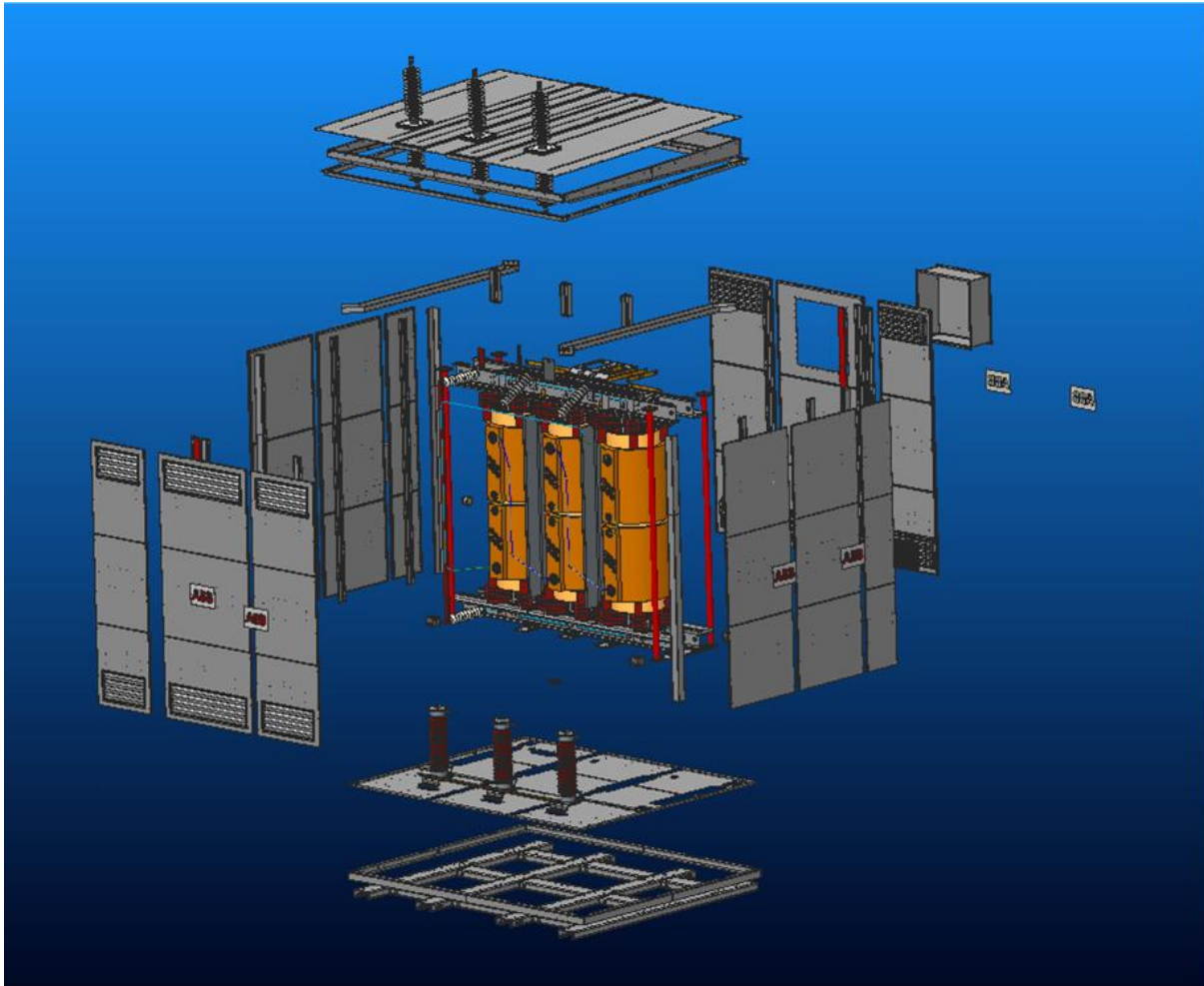
Painting system shall support the atmospheric-corrosive environmental categories C2, C4H or C5M defined on EN-ISO 12944 standard.

The finishing colours preferred shall be RAL7035. Other colours can be considered under customer request.

Some examples:



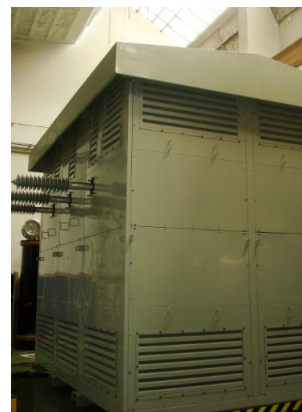
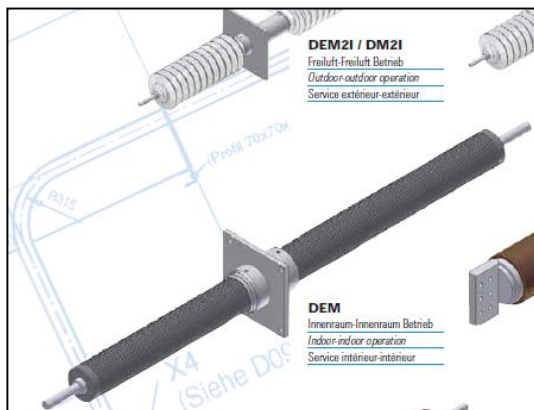
This exploded view shows another example for outdoors enclosure but including wall-bushings:



7.3.3 Insulators / wall-bushings for outdoors

Depending on the type of attacking in both HV and LV sides, when required, it will be assembled insulators in suitable parts of the transformer IP00, or even wall-bushings on the enclosure. Final allocation will depend on the relative position of the rest of accessories, in order to keep a minimum distance between active parts (points with voltage).

Examples of wall-bushings:



8 Protective painting

Painting cycles for pollution level “Medium, High or Very high“, can be proposed by the transformer supplier.

Painting system shall support the atmospheric-corrosive environmental categories C2, C4H or C5M defined in EN-ISO 12944 standard.

The surfaces to be painted shall be prepared by manufacturer practice with suitable sandblasting or chemical cleaning (degreasing) treatments, specific for the painting cycle adopted.

The paint shall be free of lead oxides or chromates.

Preferred finishing colour shall be RAL7035

The following procedures shall be applicable to the metallic parts of the transformer and enclosure in case.

C2H corrosivity category (ISO 9223:2012):

Description of powder paint system	
Material (EN 10025-2:2004) (EN 10111: 2008)	tk ≥ 3 mm hot rolled carbon steel S235JR tk < 3 mm continuously hot rolled steel sheet DD11 (1.0332)
Surface treatment (ISO 12944-4:1988)	Water-blast cleaning Fresh water rinse Alkaline degreasing Deionized water rinse Drying
Painting	Polyester powder paint
Nominal dry film thickness NDFT (EN ISO 2808:2007)	70 µm
Standard finishing color	RAL7035 enclosure RAL7035 metallic parts of transformer
Test of powder paint system according to the ISO 12944-6:1998	
Previous adherence degree (EN ISO 2409)	Classification 0 or 1
Condensation water test (ISO 6270)	Minimum 120 hours
Neutral salt spray test (ISO 9227) (ISO 4628-2) (ISO 4628-3) (ISO 4628-4) (ISO 4628-5) (EN ISO 2409)	After artificial ageing ISO 7253 any corrosion of the substrate from X-shaped scratch without the oxidation progressing for more than 1 mm Minimum 250 hours Blistering 0 (S0) Rusting Ri 0 Cracking 0 (S0) Flaking 0 (S0) Classification 0 or 1

C4H corrosivity category (ISO 9223:2012):

Description of powder paint system	
Material (EN 10025-2:2004) (EN 10346: 2009)	tk ≥ 3 mm hot rolled carbon steel S235JR tk < 3 mm continuously hot-dip coated steel DX51D (1.0226)
Surface treatment (ISO 12944-4:1988)	Sand blasting Sa 2.5 according to ISO 8501-1:2007 (tk ≥ 3 mm) Water-blast cleaning Fresh water rinse Alkaline degreasing Deionized water rinse Drying
Painting	Polyester powder paint Zinc enriched epoxy powder primer (only tk ≥ 3 mm)
Nominal dry film thickness NDFT (EN ISO 2808:2007)	140 µm in 2 layers with substrate hot rolled carbon steel S235JR (tk ≥ 3mm): <ul style="list-style-type: none"> - 70 µm zinc enriched epoxy powder primer - 70 µm polyester powder finish layer 70 µm polyester powder finish layer with substrate hot-dip coated steel sheet (tk < 3 mm)
Standard finishing color	RAL7035 enclosure RAL7035 metallic parts of transformer
Test of powder paint system according to the ISO 12944-6:1998	
Previous adherence degree (EN ISO 2409)	Classification 0 or 1
Condensation water test (ISO 6270)	Minimum 480 hours
Neutral salt spray test (*) (ISO 9227) (ISO 4628-2) (ISO 4628-3) (ISO 4628-4) (ISO 4628-5) (EN ISO 2409)	After artificial ageing ISO 7253 any corrosion of the substrate from X-shaped scratch without the oxidation progressing for more than 1 mm Minimum 720 hours Blistering 0 (S0) Rusting Ri 0 Cracking 0 (S0) Flaking 0 (S0) Classification 0 or 1

(*) Neutral salt spray test only required for hot rolled carbon steel S235JR (tk ≥ 3mm).

It is also available other higher demanding painting systems as C5I and marine, under customer request.

9 Tests

Unless otherwise specified, IEC 60076-11 applies.

9.1 List and classification of tests

9.1.1 Routine tests

- 1) Measurement of winding resistance (IEC 60076-1 clause 11.2).
- 2) Measurement of voltage ratio and check of phase displacement (IEC 60076-1 clause 11.3).
- 3) Measurement of short-circuit impedance and load loss (IEC 60076-1 clause 11.4).
- 4) Measurement of no-load loss and current (IEC 60076-1 clause 11.5).
- 5) Separate-source AC withstand voltage test (IEC 60076-3 clause 12).
- 6) Induced AC withstand voltage test (IEC 60076-3 clause 11.2).
- 7) Partial discharge measurement (IEC 60076-11 clause 22).
- 8) Tests on On-Load Tap Changer, where appropriate (IEC 60076-1 clause 11.7).
- 9) Check of the ratio and polarity of built-in current transformers, where applicable (IEC 60076-1).
- 10) Check of core and frame insulation (IEC 60076-1 clause 11.12), when possible.
- 11) Check and verification of the functionalities of accessories (IEC 60076-3 clause 9).
- 12) Check of external coating (ISO 2178 and ISO 2409 or as specified).

9.1.2 Type tests

- 1) Lightning impulse test (IEC 60076-3 clause 13). (*)
- 2) Temperature-rise type test (IEC 60076-11).
- 3) Measurement of the power taken by refrigeration system, if any.

(*) About the lightning impulse test, and according to IEC/UNE-EN 60076-3, there are some cases, where getting the normalized impulse wave shape for the test, it is quite difficult, due to the low inductance of the winding or to the high capacitance to earth. In these cases, this impulse wave fluctuates quite often and wider tolerances shall be agreed under purchaser and seller. Regarding ABB transformers of our production and due to so wide range of power and tensions, the wave shape will be obtained by applying the best practices on the adjustment of the lightening installation in the test room.

9.1.3 Special tests

- 1) Determination of sound level (IEC 60076-10) for each method of cooling for which a guaranteed sound level is specified.
- 2) Measurement of D.C. insulation resistance between each winding to earth and between windings.
- 3) Determination of capacitances windings-to-earth and between windings.
- 4) Measurement of dissipation factor ($\tan \delta$) of the insulation system capacitances.
- 5) Measurement of frequency response (Frequency Response Analysis or FRA. (IEC 60076-18).
- 6) Measurement of zero-sequence impedance(s) on three-phase transformers.
- 7) Short-circuit withstand test (IEC 60076-5).
- 8) Environmental test (IEC 60076-11 clause 26).

- 9) Climatic test (IEC 60076-11 clause 27).
- 10) Fire behaviour test (IEC 60076-11 clause 28).

9.1.4 Inspection at factory

The equipment shall be subject to inspection and testing during manufacture and after completion by one representative from the buyer. All the expenses for travel, accommodation, visa, etc. of the representatives in connection with the inspection, shall be borne by the buyer. Acceptance by buyer's representative of any transformer shall not relieve the manufacturer from any of this performance guarantee, or from any of the other obligations resulting from this contract.

9.1.5 General statements for the tests

All the transformers shall be tested in a laboratory accredited according to the criteria collected in Standards UNE-EN ISO/IEC 17025:2000 (CGA-ENAC-LEC).

The repetition of type and special tests can be optionally requested by the customer for already homologated/certificated/ approved transformer types, in addition to the required routine tests. Further tests in addition to the ones listed above can be requested to the transformers Manufacturer in case of particular technologies adopted.

9.1.5.1 Short circuit test criteria

The short circuit test is required in compliance with IEC 60076-5 and in accordance to the following criteria.

For each type of transformers, the capability to withstand the short circuit test can be verified by calculation, based on a test performed on a similar transformer, in compliance with IEC 60076-5 Annex B.

9.1.5.2 Environmental, climatic and fire behaviour tests

If required, the environmental, climatic and fire behaviour tests will be done according to IEC60076-11.

Due to the limitations of some of the tests because of coils sizes, the validity of the results of similar test carried out on a transformer can be extended to other transformers based on the same design criteria, such as:

- Same conceptual design (for example, windings contained in solid insulation or not, winding type, degree of protection, etc.).
- Same average temperature rise for the windings (according to Table 2).
- Same conducting materials.
- Same main insulating materials. Mainly, the epoxy resin used as coil insulation must be demonstrated to be the exactly the same and treated with the same process to obtain exactly the same characteristics described in clause 6.4.
- Insulation level of the tested transformer must be 36 kV or more.

9.2 Test description

The prescriptions and the tests conditions shall be compliant with the reference standards, unless otherwise specified.

The transformers shall be completely assembled (as in operation) during the tests.

All measurements and tests requiring power frequency supply shall be performed with the supply frequency within 1 % of the rated frequency of the transformer.

9.2.1 Routine tests

9.2.1.1 Measurement of winding resistance

According to IEC 60076-1 clause 11.2.

9.2.1.2 Measurement of voltage ratio and check of phase displacement

According to IEC 60076-1 clause 11.3.

For transformers with different voltage configurations (double MV voltage, etc.), the measurement shall be performed on each voltage position. For type of transformers homologated or certificated, submitted only to routine tests, the test can be performed on the delivering configuration.

9.2.1.3 Measurement of short-circuit impedance and load loss

According to IEC 60076-1 clause 11.4.

9.2.1.4 Measurement of no-load loss and current

According to IEC 60076-1 clause 11.5.

The measurements shall be performed at 90 %, 100% and 110 % of rated voltage.

9.2.1.5 Separate-source AC withstand voltage test

According to IEC 60076-3 clause 12.

In case of different voltage configurations, the dielectric routine tests shall be performed in the delivering configuration or in the most stressed configuration by agreement.

9.2.1.6 Induced AC withstand voltage test

According to IEC 60076-3 clause 11.2.

In case of different voltage configurations, the dielectric routine tests shall be performed in the delivering configuration or in the most stressed configuration by agreement.

9.2.1.7 Lightning impulse test

According to IEC 60076-3 clause 13.

In case of different voltage configurations, the dielectric routine tests shall be performed in the delivering configuration or in the most stressed configuration by agreement.

9.2.1.8 Partial discharge measurement

According to IEC 60076-11 clause 22.

The additional procedure test described in the clause 22.4.1.2 will be only used in case transformer is connected to systems which are isolated or earthed through a high value impedance and which can continue to be operated under a single phase line to earth fault condition.

9.2.1.9 Tests on on-load tap changer, where appropriate

According to IEC 60076-1 clause 11.7.

9.2.1.10 Check of the ratio and polarity of built-in current transformers

According to IEC 60076-1.

To be performed only in case of built-in current transformers.

9.2.1.11 Check of core and frame insulation

To be performed only in case that the magnetic core and core frame are insulated.

If so, then according to IEC 60076-1 clause 11.12.

9.2.1.12 Measurement of D.C. insulation resistance between each winding to earth and between windings

According to IEC 60076-1.

9.2.1.13 Check and verification of the components and accessories

According to IEC 60076-3 clause 9.

It shall be verified that all the components and accessories are properly installed on all the electric circuit connections and AC voltage insulation check to earth at 2 kV for 1 minute shall be performed.

The documentation (check and validation) of the sub-supplier that confirms the compliance of the components and accessories to the related standard shall be provided by the manufacturer.

9.2.1.14 Determination of sound level

According to IEC 60076-10, for each method of cooling for which a guaranteed sound level is specified.

9.2.1.15 Check of external coating

According to ISO 2178 and ISO 2409 or as specified.

9.2.1.16 Determination of capacitances windings-to-earth and between windings

According to IEC 60076-1.

9.2.1.17 Measurement of dissipation factor ($\tan \delta$) of the insulation system capacitances

According to IEC 60076-1.

9.2.1.18 Measurement of frequency response (FRA).

According to IEC 60076-18.

9.2.2 Type tests**9.2.2.1 Temperature-rise type test**

According to IEC 60076-11 clause 23.

The hot spot value has to be determined during the test and reported in the test report.

9.2.2.2 Measurement of the power taken by the fan and liquid pump motors, if any

According to IEC 60076-1.

9.2.3 Special tests

9.2.3.1 Determination of transient voltage transfer characteristics

According to Annex B of IEC 60076-3.

9.2.3.2 Measurement of zero-sequence impedance(s) on three-phase transformers

According to IEC 60076-1 clause 11.6.

9.2.3.3 Short-circuit withstand test

According to IEC 60076-5.

The partial discharge test shall be repeated after the short-circuit test. The final values shall not exceed the limits given in IEC60076-11 clause 22.5.

9.2.3.4 Environmental test

According to IEC 60076-11 clause 26.

9.2.3.5 Climatic test

According to IEC 60076-11 clause 27.

9.2.3.6 Fire behaviour test

According to IEC 60076-11 clause 28.

9.3 Commissioning

Before the first energization the manufacturer shall perform all the tests and verifications necessary to ensure the proper state and configuration of the transformer.

An appropriate form shall be released after energization.

9.3.1 Test on field

The test to be carried on field will be:

- 1) Thermographic inspection.
- 2) Dynamic winding resistance measurement operating the OLTC.
- 3) Measurement of winding resistance (IEC 60076-1 clause 11.2).
- 4) Measurement of voltage ratio and check of phase displacement (IEC 60076-1 clause 11.3).
- 5) Measurement of magnetization current with reduced voltage.
- 6) Check of core and frame insulation (IEC 60076-1 clause 11.12).
- 7) Measurement of D.C. insulation resistance between each winding to earth and between windings.
- 8) Measurement of zero-sequence impedance(s) on three-phase transformers.

- 9) Measurement of frequency response (Frequency Response Analysis or FRA (IEC 60076-18).
- 10) Check and verification of the functionalities of accessories.

10 Supply requirements

Unless otherwise specified, IEC 60076-1 applies.

10.1 Transport and storage

The transport of the transformer shall be made according to the local legislation of each country. The transformer, during the transport from the factory to the substation, shall be equipped with an impact recorder capable to discriminate the three spatial axis, made available by the supplier.

When received the impact recorder, recording shall be checked and, in case of solicitations stronger than the specified limits, the manufacturer shall verify by a proper method the good transformer conditions.

Dry-type large power transformers without enclosure must be stored in a dry, clean and good ventilated area.

- The storage temperature must be between -25 and 60°C.
- The storage relative humidity must be below 90%.
- Preferably, this type of transformer should remain inside manufacturer packaging.

10.2 Package

The package system will follow different rules depending on the way the transformer will be transported.

Specially, the transport by ship should be done with a special package containing at least a thermo-isolating bag involving the whole transformer that should be placed inside a wooden crate.

The seller shall always submit the package system for the buyer's approval. The approval of the package system does not relieve the manufacturer from any of its responsibilities of assure the good quality of the package.

Examples of standard packing and seaworthy packing:



Either final packing system will include impact registers, in order to monitorize during transport that accelerations limits are not exceeded.

10.3 Documentation

10.3.1 Documentation for the offer

The technical documentation to be produced by the supplier for the economical offer shall contain the following items:

- 1) Description of the product.
- 2) Short circuit test and related Manufacturer report for validation.
- 3) The Transformer data-sheet.

The full compliance to the prescriptions indicated in this document and relevant standards of the main components and the accessories shall be ensured by the Manufacturer. Each exception to the technical customer specification shall be expressly evidenced during the technical offer submission.

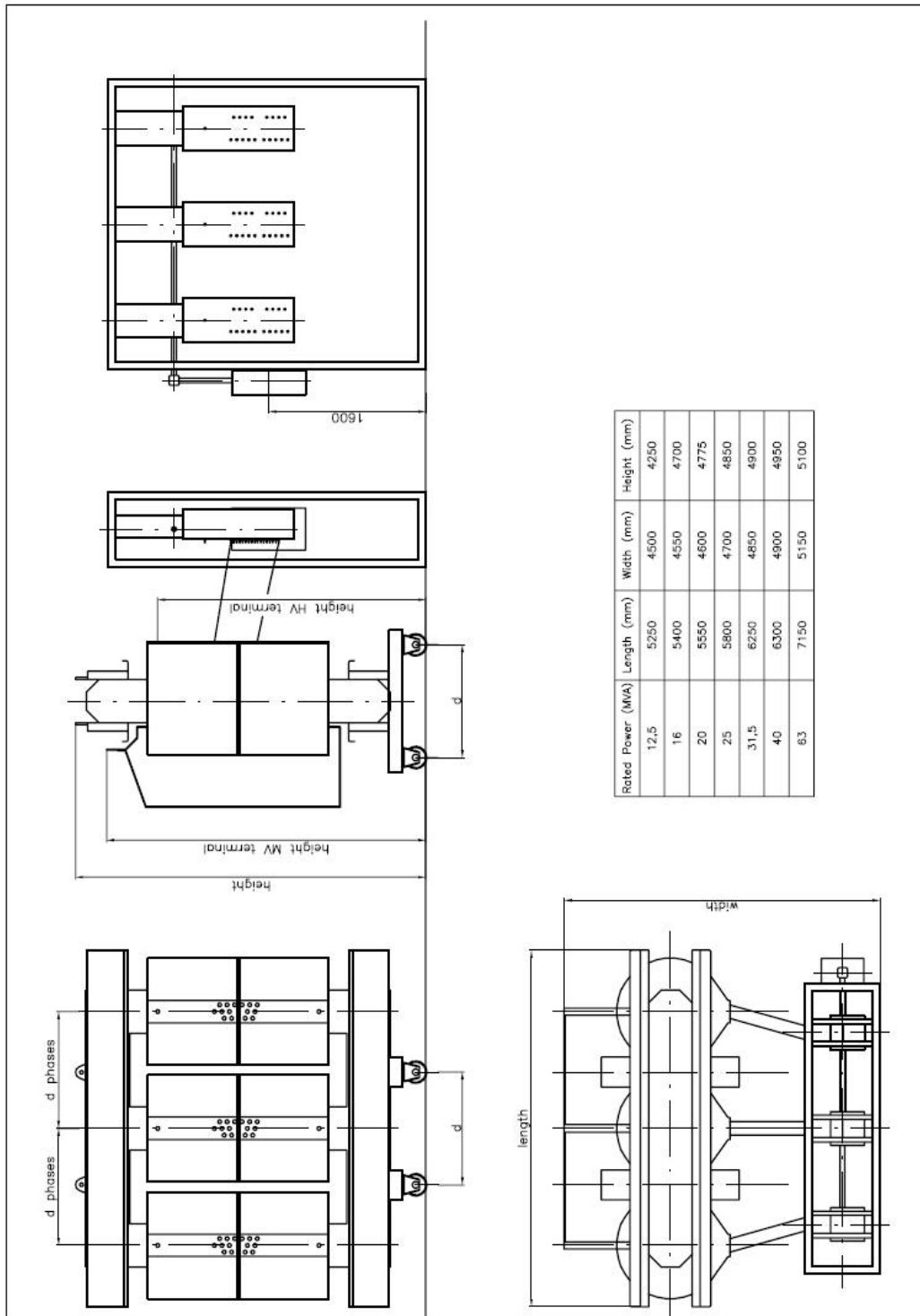
10.3.2 Documentation for homologation, certification and approval

When required by the customer, the supplier, for each transformer type code to be subjected to homologation, certification or approval procedure, shall make available a complete documentation containing calculations, drawings, schemas, pictures of the HV and MV side, internal and external, descriptions, list of characteristics, performances, assembling, maintenance and operational norms and whatever necessary for the complete acknowledgment of the transformer.

All the final technical documentation shall be delivered in electronic form.

11 Figures

11.1 Layout diagrams



12 REVISION

ID	Date	Description	Author	Approved
-	2010-06-30	Document issued first time		
A	2016-11-11	1 st revision	Mariano Berrogaín	Joel Kern
B				
C				
D				