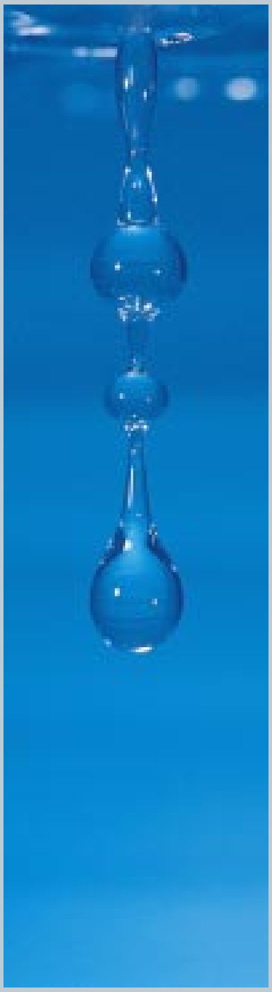
<< Go back

Trihal cast resin dry type transformers

Tests results according to the standard HD 464 S1



C2
resistant to load variations and overloads

E2
resistant to pollution and to condensation

F1
self extinguishing when exposed to fire

in compliance with the standard HD 538.1-S1

france transfo
GROUPE SCHNEIDER

dry type transformers

european standards HD 538.1-S1 and HD 464 S1*

For both process supply and distribution, the transformer is a vital part of the electrical installation.
For the safety of the installation and the peace of mind of the users, we must be able to count on the resistance of the transformer throughout its life whatever occurs: incidents on network, high load variations or agressive environment,etc…

The design of any dry type transformer must take into account storage and operating conditions (humidity, condensation, pollution and ambient temperature).
It may or may not included flammability or better still self-extinguishing properties when external flames are put out.

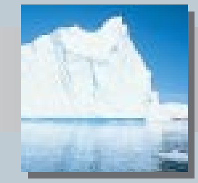
Lastly it may or may not take into account the emission of toxic fumes in the event of pyrolysis or combustion.
The new European standard for dry type transformers covers these aspects.

In addition to the usual dielectric tests, standard HD 464 S1 (1988) defines new tests to demonstrate resistance to 3 types of agressive conditions: environmental, climatic and fire.
Each category has several levels of performance.
Manufacturers must now indicate on dry type transformer identification plates the classes for which they are suitable; buyers can request the reports of tests conducted in compliance with the standard.
For the users, this is a true guarantee of the availability and the reliability of the transformers.

Trihal transformers are classed C2, E2 and F1 according to Hd 464 S1, backed up by test reports. They are therefore in compliance with standard HD 538.1-S1 and guarantee safety for goods and persons.

* HD = CENELEC Harmonization Document

2 climatic classes C

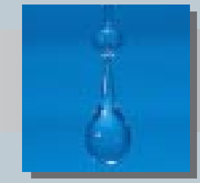


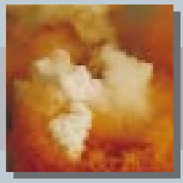
They are defined in relation to the minimum ambient temperature to which the transformer can be exposed in order to approach the temperature variations substained during load variations and overloads.

class C1 = operation at ambient temperatures down to – 5°C;
transport and storage at ambient temperature down to – 25°C;
installation inside.

class C2 = operation, transport and storage at ambient temperatures down to – 25°C;
installation outside.

3 environmental classes E





This is defined in relation to the condensation or humidity existing in the local environment of the transformer.

class E0 = clean and dry installation, no condensation or pollution.
class E1 = occasional condensation and/or limited pollution.
class E2 = frequent condensation and high pollution or a combination of the two.

3 fire behaviour classes F

They are defined in relation to the fire risks and therefore in relation to the needs of goods and security.

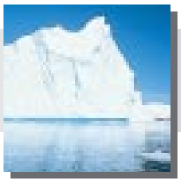
class F0 = no special risk of fire to be considered.
class F1 = risk of fire exists, limited flammability is acceptable. Self extinguishing of the fire must occur within 60 minutes following the start of the special test in accordance with appendix Z.C.3 as per HD 464 S1 (see page 5); materials must be free from halogens; emission of toxic substances and thick smoke must be reduced to a minimum.
class F2 = class F1 requirements must be fulfilled;
in addition, the transformer must be capable of operating for a defined time* when subjected to an external fire.

* to be agreed between the manufacturer and the buyer.

Trihal cast resin dry type transformers tests results according to the standard HD 464 S1:

- following two methods of manufacturer choice (a and b for C2 and E2).
- on one and the same standard transformer manufacture for C2a, E2a and F1 tests.
- in laboratories of international renown.

C_2 E_2 F_1



Climatic C2

Test C2a
(as per standard appendix ZB.3.2.a)

Thermal shock

KEMA laboratory in Holland
Test report No 31813.00-HSL 94-1258
(included in appendix).

630 kVA No 601896.01

Test method
The Trihal transformer was placed for 12 hours in a climatic room where the ambient temperature was initially lowered down to – 25°C (± 3°C) in 8 hours.

Evaluation of results
The Trihal transformer was subjected to a visual inspection followed by dielectric tests (applied voltage and induced voltage tests at 75% of standard values) and partial discharges measurements.
Partial discharges level is critical for cast resin transformer reliability.
The standard HD 538.1-S1 imposes lower than or equal to 20 pC. The result for Trihal transformer was ⩽ 2 pC(1).
No flashover or breakdown occured during the dielectric tets.

photo KEMA

photo KEMA

(1) Trihal transformers are guaranteed ⩽ 10 pC.

Test C2b in addition
(as per standard appendix ZB.2.2.b)

Thermal shock

KEMA laboratory in Holland
Test report No 31882.00-HSL 94-1259
(included in appendix).

Test method
The coils of the Trihal transformer were alternately immersed in 2 tanks, one containing boiling water > 96°C, the other containing iced water < 5°C.
The operation was repeated 3 times. Each immersion lasted for 2 hours. Transfer time between tanks was less than 2 minutes.

Evaluation of results
The Trihal transformer was subjected to a visual inspection followed by dielectric tests (applied voltage and induced voltage tests at 75% of standard values) and partial discharges measurements.
Partial discharges level is critical for a cast resin transformer reliability.
The standard HD 538.1-S1 imposes lower than or equal to 20 pC. The result for Trihal transformer was ⩽ 1 pC(1).
No flashover or breakdown occured during the dielectric tests.

photo KEMA

photo KEMA

Envi

Test E2a
(as per standard appendix ZA.2.2.a)

Condensation and humidity

KEMA laboratory in Holland
Test report No 31813.00-HSL 94-1258
(included in appendix).

630 kVA No 601896.01

1 - Condensation

Test method
The Trihal transformer remained for more than 6 hours in a climatic chamber with the temperature control to obtain condensation. Humidity was maintained by continuous water vaporization above 93%.

Evaluation of results
Within 5 minutes of the end of the vaporization, the Trihal transformer was subjected, in the climatic chamber, to an induced voltage test at 1.1 Um its rated voltage for 15 minutes. No flashover or breakdown occured.

2 - Humidity

Test method
The transformer remained in a climatic chamber for 144 hours with the temperature held at 50°C (± 3°C) and relative humidity at 90% (± 5%).

Evaluation of results
At the end of this period, the Trihal transformer was subjected to applied voltage and induced voltage tests at 75% of standard values.
No flashover or breakdown occured.

photo KEMA

ronment E2

Test E2b in addition

(as per standard appendix ZA.2.2.b)

Condensation and humidity

KEMA Laboratory in Holland
Test report No 31882.00-HSL 94-1259
(included in appendix).

Test method

The Trihal transformer was immersed in water at room ambient temperature for a period of 24 hours.

Evaluation of results

Within the 5 minutes of removal from the water, the Trihal transformer was subjected to an induced voltage test at 1.1 Um its rated voltage for 15 minutes.
No flashover or breakdown occured.
Then after drying the Trihal transformer was subjected to induced and applied voltage test at 75% of standard values.
No flashover or breakdown occured.

photo KEMA

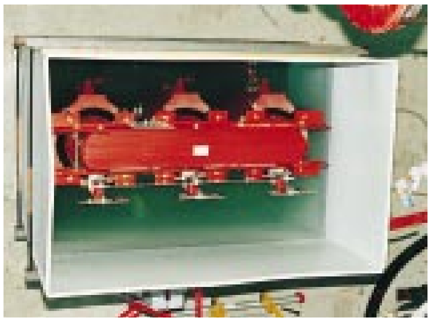


photo KEMA

Fire behaviour F1

Test F1

(as per standard appendix Z.C.3)

Fire

CNPP test laboratory (Centre National de Prévention et de Protection)
Test report No PN94 4636
(included in appendix).

630 kVA No 601896.01

Test method

A complete Trihal transformer coil was placed in the chamber described in IEC 332-3 (relevant to electric cables) see figure 1.
The test was started when the alcohol in the tank (initial level 40 mm) was ignited and when the 24 kW radiant panel was switched on. Test time was 60 minutes in compliance with standard.

Evaluation of results

The temperature rise was measured throughout the test. In compliance with the standard, it remained lower than or equal to 420°C.

At t = 45 min: temperature rise was 85°C (lower than 140°C, and in compliance with standard) see figure 2,

At t = 60 min: temperature rise was 54°C (lower than 80°C, and in compliance with standard) see figure 2.

No components such as hydrochloric acid (HCl), hydrocyanic acid (HCN), hydrobromic acid (HBr), hydrofluoric acid (HF), sulphur dioxide (SO_2), formic aldehyde (HCOH) were detected.

photo from CNPP

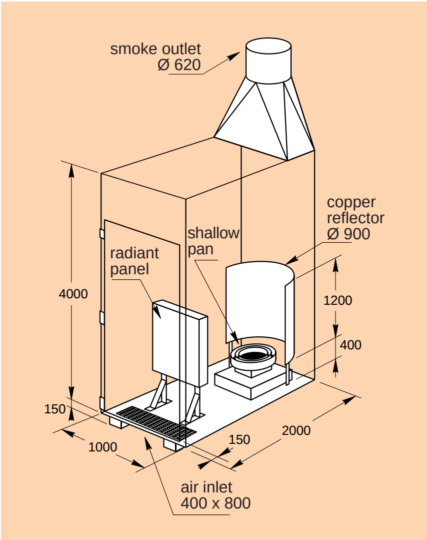


Figure 1: test chamber CEI 332-3

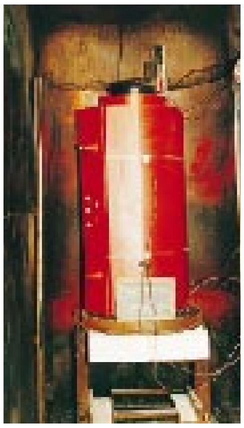
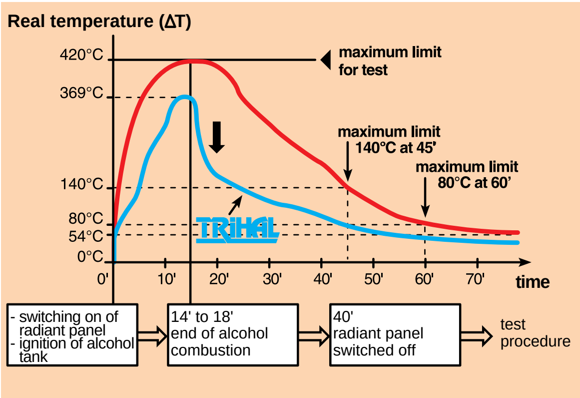


photo from CNPP

Figure 2



France Transfo
BP 140
F-57 211 Maizières-lès-Metz Cedex • France
phone: (33) 03 87 70 57 57 • fax: (33) 03 87 51 10 16

ref. GEa.29 a

design: COREDIT
photos: France Transfo
10/94 - printed in France.

cast resin transformer

Trihal

france transfo
GROUPE SCHNEIDER

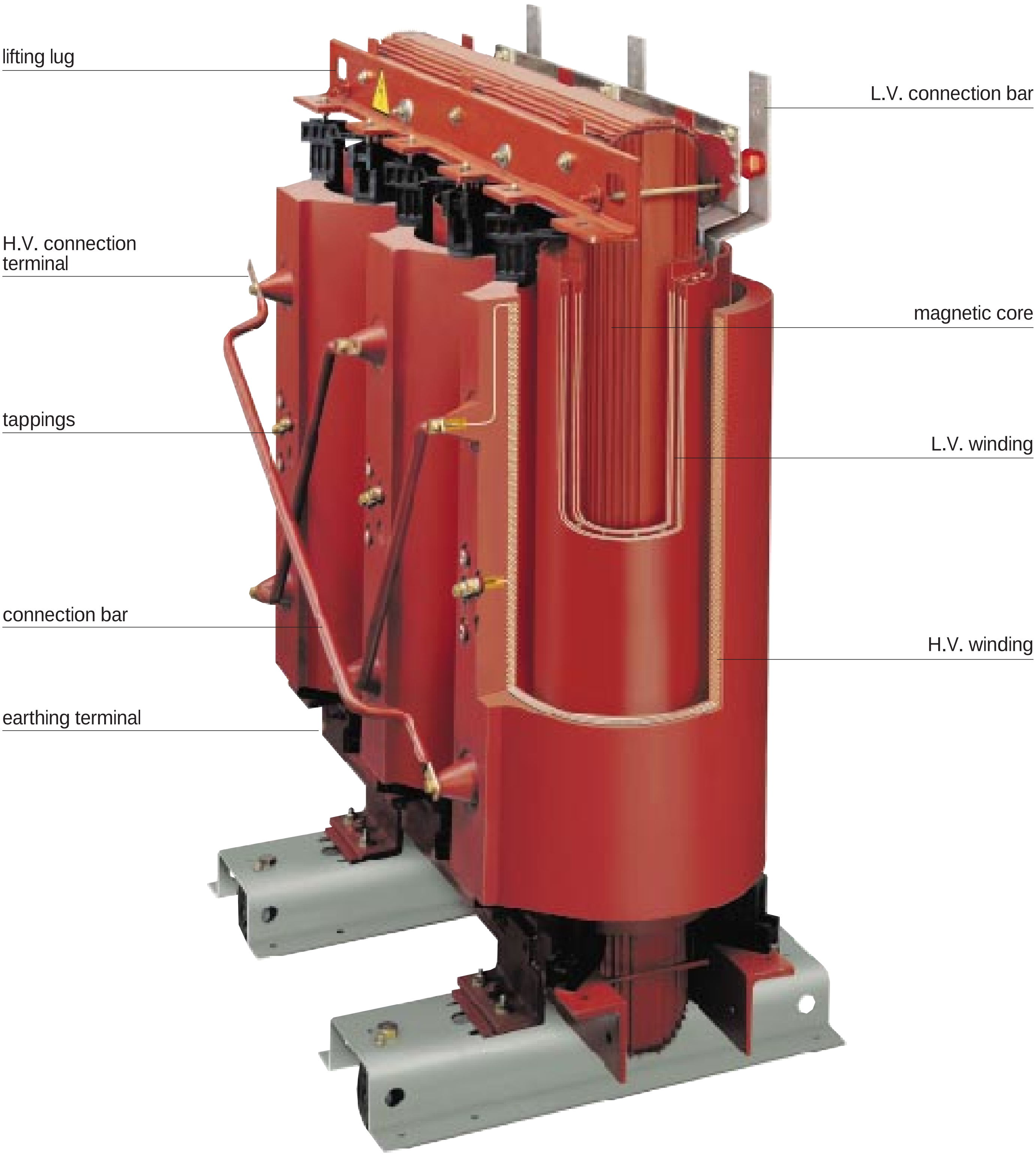
Trihal
contents

(tecnical data sheets inserted in the rear cover of this document or available on request from France Transfo.)

Trihal

A transformer:
- no hazard to the environment,
- minimal maintenance,
- easy installation,
- self-extinguishing.

Trihal



"Illustration only"

type

Trihal is a three-phase dry type transformer **cast under vacuum in filled epoxy resin.**

It is this active filler, essentially composed of **tri-hydrated alumina**, a fire suppressant, which is the origin of the **Trihal** trademark.

Trihal is an indoor type transformer (for outdoor installation, please consult us).

standard

Trihal complies with standards:

■ IEC 76-1 to 76-5;

■ IEC 726 (1982);

■ CENELEC (European Committee for Electrotechnical Standardization) harmonization document HD 538-1 S1: 1992 and HD 464-S1: 1988/A2: 1991 /A3:1992 concerning dry type transformers.

range

■ **HV/LV distribution transformers from 100 to 3150 kVA up to 24 kV.**

For higher rated power and voltages, please consult us.

Trihal transformers are supplied in two versions:
□ **without enclosure (IP00);**
□ **with IP31 metal enclosure.**

The first version do not ensure any protection against direct touch.

■ **HV/HV power transformers up to 15 MVA and 36 kV. Please consult us.**

technology and construction

Trihal, entirely designed and produced by France Transfo benefits from two key patented processes:

■ **a linear voltage gradient from the top to bottom of HV coil.**

The very low electrical stress between adjacent conductors makes interlayer barriers unnecessary and improves the quality of the casting process.

■ **a fireproof casting system.**

This technology, patented by France Transfo is implemented in the Ennery plant in France.

The unit's production capacity allows assuring delays adapted to clients' needs.

quality system

The certificate issued by **AFAQ** (French Association for Quality Assurance) states that Trihal transformers are manufactured in accordance **with a quality system in compliance with the international standard ISO 9001.**

a technology developed and patented by France Transfo

TRIHALHV/LV transformers

TRIHAL HV/HV tranformer
10 MVA-20kV/6350V

rating up to 140 % with AF cooling.

(1) reminder on IP protection indexes:

	1st digit	2nd digit
definition	protection against solid substances	protection against liquid
scale*	0 to 6	0 to 8
IP 31	protection against solid substances > 2.5 mm	protection against vertically falling water drops
IP 21	protection against solid substances > 12 mm	protection against vertical falling water drops

***** 0 = no protection

(2) reminder on IK protection indexes:

definition	protection against mechanical shocs
scale**	0 to 10
IK 7	protection against mechanical shocs ⩽ 2 Joules

** 0 = no protection

Trihal
technology

Excellent impulse strength

Very low partial discharge level (≤ 10 pC)

magnetic core

The magnetic core is made from laminations of grain oriented silicone steel insulated with mineral oxide.

The performance of the core depends on the grade of steel, the cutting pattern and the method of assembly.

low voltage winding

The low voltage winding is usually made of aluminium sheet (copper upon request). This technique reduces axial stresses under short circuit.

The layers of the winding are insulated by a class F material. The core and LV windings assembly is given an additional protective coating of alkyd resin.

This process guarantees **excellent resistance to aggressive industrial atmospheres and excellent dielectrical properties.**

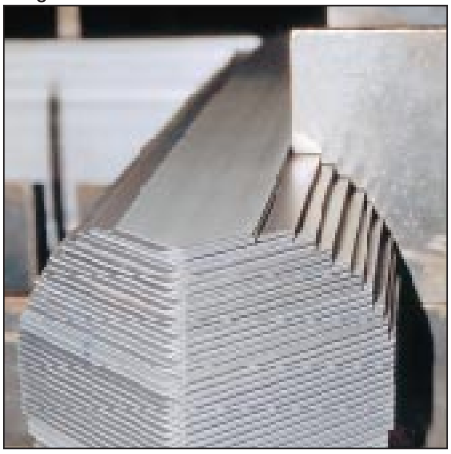
high voltage winding

The high voltage winding is usually wound from insulated aluminium wire (copper upon request) using **a method developed and patented by France Transfo.**

This system gives a very low stress between adjacent conductors because there is a linear voltage gradient from top to bottom of the coil. **It increases series capacity in the coil improving the linearity of impulse wave distribution.** This low stress makes the uses of interlayer insulation unnecessary and the resin can therefore flow round all the conductors forming **a cast resin structure of high quality.**

The high voltage winding is vacuum cast in a class F casting system. The mixing and casting process is carried out under vacuum using epoxy resin filled with inert and fire resistant fillers (see page 5). **These processes combine to give coils of very high dielectric properties with very low partial discharge level (see page 9).**

magnetic core



winding an LV coil

Ennery assembly line.

winding an HV coil

high voltage casting system

It is **a vacuum cast coating of fire resistant filled resin**, a technology developed and patented by France Transfo.

The class F casting system comprises:

■ a bisphenol based **epoxy resin** with a suitable viscosity to ensure excellent impregnation of the windings;

■ an anhydride **hardner** modified by a flexiblishing additive. This type of hardner assures very good thermal and mechanical properties. The flexiblishing additive gives the casting system the necessary elasticity to prevent cracking during operation.

■ **an active powdered filler composed of silica and especially of trihydrated alumina** througly mixed with the resin and the hardner.

Silica reinforces the casting's mechanical strengh and improves heat dissipation.

The trihydrated alumina guarantees the Trihal transformer's intrinsic fire performance. The trihydrated alumina produces 3 anti-fire effects which occur in case of calcination of the casting system (when the transformer is exposed to flames):

- 1st anti-fire effect (1) = refracting shield of alumina,
- 2nd anti-fire effect (1) = barrier of water vapour,
- 3rd anti-fire effect (1) = temperature held below the fire point.

The result of the combination of those 3 anti-fire effects is an immediate self-extinguishing of the Trihal transformer (1).

In addition to its dielectric qualities, the casting system gives the Trihal transformer **excellent self extinguishing fire resistance and excellent environmental protection against aggressive industrial atmospheres.**

(1) See page 6: The anti-fire effects are represented on a section of a Trihal coil.

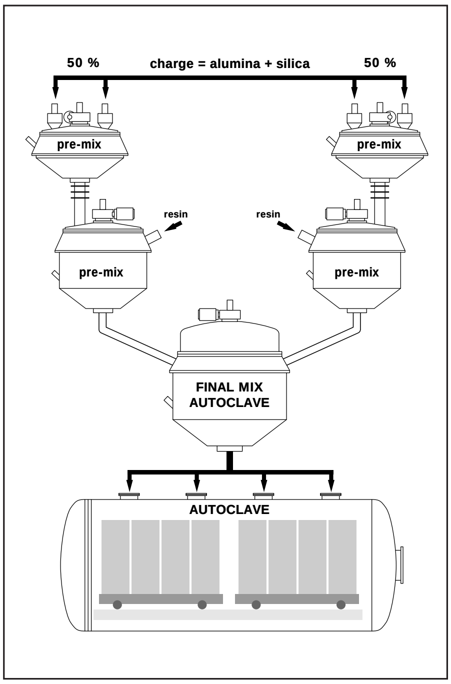


diagram of the vacuum casting process.

high voltage coil casting process

The process from proportioning the resin up to polymerization, is fully controlled by microprocessor.

The trihydrated alumina and the silica are vacuum dried and degased to eliminate all traces of humidity and air which could degrade the casting systems dielectric characteristics.

Half is mixed with the resin and half with the hardner under hard vacuum and controlled temperature, to give two homogenous premixes.

A new thin film degassing precedes the final mixing. Vacuum casting is then carried out in dried and pre-heated moulds at an optimal impregnation temperature.

The polymerization cycle begins with a gelification at 80 Deg. C and ends with a long polymerization at 140 Deg. C.

Immediate self extinguishing

No risk of cracking

control for the casting process

casting premixers

autoclave

Trihal

tests

Trihal is classified F1 as per the HD 538.1-S1* standard

fire behaviour tests

The fire behaviour test of the Trihal transformer's casting system is made up of tests on material and a test F1 according to the HD 464 S1 standard.

■ tests on material

Tests on specimens of the Trihal casting resin were carried out by independent laboratories.

□ decomposition products

The analysis and quantity of gases produced by the material's pyrolisis are carried out according to the clauses of standard NF X 70.100, identical to those of standard UTE C 20454.

Pyrolisis are carried out at 400, 600 and 800 Deg.C, on specimens weighing about 1 gramme each. This test was carried out by *le Laboratoire Central Préfecture de Paris* (Central Laboratory Prefecture of Paris).

□ test results:

The table below indicates the average field (in mass of gas/mass of material) obtained from the values of the three tests carried out at 400, 600 and 800 Deg.C. The NS indication signifies the results are close to the limit of sensitivity thus lacking precision and therefore non-significant. The 0 indication signifies that the gases are absent or that their contents are below the equipments sensitivity.

Laboratoire Central Préfecture de Paris
(Central Laboratory Prefecture of Paris)
Test certificate number 1140/86
on December 2nd 1986

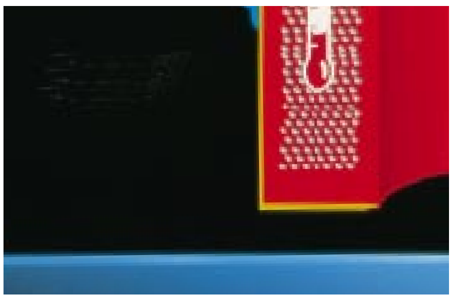
1st anti-fire effect: refracting shield.

2nd anti-fire effect: barrier of water vapour.

3rd anti-fire effect: temperature held below the fire point.

Combination of the 3 anti-fire effects.

Decomposition products : gas content/temperatures			400 °C	600 °C	800 °C
Carbon monoxide	CO		2.5 %	3.7 %	3.4 %
Carbon dioxide	CO_2		5.2 %	54.0 %	49.1 %
Hydrochloric acid	HCl	in the form of chloride ions Cl^-	0	NS	NS
Hydrobromic acid	HBr	in the form of bromide ions Br^-	0	0	0
Hydrocyanic acid	HCN	in the form of cyanide ions CN^-	0	NS	NS
Hydroflouric acid	HF	in the form of fluoride ions F^-	0	0	0
Sulphurous anhydride	SO_2		0.2 %	0.17 %	0.19 %
Nitrogen monoxide	NO		0	NS	NS
Nitrogen dioxide	NO_2		0	NS	NS



Immediate self-extinguishing.

* CENELEC European Harmonization Document.

The HD 464 S1* standard defines 3 tests (Climatic, Environment and Fire) on one and the same dry standard transformer.

■ test F1
(as per the HD 464 S1 standard appendix ZC.3)
Test on a representative model
This test was carried out by *le Laboratoire STELF du Centre National de Prévention et de Protection CNPP* (the STELF Laboratory of the National Prevention and Protection Centre).
Test report No PN94 4636

630 kVA No 601896.01

□ test method

A complete Trihal transformer coil (HV+LV+core) was placed in the chamber described in IEC 332-3 (relevant to electric cables) see figure 1. The test was started when the alcohol in the tank (initial level 40 mm) was ignited and when the 24 kW radiant panel was switched on. Test time was 60 minutes in compliance with standard.

□ Evaluation of results

The temperature rise was measured throughout the test. In compliance with the standard, it remained lower than or equal to 420°C.

At t = 45 min: temperature rise was 85°C (lower than 140°C, and in compliance with standard) see figure 2,

At t = 60 min: temperature rise was 54°C (lower than 80°C, and in compliance with standard) see figure 2.

No components such as hydrochloric acid (HCl), hydrocyanic acid (HCN), hydrobromic acid (HBr), hydrofluoric acid (HF), sulphur dioxide (SO2), formic aldehyde (HCOH) were detected.

test F1 on a complete Trihal transformer coil.

in compliance with the standard HD 538.1-S1*

Trihal transformer coil after the test F1.

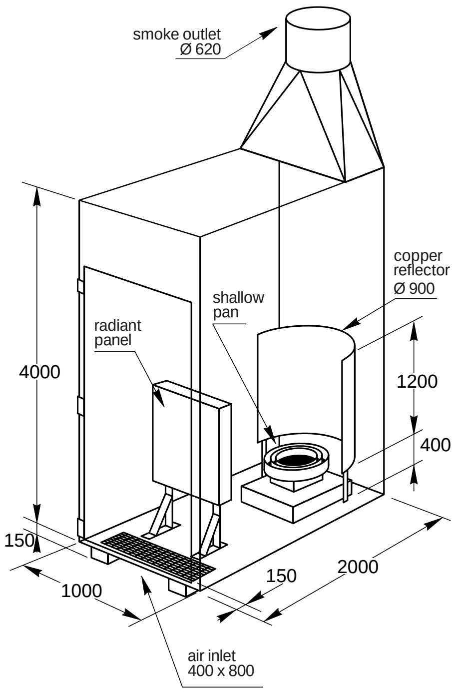
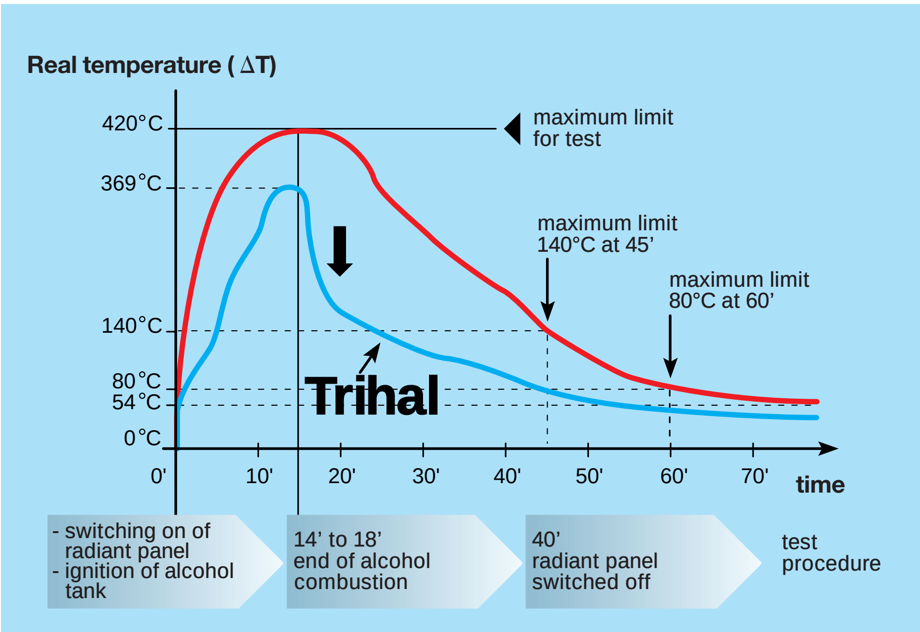


figure 1: test chamber CEI 332-3.

figure 2



* CENELEC European Harmonization Document.

Trihal
tests

Trihal resists to load variations and overloads.

Trihal is classified C2 and E2 as per the HD 464 S1 standard.*

figure 1: C2a

figure 2: C2b

figure 3: E2a

figure 4: E2b

climatic tests

■ test C2a
(as per the HD 464 S1* standard appendix ZB.3.2.a)
Thermal shock
Kema laboratory in Holland
Test report No 31813.00-HSL 94-1258

630 kVA No 601896.01

□ test method

The Trihal transformer was placed for 12 hours in a climatic room where the ambient temperature was initially lowered down to – 25°C (±3°C) in 8 hours (figure 1).

□ evaluation of results

The Trihal transformer was subjected to a visual inspection followed by dielectric tests (applied voltage and induced voltage tests at 75% of standard values) and partial discharges measurements.
Partial discharges level is critical for cast resin transformer reliability.
The standard HD 538.1-S1 imposes lower than or equal to 20 pC. The result for Trihal transformer was ⩽ 2 pC (1).
No flashover or breakdown occured during the dielectric tests.

■ test C2b in addition**
(as per the HD 464 S1* standard appendix ZB.2.2.b)
Thermal shock
KEMA laboratory in Holland
Test report No 31882.00-HSL 94-1259

□ test method

The coils of the Trihal transformer were alternately immersed in 2 tanks, one containing boiling water > 96°C, the other containing iced water < 5°C.
The operation was repeated 3 times.
Each immersion lasted for 2 hours. Transfer time between tanks was less than 2 minutes (figure 2).

□ evaluation of results

The Trihal transformer was subjected to a visual inspection followed by dielectric tests (applied voltage and induced voltage tests at 75% of standard values) and partial discharges measurements.
Partial discharges level is critical for a cast resin transformer reliability.
The standard HD 538.1-S1 imposes lower than or equal to 20 pC. The result for Trihal transformer was ⩽ 1 pC (1).
No flashover or breakdown occured during the dielectric tests.

environment tests

■ test E2a
(as per the HD 464 S1* standard appendix ZA.2.2.a)
Condensation and humidity
KEMA laboratory in Holland
Test report No 31813.00-HSL 94-1258

630 kVA No 601896.01

1 - condensation

□ test method

The Trihal transformer remained for more than 6 hours in a climatic chamber with the temperature control to obtain condensation. Humidity was maintained by continuous water vaporization above 93% (figure 3).

□ evaluation of results

Within 5 minutes of the end of the vaporization, the Trihal transformer was subjected, in the climatic chamber, to an induced voltage test at 1.1 Um its rated voltage for 15 minutes.
No flashover or breakdown occured.

2 - humidity

□ test method

The transformer remained in a climatic chamber for 144 hours with the temperature held at 50°C (± 3°C) and relative humidity at 90% (± 5%).

□ evaluation of results

At the end of this period, the Trihal transformer was subjected to applied voltage and induced voltage tests at 75% of standard values.
No flashover or breakdown occured.

■ test E2b in addition**
(as per the HD 464 S1* standard appendix ZA.2.2.b)
Condensation and humidity
KEMA laboratory in Holland
Test report No 31882.00-HSL 94-1259

□ test method

The Trihal transformer was immersed in salted water at room ambient temperature for a period of 24 hours (figure 4).

□ evaluation of results

Within the 5 minutes of removal from the water, the Trihal transformer was subjected to an induced voltage test at 1.1 Um its rated voltage for 15 minutes.
No flashover or breakdown occured.
Then after drying the Trihal transformer was subjected to induced and applied voltage test at 75% of standard values.
No flashover or breakdown occured.

* CENELEC European Harmonization Document.
** two methods (a or b) of manufacturer choice.
(1) Trihal transformers are guaranteed ⩽10 pC.

electrical tests

These tests verify contractual electrical characteristics. They include:

■ routine electrical tests

These tests are systematically carried out on all Trihal transformers at the end of manufacturing and are subject to an official test report. They consist of:

□ measurements
- resistance of windings;
- transformation ratio and vector group;
- impedance voltage;
- load loss;
- no load loss and no load current.

□ dielectric tests
- applied voltage tests
- induced voltage tests
- measurement of partial discharge, acceptance criterion:
  - ⩽10 pC at 1. 1 Um (1)
  - ⩽10 pC guaranted at 1.375 Un if Um > 1.25 Un
    Un = rated voltage
    Um = system highest voltage

■ type test

They are carried out on request and are at the clients expense.

□ lightning test
The impulse test voltage is usually of negative polarity. The test sequence is composed of a calibration impulse between 50 % and 75 % of the full voltage followed by three impulses at full voltage.
The applied is full standardized lightning impulse, see diagram.

□ temperature rise test in accordance with IEC726
Carried out according to the simulated loading method. Heating measured by two tests:
- one with only no load losses;
- the other with only load losses.
The total temperature rise is calculated in accordance with IEC 726.

■ special tests

They are carry out on request and are at the expense of the customer.

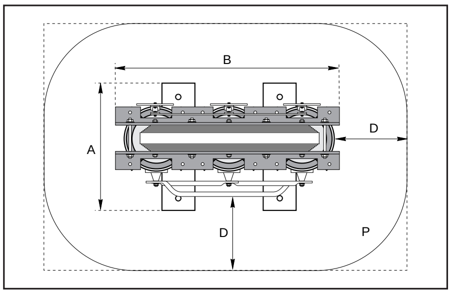
□ short circuit test
These tests are carried out on a special platform according to standard IEC 76-5.
These tests are carried out per leg for 0.5 seconds.
Satisfactory test result carried out on a Trihal transformer 800 kVA-20kV/410v on February 29th 1988 at Centre d'Essais EDF (Electricité de France) des Renardières (The EDF Test Centre of Les Renardières).

Centre d'Essais EDF des Renardières
(EDF Test Centre of Les Renardières)
Official Tests results HM51/20. 812
Dated March 4th 1988.

□ noise level measurements
- Measurements of noise level is part of the special tests carried out on request.
- The transformer noise is produced mainly by the magnetrostriction of the core.
- The noise level can be expressed in two ways:
  - in acoustic pressure level L_P(A) obtained by calculating the quadratic average of measurements carried out according to standard IEC551 at a distance given on a transformer energised at rated voltage.
  - L_W(A), the acoustic power level is calculated from the acoustic pressure level using the following formula:

$L_W(A) = L_P(A) + 10 \log S$

L_W(A) = mean acoustic power level in dB (A);
L_P(A) = average level of acoustic pressure levels measured in dB (A);
S = equivalent surface in sq m.
=1.25 x H x P
Where H = transformer height in metres;
and P = measurement contour perimeter at a distance D.



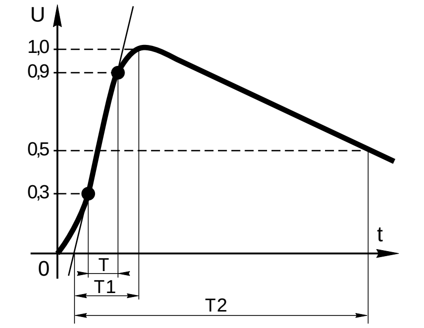
$P = 2 (A + B + D\pi)$
D = 1 m for Trihal IP00
D = 0.3 m for Trihal with enclosure

partial discharge level ⩽ 10 pC

insulation 24 kV:
impulse tested at 125 kV

insulation 36 kV:
impulse tested at 170 kV

full wave lightening impulse



front time	T1 = 1.2 µs ± 30 %
tail time	T2 = 50 µs ± 20 %
relation between T1and T	T1 = 1.67 T

(1) summary of standard test levels

system highest voltage (kV)	**3.6**	**7.2**	**12**	**17.5**	**24**	**36**
eff. kV 50 Hz - 1mn	10	20	28	38	50	70
impulse kV 1.2/50 µs	40	60	75	95	125	170

test department control room

Trihal
installation

Easy and fast installation

Trihal transformers with IP 31 metal enclosure installed in a steel works.

One instruction leaflet for installation, commissioning and maintenance is provided with the transformer.

general information

Due to the absence of any liquid dielectric and the excellent fire behaviour of Trihal transformers, no anti-fire precautions are necessary providing the following guidlines are followed:

□ The transformer should not be installed in a flood hazard area;
□ The altitude should not be above 1000 metres unless a higher altitude is specified at the time of enquiry;
□ The ambient temperature for the transformer to be within the following limits:
- minimum: – 25 Deg.C;
- maximum: + 40 Deg.C (unless a special demand requiring special calculating of the transformer is made at the time of enquiry).

Standard transformers are designed in accordance with IEC 76 for an ambient temperature of:
• maximum : 40 Deg.C
• daily average : 30 Deg.C
• yearly average : 20 Deg.C

□ The local ventilation should allow the dissipation of the transformer total losses.
□ The transformer even with IP31 metal enclosure is designed for an indoor installation. (Please consult us for an outdoor installation).
□ Provision should be made for access to connectors and tapping links.
□ For mobile installations please consult us.

■ Trihal without enclosure (IP 00) (figure 1)

In this configuration the transformer must be protected against direct contact.
□ care must also be taken to eliminate risks of water drops on the transformer (example : condensation from overhead pipings).
□ maintain minimum clearance to the walls etc. according to the following table:

insulation (kV)	dimensions X(1) (mm) full wall	ventilation grill
7.2	90	300
12	120	300
17.5	220	300
24	220	300
36	320	320

Please consult us if any of these distances can not be achieved.

■ Trihal with IP31 metal enclosure (figure 2)

A minimum distance of 200 mm between the exterior of the enclosure and the walls of the building should be maintained to ensure adequate cooling.

(1) do not take account of access to the variation tapping links.

figure 1

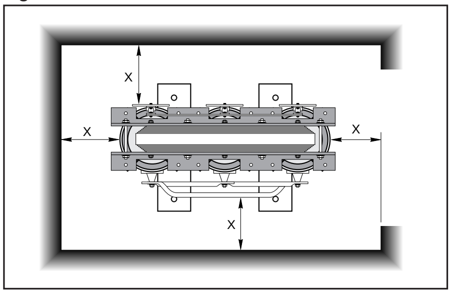
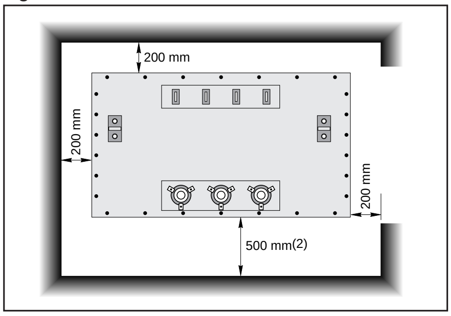


figure 2



(2) for access to the voltage variation tapping links but 200 mm minimum.

Trihal transformaters (IP 00) installled on the universal exhibition from Seville, EXPO 92.

ventilation

■ determination of the height and area of ventilation grills.

In the general case of natural cooling (AN) the ventilation of the substation or of the enclosure must ensure by natural convection the dissipation of the heat produced by the transformer's total losses.
In case of a no sufficiently ventilation substation, appropriate ventilation will consist of a fresh air intake opening of S section at the bottom of the local and an air outgoing opening S' located above on the opposite wall at height H metres above the intake opening (figure 1).
It must be noted that restricted air circulation reduces the transformer's continuous and short term overload capacity.

■ formula for ventilation:

$$S = \frac{0.18\,P}{\sqrt{H}} \quad \text{and} \quad S' = 1.10 \times S$$

P = sum of the transformer's no-load and load losses expressed in kW at 120°C.
S = area of the lower air intake opening (allow for mesh factor) expressed in sq m.
S' = area of the air outlet opening (allow for mesh factor) expressed in sq m.
H = height difference between the two openings expressed in metres.

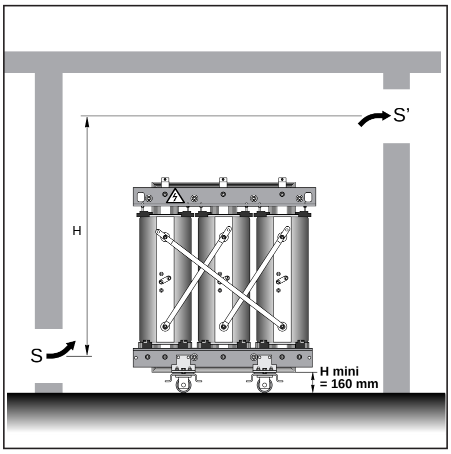
This formula is valid for an average ambient temperature of 20 Deg.C and an altitude of 1000 m.

■ forced ventilation

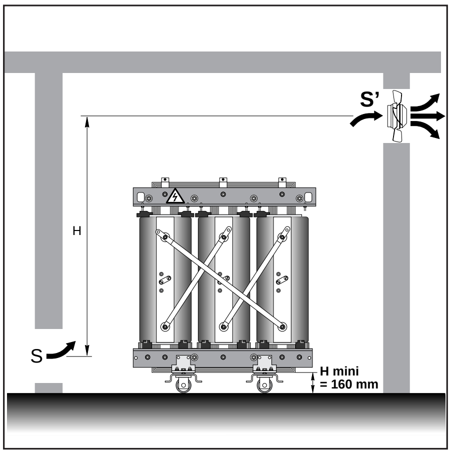
Forced ventilation of the substation is necessary for ambient temperatures above 20 Deg.C or small or badly ventilated rooms for applications with frequent overloads.
The fan can be controlled by a thermostat.
Advised flow (m^3 / second) at 20 Deg.C : 0.1 x P.

P = total losses in kW.

figure 1



forced ventilation



Trihal
installation

connections

In all cases shown the cables or busbars must be supported to avoid mechanical stress on the HV or LV terminals or HV plug in connectors.
The HV connections should be made to the top of part of the delta connection bars.
The LV connections are made at the top of the transformer.

Warning:
- The distance between HV cables or busbars and the surface of the winding should be at least 120 mm except on the flat face of the HV side where the minimum clearance will be set by the HV terminal.
- The clearance to the outer HV delta bar should also be a minimum of 120 mm.
- The resin coating, or the use of plug in connectors does not give protection against direct contact and the transformer must not be touched when it is energised.

■ Trihal without metal enclosure (IP00)

□ standard HV and LV connections.
- the outgoing (or incoming) LV conductors can be made from above or below (figures 1 and 2).
- the outgoing (or incoming) HV conductors can be made from above or below (figures 1 and 2)
- In case of an outgoing (or incoming) conductors from below it is necessary to put a spacer (spacer will not be supplied by France Transfo)

■ HV connections with plug in connectors (figure 3)

figure 1- standard HV and LV connections from above

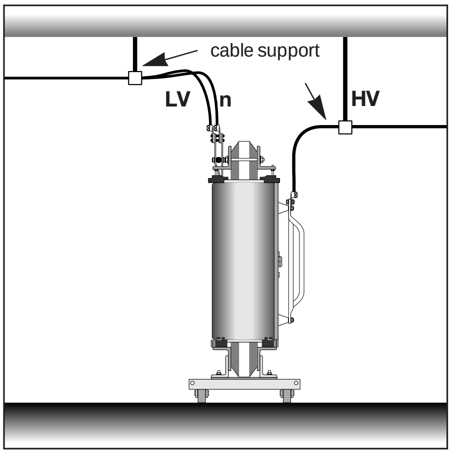


figure 2 - standard HV and LV connections from below

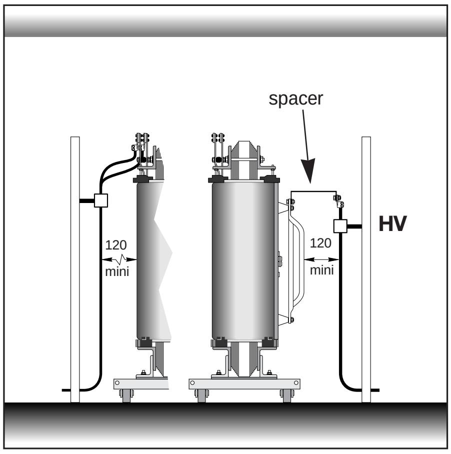
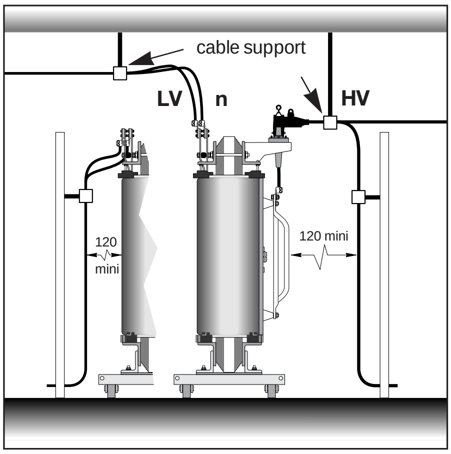


figure 3 - HV connections with plug in connectors



Standard HV and LV connections from above

■ Trihal with IP31 metal enclosure

□ standard HV and LV connections (figures 1 and 2)
- the outgoing (or incoming) LV conductors must go upwards from the terminals under the enclosure cover.
- the LV conductors should never pass between the HV coils and the enclosure.
- the outgoing (or incoming) HV conductors can pass above (figure 1) or below (figure 2).

□ HV connection from below
- the outgoing (or incoming) HV conductors can come from below directly to the connection terminal (figure 2). In this case incoming conductors are passed through the removable flap door located at the bottom on the right HV side.
- the HV cables must be fastened inside the enclosure on the HV side panel. Two blanked off holes with screw nut system are provided for fitting cables inside the enclosure on the HV side (figure 2) (the fixing system is not supplied by France Transfo).
  It is advisable to verify the feasibility of this type of connection in relation to the section and the bending radius of cables and the space available in the enclosure.

□ HV connection by plug in connector (figure 3)

Warning:
It is necessary to verify conformity with the IP31 protection index after having drilled the insulation gland plate for HV, LV and other connections (thermal protection…)

Standard LV connections from above (1).

HV connections from above with plug-in connectors (1) (option).

HV and LV connections from above.

(1) by removing dismantled panels of the enclosure.

figure 1 - standard HV and LV connections from above

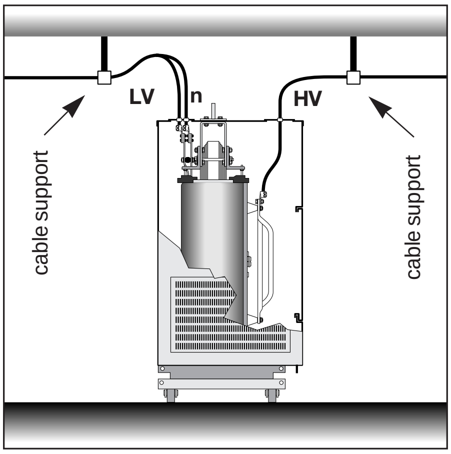


figure 2 - standard HV connection from below

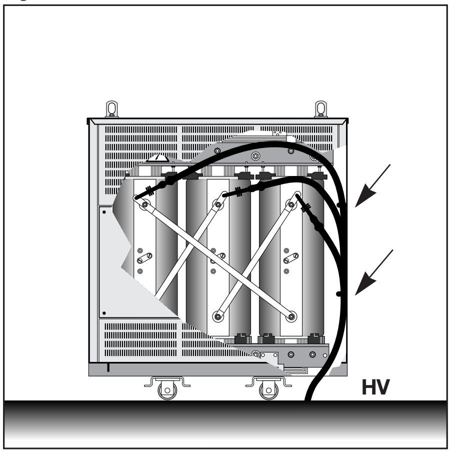
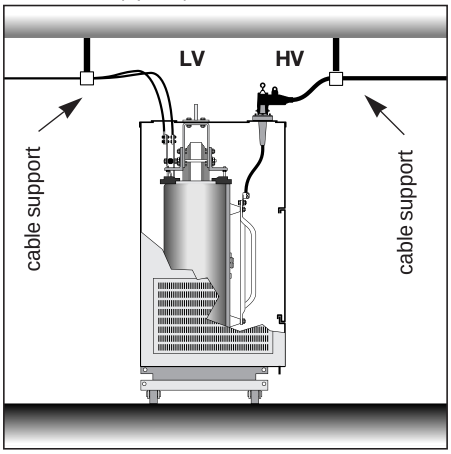


figure 3 - HV connections with plug in connectors (option)

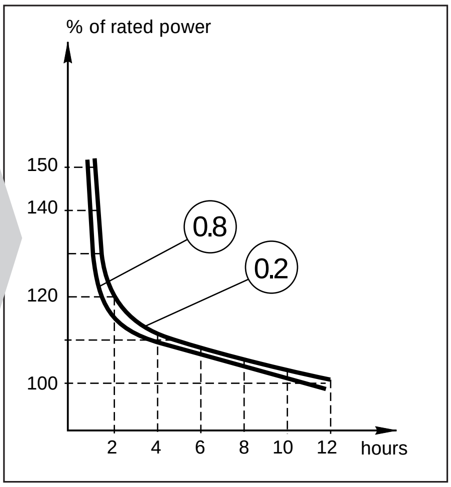


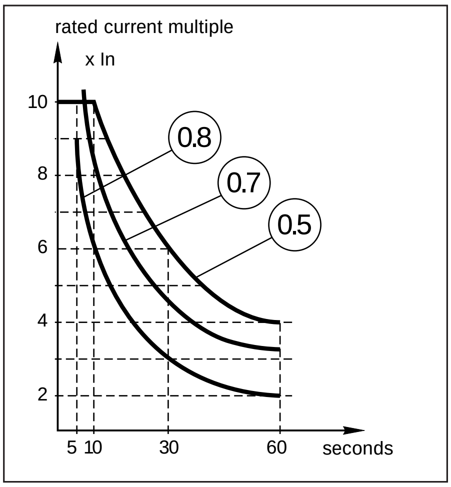
Trihal
overloads

admissible temporary overloads for daily load cycle

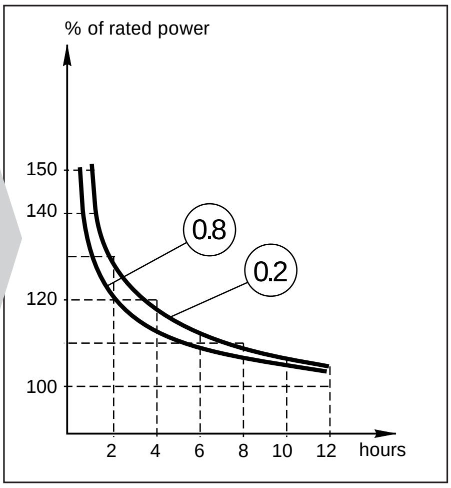
acceptable short time overloads

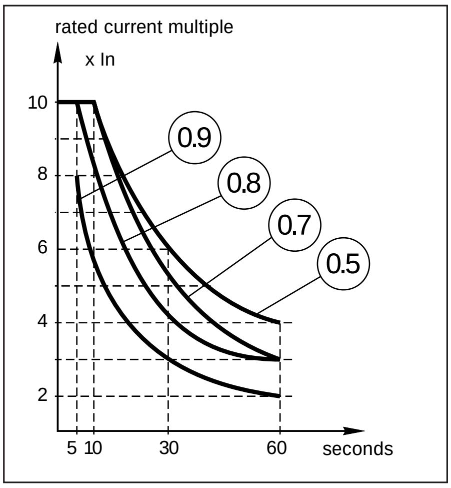
annual ambient temperature + 10 Deg.C



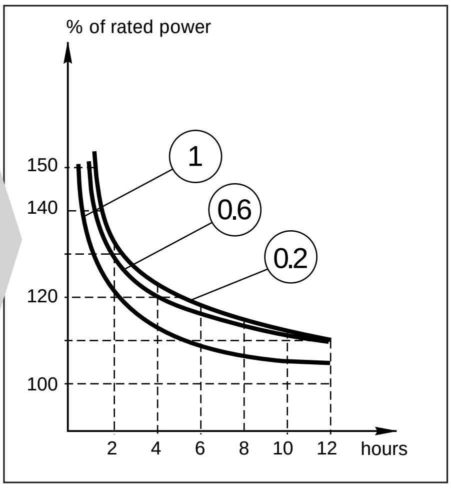


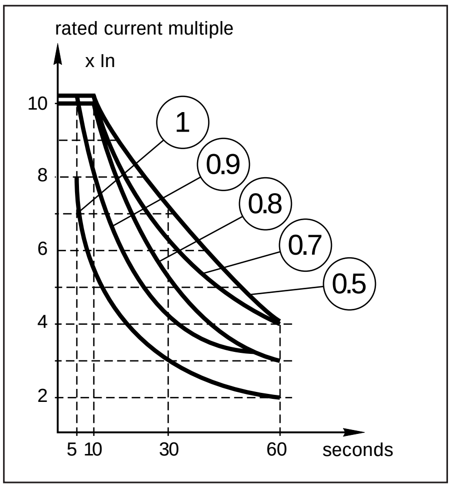
annual ambient temperature





annual ambient temperature – 10 Deg.C





general information

The transformers are designed to operate at rated power at ambient temperature defined by IEC 76:

- maximum : 40 Deg.C
- daily average : 30 Deg.C
- yearly average : 20 Deg.C

Without particular specification, the reference temperature is the annual average of 20°C.

■ overloads are allowed without reducing the transformer's service life if they are compensated by a normal load below the rated power.

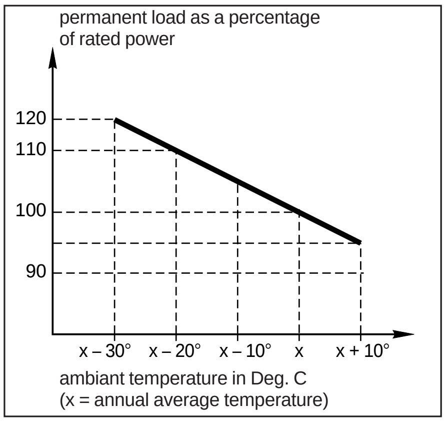
$$K = \frac{\text{load}}{\text{rated power}}$$

The admissible overloads are also subject to the average mean ambient temperature.

The 1st column gives the cyclical daily overloads.

The 2nd column indicates the acceptable short time overloads.

■ the figure below shows the acceptable constant load as a function of the average temperature compatible with normal life duration.



■ one can operate a transformer designed for operation in ambient of 40 Deg.C at higher temperatures by reducing the rating as shown in the table.

maximum ambient temperature	admissible load
20°C	P
25°C	0.97 x P
30°C	0.94 x P
35°C	0.90 x P

handling

The transformers are equiped with provisions for safe handling.

■ lifting with slings (figure 1)

Lifting is carried out using the 4 lifting holes for a transformer without an enclosure and by 2 lifting lugs in the case of a transformer with an enclosure. The slings should not form an inside angle greater than 60 Deg.C.

■ lifting with a fork lift truck (figure 1)

The lifting capacity of the fork lift truck should first be checked. If suitable, the forks should be inserted inside the base channels after removing the rollers.

■ towing

Towing the transformer with or without enclosure should be done from the underbase. For this purpose hole of 27 mm. diameter are provided on every side of the underbase. Towing can be done in two directions : in the axis of the underbase and perpendicular to that axis.

■ fitting the rollers

□ either by lifting with slings (figure 1)

□ or by lifting with a fork lift truck (figures 1 and 2)

In this case position the lifting forks in the underbase channels.
Place timbers of greater height than the rollers under the channels and lower the transformer on to them.
Position jacks and remove the planks.
Attach the rollers in the desired position (bi-directional rollers).
Lower and remove allowing the Trihal to rest on its rollers.

storage

The Trihal transformer should be protected in storage from water drops and dust generating work (masonry, sanding etc…).
If the Trihal transformer is delivered with a plastic cover which should be kept over the equipment whilst it is in storage.

The Trihal transformer can be stored at a temperature down to 25 Deg.C.

figure 1

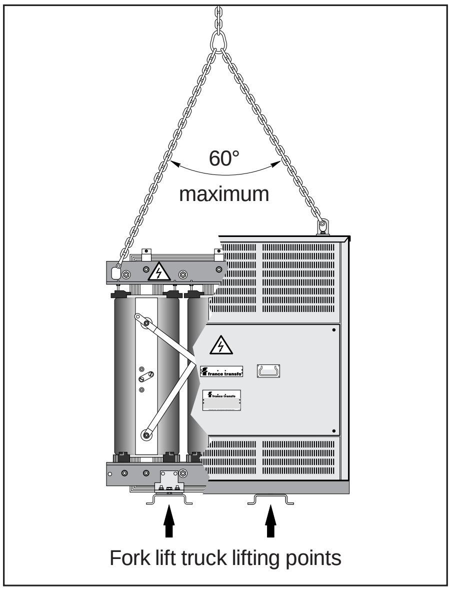
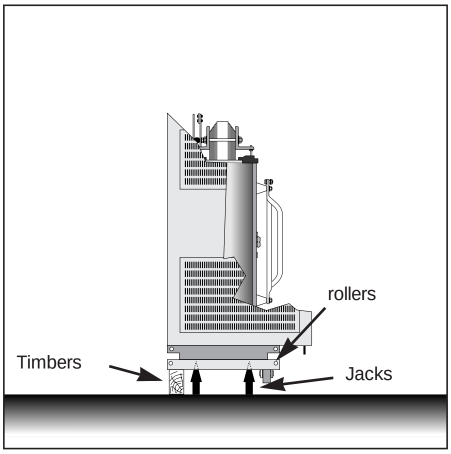


figure 2



loading

Trihal
commissioning and maintenance

commissioning (1)

■ installation local (see page 12)

The location should be dry, clean, finished and free from risk of water entry.
The Trihal transformer should not be installed in an area liable to be flooded.
The location should have sufficient ventilation to ensure the transformers total heat losses can be dissipated (see p 11).

■ checking the condition after storage

If the Trihal transformer is found accidentally to be very dusty clean it by vacuum cleaner or by blowing with compressed air or nitrogen and thoroughly clean the insulators using paper towels.

■ Trihal transformers supplied with a plastic cover: transformers without enclosure (IP 00)

To avoid contamination by foreign bodies such as screws, nuts, washers etc… the cover should remain in place during the whole connecting operation: to gain access to HV and LV connections tear the cover.

NB : The plastic cover must be removed before putting the transformer into service.

■ Trihal transformer supplied with metal enclosure

The enclosure should in no place support loads other than the supply cables for the transformer. The installation inside the enclosure of unauthorised equipment or accessory not supplied by France Transfo except the connection cables correctly installed as shown in the relevant section, is not permitted and invalidates the guarantee. For any modifications, attachements and mounting of accessories, please consult us.

■ HV and LV connections cables (see page 13)

In no case should fixing points be made on the transformer core and windings. The distance between the HV cables, the LV cables, or the LV bars and the surface of the HV winding should be at the least 120 mm. except on the high voltage side where the minimum distance is to be considered from the farthest delta connection.

■ connection of HV connectors

Connection tightening torque on the HV terminal and tapping links:

tightening torque for bus bars bolts	M8	M10	M12	M14
tightening torque mkg	1	2	4	6

■ connection of LV connectors.

Connection tightening torque for the LV bars:

tightening torque for bus bar bolts	M8	M10	M12	M14	M16
tightening torque mkg	1.25	2.5	4.5	7	10

■ auxiliary wiring

Auxiliary wiring from the transformer should be attached on rigid supports (without any ties) and have sufficient clearance from live parts. The minimum clearance to respect is determined by the insulation voltage indicated on the rating plate.

insulation voltage (kV)	minimum clearance (mm)
7.2	270
12	450
17.5	450
24	450
36	650

NB : Do not fix accessories etc… to the core and windings of the transformer.

■ parallel operation

Verify the identity of the HV and LV voltages and the compatibility of characteristics and especially the vector groups and the impedance voltage. Make sure that the same tapping is selected for transformers to be coupled in parallel according to the HD 398 standard.

■ checks before commissioning:

□ remove the protective cover and check all the connections (arrangements, distances, tightening torques);
□ check cable and bus bars entries after connection to ensure IP rating has been maintained;
□ verify the position identity of tapping links on the three phases are in accordance with the diagram on the rating plate;
□ verify the transformers general state of cleanliness and carry out an insulation test verifying HV and LV earth and HV and LV insulations using a 2500 V insulation tester (Megger).

The approximate values of resistances are:

HV/earth = 250 MΩ
LV/earth = 50 MΩ
HV/LV = 250 MΩ

If the values measured are significantly below, verify the transformer is not moist. If it is, dry it with a rag and repeat the verification.

In the contrary please contact our after sales department.

maintenance (1)

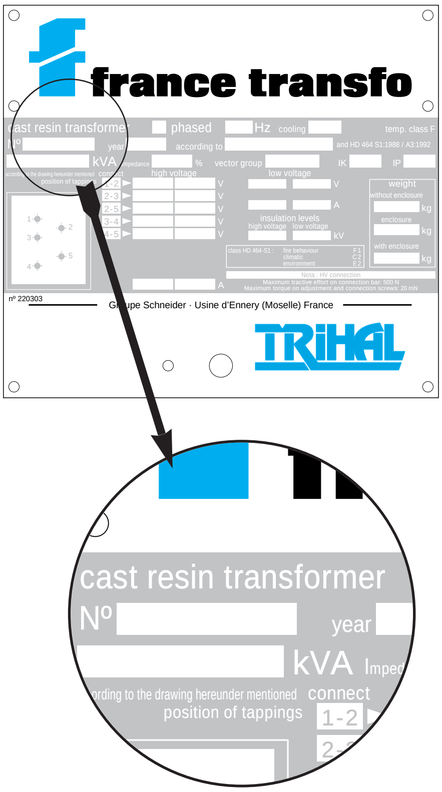
In normal use and environment at conditions inspect the transformer each year and vacuum clean or blow with dry compressed air to remove excessive dust. The frequency of cleaning will be a function of service conditions. During such maintenance the connection bolts should be checked for tigtness using a torque wrench.

In the case of greasy dust deposits, only use a cold degreasing product to clean the resin surfaces (example: DARTOLINE SRB 71 or HAKU SRB 71).

(1) One instruction leaflet for installation, commissioning and maintenance is provided with the transformer.

after sales services

For any information or replacement parts it is essential to quote the main characteristics on the rating plate and especially the transformers serial number.



HV/LV distribution transformers

TRIHAL cast resin transformers
thermal protection by PTC sensors

france transfo
GROUPE SCHNEIDER

An optional thermal protection module is available on request. This will monitor the temperature of the windings and prevent overheating.

the standard thermal protection comprises:

■ **2 PTC sensors assemblies,** each one comprising three positive temperature coefficient thermistors connected in series. The first one gives an alarm signal at 150°C (alarm 1), the second an alarm signal at 160°C (alarm 2).
The PTC sensor abruptly changes its resistance value at its operating temperature threshold. This is preset during manufacture and not adjustable. The rapid increase in resistance of the sensors at their operating temperature is detected by the Z electronic converter, to which they are connected. Sensors, one for alarm 1 and one for alarm 2 per phase are located in tubes between the magnetic core and the LV winding and can be withdrawn and replaced should this ever be necessary.

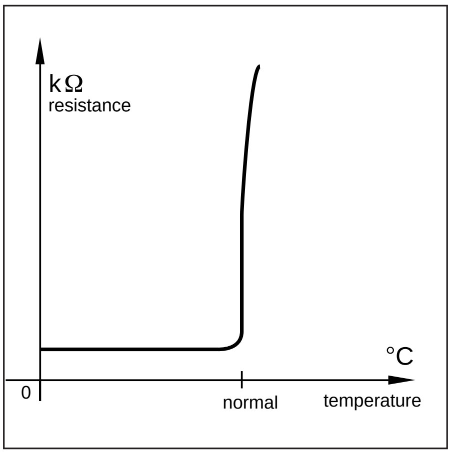
■ **1 A Z electronic converter with 3 independent metering circuits.**
Two of these circuits respectively control the variation in resistance between the 2 PTC sensor units. When the temperature reaches 150° C (or 160° C), information from Alarm 1 (or Alarm 2) is respectively processed by the 2 independent output relays equipped with a changeover switch contact; the position of these two relays is signalled by 2 red coloured LED's.
The third metering circuit is shunted by an external or enclosure mounted resistance R; it can control a 3rd PTC sensor unit at 140° C as long as this resistance is eliminated. In this case ("Forced Air" option on request), the FAN information is processed by a 3rd independent output relay equipped with a closing contact; the position of this relay is signalled by a yellow LED.
In case of the failure of one of these 3 probe circuits (breaking or short-circuit), a red coloured LED marked SENSOR flashes, together with that of the incriminating circuit.
A green coloured LED signals the presence of voltage to the enclosure.

■ **a terminal board with plug-in connectors** in order to connect the PTC sensors to the electronic converter.
The PTC sensors are supplied connected to the terminal board fixed on the upper core clamp of the transformer.

Z electronic converter

terminal-board with plug-in connectors connecting the PTC sensor and the Z electronic converter

PTC sensors



characteristic curve diagram of a PTC sensor

HV/LV distribution transformers

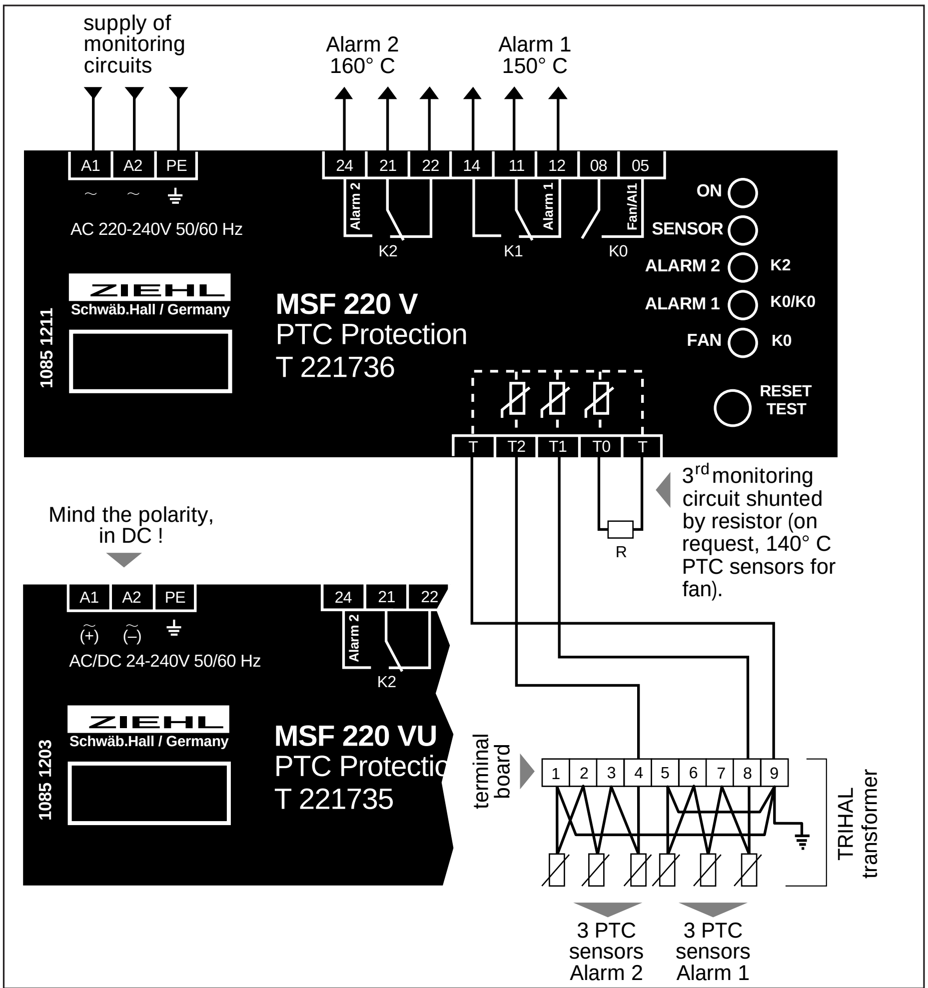
TRIHAL cast resin transformers
thermal protection by PTC sensors

france transfo
GROUPE SCHNEIDER

Z converter technical data

monitoring circuits	supply voltage (1)	**AC 230 V***
	tolerance voltage	– 15 % to + 10 %
	frequency	48 to 62 Hz
	input	< 5 VA
	maximum resistance of a PTC sensors circuit before operation of the converter	⩽ 1500 Ω
output contacts : alarm 1 and alarm 2	maximum switching voltage	AC 415 V
	maximum switching current	5 A
	switching power	AC 2000 VA (ohmic load)
	continuous rated current	AC 2 A
	rated service current	AC 2 A under 400 V
	advised above fuse	4 A rapid
	contact life — mechanical	3 x 10^7 operations
	contact life — electrical	10^5 operations
	contacts load reduction ratio	0.50 max with power factor = 0.30
Z electronic converter	admissible ambient temperatures range	0°C to + 55° C
	dimensions (H x L x P)	90 x 105 x 60 mm
	weight	250 g
	protection index — terminal board	IP 20
	protection index — protective housing	IP 20
	maximum capacity on a terminal connection	1 x 2.5 mm^2 rigid
	fixing	either on a DIN 35 mm rail or with M4 screw

(1) must be specified at the order
*** standard version. Other voltage on request: AC/DC 24 to 240 V, tolerance ± 15 %.**



power supply

Monitoring circuits have to be supplied from an auxiliary supply (standard: AC 220 to 240 V). If no suitable supply is available they may be supplied from the transformers secondary voltage.

installation

Z converter should never be installed on the transformer or inside its metal enclosure due to the limit on operating temperature (see table opposite).

■ it can be installed in the low voltage switch-board or on a wall in a vertical or horizontal position (see table opposite for fixing details).

■ **it is advised, especially for an installation in a low voltage switchboard, to keep a minimal clearance of 2 cm to other equipment or heat sources and to ensure adequate ventilation. Take care also to the highest voltage according to insulation voltage.**

■ **connections :**
The PTC sensors are supplied connected to the terminal board fixed on the upper core clamp of the transformer. The wiring from to the terminal board of the electronic converter is not supplied by France Transfo (see chart opposite).

the following guidelines in connection wiring should be followed :

- maximum length of connection: .... 40 metres
- minimum conductor area:...... 0.5 sq mm
- screened cables should be used if wiring passes near power conductors.
- terminal tightening : 0.5 Nm max.
- no fixings should be made on the transformer.
- the following minimum clearances to live conductors must be maintained:

system highest voltage (kV)	**minimum clearance** (mm)
7.2	270
12	450
17.5	450
24	450
36	650

connection diagram
of the Z thermal protection module
(usual case of utilization)
Shown unenergized

Due to the evolution of standards and materials, the present document will bind us only after confirmation from our technical department.

France Transfo
BP 10140
F 57281 Maizières-lès-Metz Cedex
tel. (+33) 03 87 70 57 57 - fax (+33) 03 87 51 10 16

Ref : GEa 105 g

N° Ident. TVA: FR 78 357801109 • Edition France Transfo - Limited company - Social capital 10 280 000 FRF - RCS Metz B 357 801 109 • Printed in France • Composition and illustrations: COREDIT • 07/98

HV/LV distribution transformers

Trihal cast resin transformers T thermal protection module with PT 100 sensors

france transfo
GROUPE SCHNEIDER

An optional thermal protection module is available on request for Trihal cast resin transformers. This will monitor the temperature of the windings and prevent overheating.

the standard, T thermal protection module comprises:

■ **PT 100 sensors**

The main feature of the PT 100 is that it gives the temperature in real time progressively from 0°C to 200°C -see the graph opposite (accuracy +/- 0,5 %, i.e. on the measurement scale +/-1 deg.).
The temperature is monitored and displayed by a digital thermometer. The 3 sensors, each comprising one white and two red wires, are located in tubes between the magnetic core and the LV winding, on each phase. So they can be withdrawn and replaced as and when necessary.

■ **1 T digital thermometer**, featuring three independent circuits.
Two of the circuits monitor the temperature read by the PT 100 sensors, one for alarm 1 and one for alarm 2.
When the temperature reaches 150 °C (or 160 °C) alarm 1 (or alarm 2) information is processed by two independent output relays fitted with change-over switches. The status of these relays is displayed by two red coloured diodes (LED).
The third circuit monitors for sensor faults or breaks in power supply. The corresponding relay (FAULT), which is independent and fitted with change-over switches, is instantly switched on when power is connected to the device.
Its status is also displayed by a red coloured diode.
The T digital thermometer is delivered with full instructions for installation and use.

■ **1 terminal block** to connect the PT 100 sensors to the T digital thermometer.
The block is equipped with a plug-in connector.
The PT 100 sensors are delivered pre-connected to the terminal block attached to the upper part of the transformer.

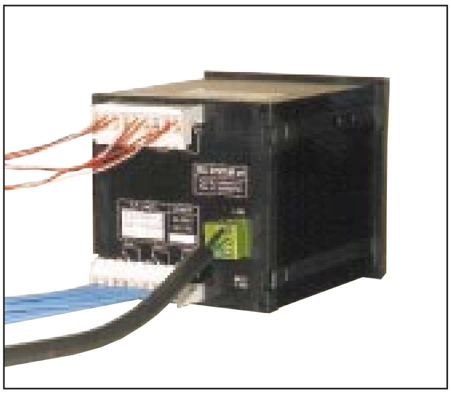
options

The following extras can be fitted to the T thermal protection module:

■ **1 additional sensor** to be placed on the transformer or in the local vicinity.

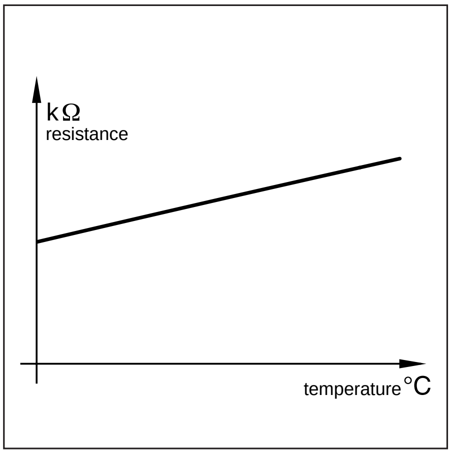
■ **ventilation system control**
- 1st ventilation (1st relay)
- 2nd ventilation (2nd relay): external to the transformer.

■ **1 analog output** with serial RS 232/485/ INTRS/4-20 mA for the hottest channel.

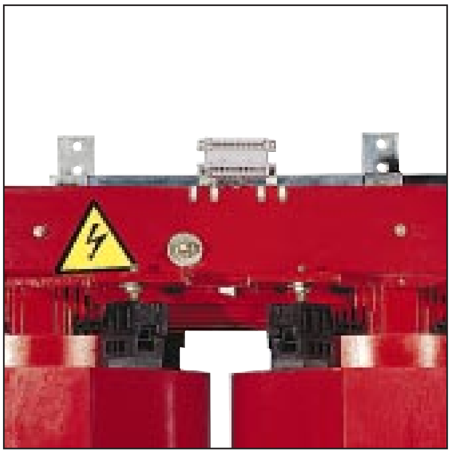


connections to the T digital thermometer

T digital thermometer



characteristic temperature curve given by a PT 100 sensor



terminal block connecting the T digital thermometer to the PT 100 sensors

HV/LV distribution transformers

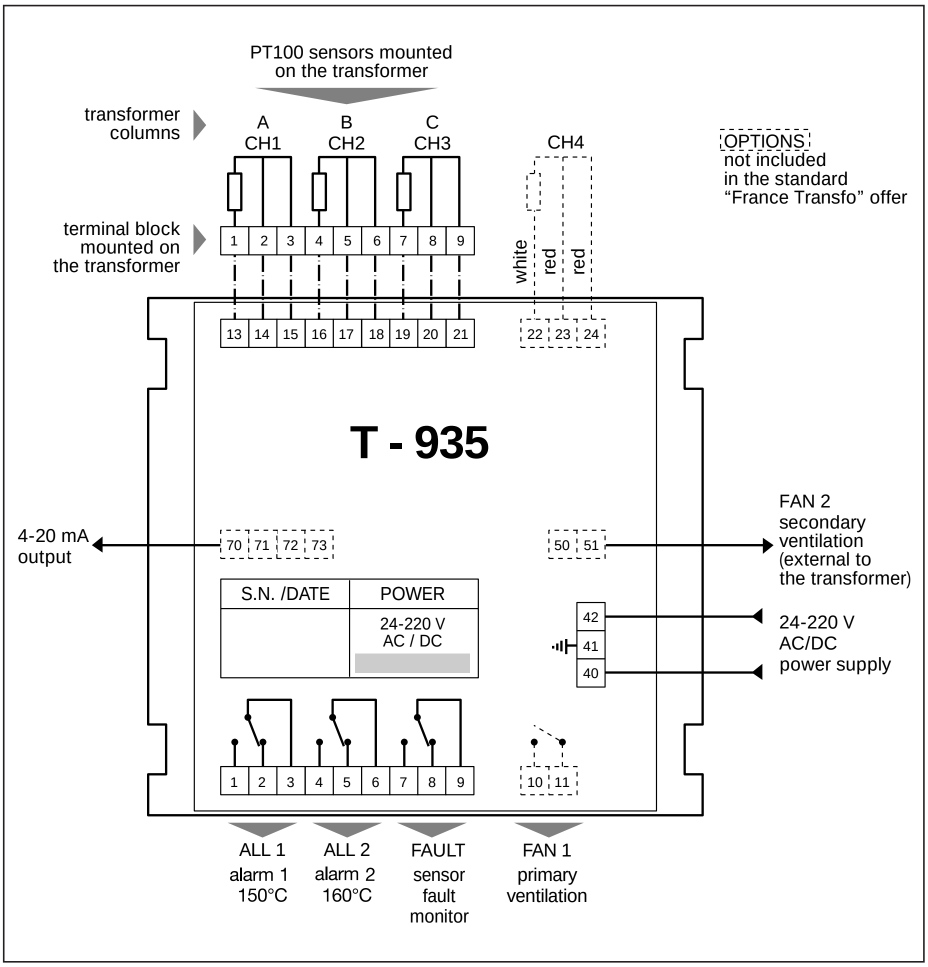
Trihal cast resin transformers
T thermal protection module
with PT 100 sensors

france transfo
GROUPE SCHNEIDER

T digital thermometer - technical data
conformity with standards IMQ - VDE - UL - CEE

monitoring circuits	supply voltage(1)	24 V to 220 V AC/DC
	frequency	50-60 Hz AC/DC
	power consumption	10 VA AC/DC (40 VA pick up)
output contacts: alarm 1 and alarm 2	maximum switching voltage	250 V AC
	maximum switching current	5 A (resistive circuit)
	rated continuous / service current	2 A at 220 V AC/DC
	recommended upstream fuse rating	3 A
	contact life — mechanical	2 x 10^7 operations
	contact life — electrical	5 x 10^5 h/85°C
T digital thermometer	**operating conditions**	
	admissible ambient temperature range	– 20° C to + 60° C
	max. ambient humidity	90% RH (non condensable)
	dimensions (H x L x P)	96 x 96 x 130 mm
	weight	520 g
	casing protection index	IP 54 self extinguishing
	maximum capacity on a terminal connection	2.5 mm^2
	fixing	locating recess 92 x 92 mm, suppliance of two pressure clips on the rear side.

(1) universal supply irrespective of polarity.



power supply

Monitoring circuits have to be supplied from an auxiliary supply (standard: 24 to 220 V AC/DC). If no suitable supply is available they may be supplied from the transformer’s secondary side. To avoid the “FAULT” relay tripping, it is fitted with a time delay.
Warning: when the device is supplied directly from the transformer’s secondary side, it is necessary to protect it from possible over-voltages that could damage the electronic circuit. We recommend to use our surge-limiter PT 73-120 or PT 73-220 (220 V CA).

installation

The T thermometer should never be installed on the transformer or inside its metal enclosure due to its operating temperature limits (see table opposite).

- it can be installed in the low voltage switch-board (or on a wall) either horizontally or vertical-ly (see table opposite for fixing details).
- **it is recommended, especially for an install-ation in an LV switchboard, to retain a mini-mum clearance to other equipment (take into account the highest voltage) or heat sources and ensure adequate ventilation. Take care also to the highest voltage according to the insulation distances.**
- **connections:**

PT 100 sensors are to be connected to the T digital thermometer between the connecting terminal attached to the transformer and the T digital thermometer’s plug-in connector.
It is not supplied by France Transfo.
See diagram opposite.

Warning: since the transformer is of thermal class F, the T digital thermometer must be programmed with a maximum temperature of 150 °C for alarm 1 (L1) and 160 °C for alarm 2 (L2). France Transfo is in no way liable for any damage to the transformer should these maximum temperatures not be complied with.

The following conditions must be complied with

- use screened and braided cables (20 twists/meter)
- minimum conductor cross-section: 1 mm^2
- wiring should not pass near power circuits
- maximum length of connection: 300 m
- minimum clearances to live parts: see above.
- wiring should not be attached to any live part of the transformer
- the LV panel should be earthed.

insulation (kV)	minimum clearance (mm)
7,2	270
12	450
17,5	450
24	450
36	650

advised by France Transfo

connection diagram for the T digital thermometer

Due to the evolution of standards and materials, the present document is only binding subject to confirmation by our technical department.

France Transfo
BP 10140
F 57281 Maizières-lès-Metz Cedex
tel. (+33) 03 87 70 57 57 - fax (+33) 03 87 51 10 16
Ref : GEa.106 b

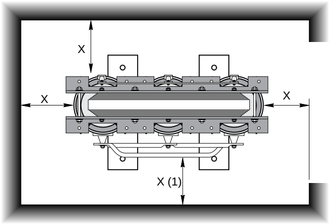
N° ident. TVA: FR 78 357801109 • Edition France Transfo – Limited company - Social capital 10 280 000 FRF – RCS Metz B 357 801 109 • Printed in France • Composition and illustrations: COREDIT • 10/96

HV/LV distribution transformers

TRIHAL cast resin transformers
160 to 3150 kVA
insulation level ⩽ 24 kV - low voltage 400 V

france transfo
GROUPE SCHNEIDER

minimum clearances required

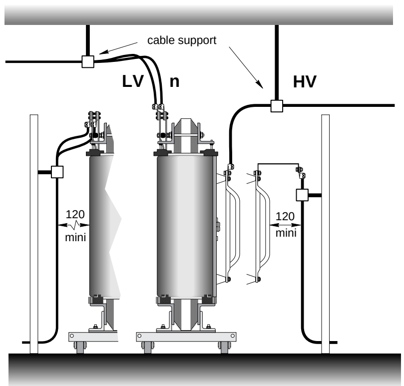


insulation (kV)	dimensions X (mm) full wall	grid wall
7.2	90	300
12	120	300
17.5 - 24	220	300

The contrator must ensure that cables and busbars are adequately supported to prevent mechanical stresses from being imposed on the transformer terminals, busbars or bushings.

(1) Don't take into account the access to tapping on the HV side.

HV and LV standard connection

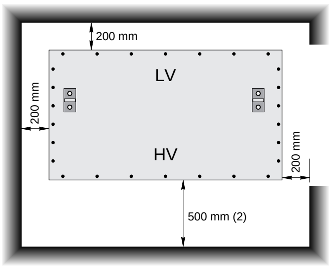


connections

TRIHAL transformers without enclosure housing (IP00)

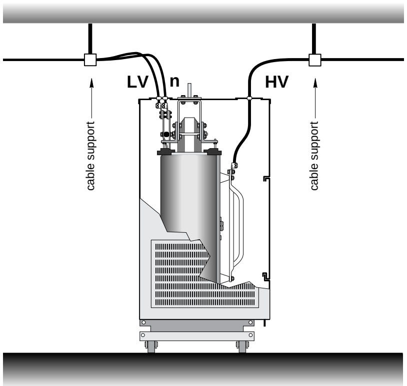
The winding resin coating and the plug-in connectors don't ensure any protection against touch when the transformer is energized.

minimum clearances required



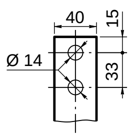
(2) 500 mm. for an access to tapping on the HV side, but 200 mm. minimum.

HV and LV connection

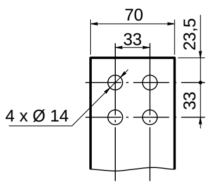


TRIHAL transformers with IP31 metal enclosure

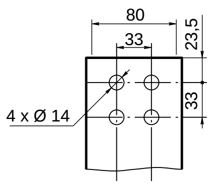
LV terminations



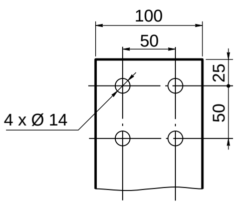
160 to 500 kVA*
thickness 5



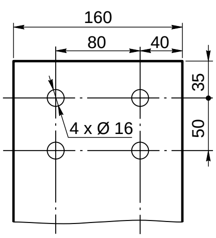
630 to 800 kVA*
thickness 6



1000 to 1250 kVA*
thickness 10



1600 kVA*
thickness 12



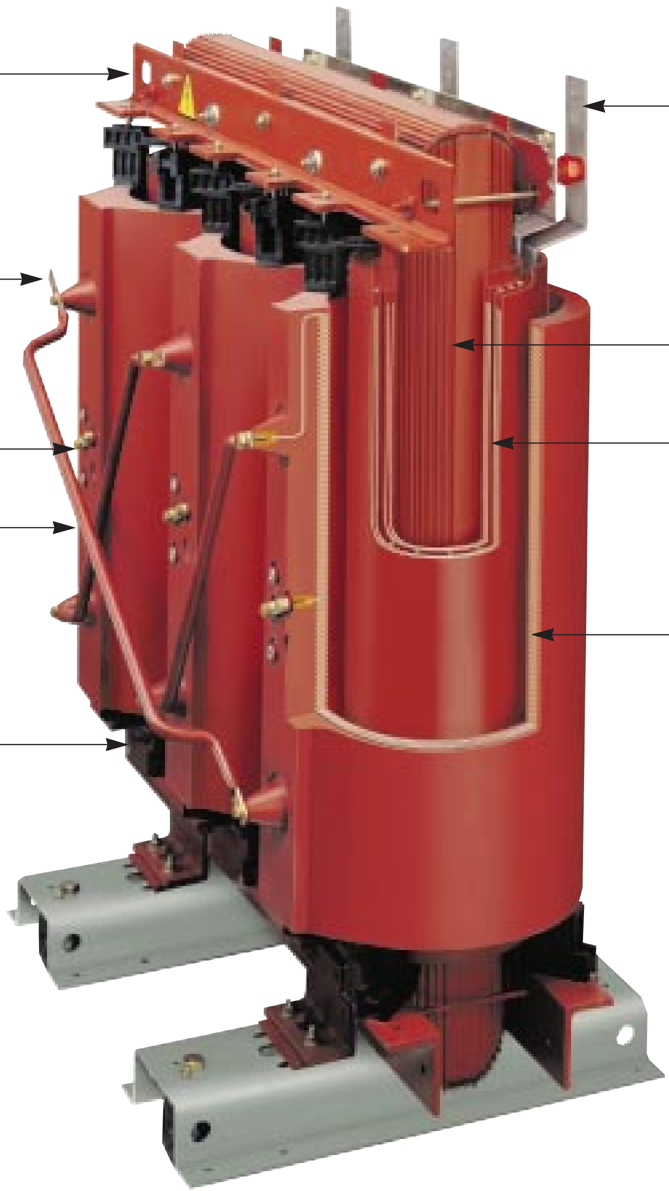
2000 kVA*
thickness 10

*Valables pour 400 et 410 V en aluminium.

The contrator must ensure that cables and busbars are adequately supported to prevent mechanical stresses from being imposed on the transformer terminals, busbars or bushings.

HV/LV distribution transformers

TRIHAL cast resin transformers
160 to 3150 kVA
insulation level ⩽ 24 kV - low voltage 400V



France Transfo
B.P. 10140
F 57281 Maizières-lès-Metz cedex
tel. (33) 87 70 57 57
telex 860 418 F
fax (33) 03 87 51 10 16

Due to the evolution of standards and materials, the present document will bind us only after confirmation from technical department.

Edition France Transfo
Conception: COREDIT
04/97 - printed in France

HV/LV distribution transformers

TRIHAL cast resin transformers
160 to 3150 kVA
insulation level ⩽ 24 kV - low voltage 400 V

france transfo
GROUPE SCHNEIDER

description

This range comprises transformers in accordance with the following specifications:
- 50 Hz three-phase transformers for indoor installation (outdoor installation or other frequency on request);
- cast resin dry type;
- thermal class F;
- ambient ⩽ 40°C, altitude ⩽ 1000m(1);
- natural air cooling type AN;
- LV winding usually made of aluminium sheet (insulated strip for low ratings). The core and LV windings assembly is given an additional protective coating of alkyd resin;
- HV winding manufactured from insulated round wire or rectangular strip;
- **HV winding is vacuum cast in epoxy resin(2) efficiently fireproofed with trihydrated alumina**;

TRIHAL transformers can be supplied:
- **without enclosure (IP00).**

The installer must ensure that access to the live core and windings is prevented (3);
- **with IP31 metal enclosure.**

It prevents direct contact with live components.

standards

These transformers are in accordance with standards:
- IEC 76-1 à 76-5;
- IEC 726 (1982);
- CENELEC (European Committee for Electrotechnical standardization) harmonization documents HD 538-1 S1:1992 and HD 464 S1: 1988 / A2: 1991 /A3:1992 concerning dry type transformers.

standard equipment

TRIHAL without enclosure (IP00):
- 4 flat bi-directional rollers;
- 4 lifting holes;
- haulage holes on the underbase;
- 2 earthing points;
- 1 rating plate (on HV side);
- 1 warning label "electricity danger";
- HV voltage variation by off circuit tapping links;
- HV connection bars for connection from above;
- LV pre-drilled terminations on above;
- 1 routine test certificate and 1 instruction leaflet for installation commissioning and maintenance;

TRIHAL with IP31 metal enclosure:
- TRIHAL without enclosure (IP00) as above;
- IP31 integral metal enclosure (except the bottom: IP21):
  - □ with standard anti corrosion protection;
  - □ lifting lugs for transformer and enclosure assembly;
  - □ access to tappings on the HV side by removing a bolted panel which is fitted with handles, warning label, rating plate and a visible braid for earthing;
  - □ blanked off holes provided for fitting Ronis ELP1 or alternatively Profalux P1 locks on the HV tapping access panel;
  - □ 2 gland plates, one on the HV and one on the LV side. These may be removed and drilled to take cable glands which are not supplied;
  - □ 1 flap door in the base on the HV side to permit HV cable entry. Connection made to top of delta bars.

options

The following fittings can be provide:
- 1 thermal protection module comprising 6 PTC thermostatic sensors (2 per phase) connected to a terminal board with a plug-in connector and an electronic converter with 2 contacts (alarm 1 and alarm 2) supplied separately;
- 3 HV plug-in connectors (HN 52 S 61) may be used as follows:
  - □ fixed on a mounting plate from the upper core clamp (TRIHAL IP00);
  - □ fixed on top of the transformer enclosure on the HV side (TRIHAL IP 31);
- straight or elbow connectors can also be supplied. Please state cable characteristics;
- additional LV terminal plates (tinned copper);
- 1 locking device to secure plug-in bushings (without lock and indiscriminitely suitable for a Ronis EPL11AP, ELP1, ELP2 or Profalux P1, P2, V1, V21 lock mounting);
- forced cooling by fans to give an AF rating of 140 %.

Nota: These options are those usually specified and many alternatives can be provided on request.

250 kVA (IP00) 20 kV/400 V + 400 kVA (IP31) 20 kV/400 V

LV pre-drilled terminations

630 kVA - 20 kV/400 V

(1) Please state when ambient > 40°C or altitude > 1000 m.
(2) a casting system developped and patented by France Transfo.
(3) when the transformer is energized, the winding resin coating and the heat shrinkable protection of the HV connection bars do not ensure any protection against touch.

HV/LV distribution transformers

TRIHAL cast resin transformers
160 to 3150 kVA
insulation level ⩽ 24 kV - low voltage 400 V

france transfo
GROUPE SCHNEIDER

electrical characteristics

insulation level: 7.2 kV and 12 kV

rated power (kVA) (1) (*)		**160** (2)	**250**	**315** (2)	**400**	**500** (2)	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
rated primary voltage (1)		5 to 12 kV (dual voltage on request)												
rated insulation level (3)		7.2 kV for 5.5 kV - 12 kV for 10 kV												
frequency (1)		50 Hz												
maximum ambient temperature		40°C												
secondary voltage at no load (1)		400 V between phases, 231 V phase to neutral												
HV tapping range (off-circuit) (1)		± 2.5 %												
vector group		Dyn 11 or Dyn 5 (delta, star neutral brought out)												
losses (W)	no-load losses	610	820	950	1150	1300	1500	1700	2000	2500	2800	3500	4300	5500
	load losses at 75°C	2300	3100	3600	4300	5200	6400	7700	8800	10500	12300	14900	18300	22000
	load losses at 120°C	2700	3500	4100	4900	6000	7300	8800	10000	12000	14000	17000	21000	25000
rated impedance voltage (%)		4	4	4	4	4	4	6	6	6	6	6	6	7
no-load current (%)		2.3	2.	1.8	1.5	1.5	1.3	1.3	1.2	1.2	1.2	1.1	1	1
switching current	Ie/In (peak value)	13.5	13	13	13	13	12	9	9	9	9	9.5	8.5	8.5
	time constant	0.13	0.18	0.20	0.25	0.25	0.26	0.30	0.34	0.35	0.42	0.4	0.5	0.6
noise level (4) dB(A)	acoustic power LWA	62	65	67	68	69	70	72	73	75	76	77	81	81
	acoustic pressure LPA at 1 metre	50	53	55	55	56	57	59	59	61	61	61	65	65

insulation level: 17.5 kV and 24 kV

rated power (kVA) (1) (*)		**160** (2)	**250**	**315** (2)	**400**	**500** (2)	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
rated primary voltage (1)		20 kV												
rated insulation level (3)		24 kV												
frequency (1)		50 Hz												
maximum ambient temperature		40°C												
secondary voltage at no load (1)		400 V												
HV tapping range (off-circuit) (1)		± 2.5 %												
vector group		Dyn 11 (delta, star neutral brought out)												
losses (W)	no load losses	650	880	1030	1200	1400	1650	2000	2300	2800	3100	4000	5000	6300
	load losses at 75°C	2300	3300	4000	4800	5700	6800	8200	9600	11500	14000	17500	20000	23000
	load losses at 120°C	2700	3800	4600	5500	6500	7800	9400	11000	13100	16000	20000	23000	26000
rated impedance voltage (%)		6	6	6	6	6	6	6	6	6	6	6	6	7
no-load current (%)		2.3	2	1.8	1.5	1.5	1.3	1.3	1.2	1.2	1.2	1.1	1	1
switching current	Ie/In (peak value)	10.5	10.5	10	10	10	10	10	10	10	10	9.5	9.5	9.5
	time constant	0.13	0.18	0.20	0.25	0.25	0.26	0.30	0.30	0.35	0.4	0.4	0.5	0.6
noise level (4) dB(A)	acoustic power LWA	62	65	67	68	69	70	72	73	75	76	78	81	81
	acoustic pressure LPA at 1 metre	50	53	55	56	56	57	59	59	61	62	63	66	65

(*) the rated power is defined by natural air cooling (AN). Should there be particular constraints, it may be increased by 40 % by forced cooling addition (AF). Please consult us.
(1) other possibilities upon request, consult us.
(2) non standard ratings available on request.
(3) reminder of insulation levels:

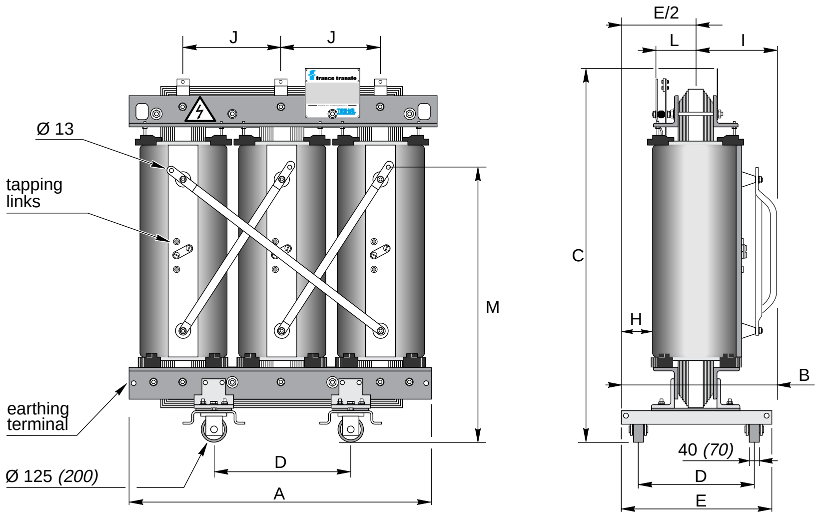
rated insulation level (kV)	**7.2**	**12**	**17.5**	**24**
kV r.m.s. 50 Hz - 1 mn	20	28	38	50
kV B.I.L. 1.2/50 µs	60	75	95	125

(4) according to CEI 551

HV/LV distribution transformers

TRIHAL cast resin transformers
160 to 3150 kVA
insulation level ⩽ 24 kV - low voltage 400 V

france transfo
GROUPE SCHNEIDER



dimensions and weights

TRIHAL transformers without enclosure housing (IP00)

7.2 to 24 kV / 400 V

Dimensions and weights indicated in the table below are provided as an example for primary single voltage transformers 7.2 to 24kV / 400V. They apply to transformers with electrical characteristics shown in the previous table. For other voltages, impedance voltages and dual-voltages, weights and dimensions are different (consult us).

In brackets, dimensions from 1000 up to 3150 kVA.

insulation level: 7.2 kV and 12 kV - low voltage 400 V

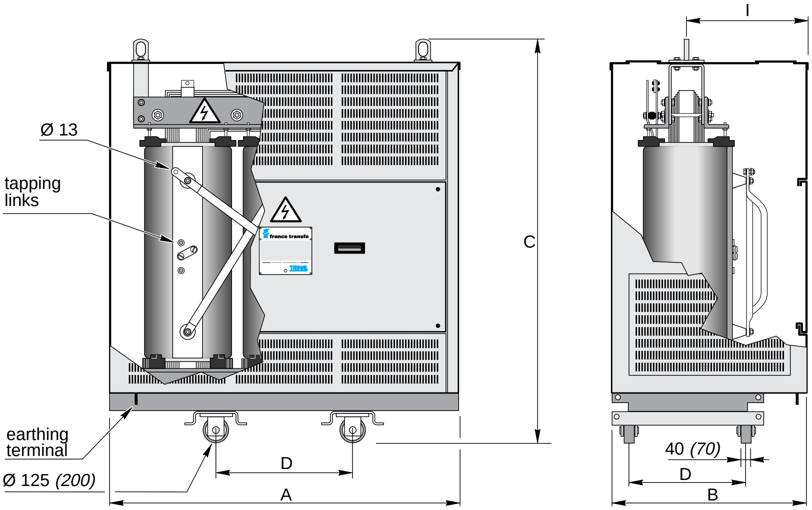
rated power (kVA) (1) (*)		**160**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
dimensions (mm)	**A**	990	1070	1160	1230	1260	1340	1380	1520	1590	1710	1900	2150	2200
	B	665	680	795	795	795	800	810	945	945	945	1195	1195	1195
	C	1330	1370	1410	1400	1600	1630	1610	1670	1830	1940	2250	2350	2600
	D	520	520	670	670	670	670	670	820	820	820	1070	1070	1070
	E	650	650	800	800	800	800	800	950	950	950	1200	1200	1200
	H	170	160	210	200	200	180	180	230	220	200	230	230	300
	I	350	360	380	390	390	410	410	430	440	460	460	470	460
	J	330	360	390	410	420	450	460	500	530	570	630	640	690
	L	200	210	230	230	240	250	260	280	280	250	280	280	380
	M	860	900	940	920	1050	1070	1110	1180	1440	1540	1700	1750	1750
weights (kg)		770	950	1150	1360	1580	1820	1880	2360	2710	3400	4800	5800	7300

insulation level: 17.5 kV and 24 kV - low voltage 400 V

rated power (kVA) (1) (*)		**160**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
dimensions (mm)	**A**	1070	1140	1170	1230	1300	1340	1400	1560	1610	1700	1950	2030	2200
	B	680	690	795	795	795	800	805	945	945	945	1195	1195	1195
	C	1320	1350	1510	1490	1580	1690	1720	1920	2030	2170	2380	2440	2600
	D	520	520	670	670	670	670	670	820	820	820	1070	1070	1070
	E	650	650	800	800	800	800	800	950	950	950	1200	1200	1200
	H	160	150	220	210	190	190	180	230	220	210	290	290	300
	I	360	370	370	380	400	400	410	430	440	460	450	460	460
	J	360	380	390	410	440	450	470	510	530	560	630	640	690
	L	180	180	190	200	210	210	220	250	250	260	310	320	380
	M	890	930	1090	1070	1110	1210	1240	1410	1510	1650	1770	1750	1750
weights (kg)		780	950	1140	1290	1520	1730	1990	2480	2810	3430	4720	5980	7300

HV/LV distribution transformers
TRIHAL cast resin transformers
160 to 3150 kVA
insulation level ⩽ 24 kV - low voltage 400 V

france transfo
GROUPE SCHNEIDER



dimensions and weights
TRIHAL transformers with IP31 metal enclosure
7.2 to 24 kV / 400 V

Dimensions and weights indicated in the table below are provided as an example for primary single voltage transformers 7.2 to 24kV / 400V. They apply to transformers with electrical characteristics shown in the previous table. For other voltages, impedance voltages and dual-voltages, weights and dimensions are different (consult us).

In brackets, dimensions from 1000 up to 3150 kVA.

insulation level ⩽ 12 kV - low voltage 400 V

rated power (kVA) (1) (*)		**160**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
dimensions (mm)	**A**	1390	1480	1530	1550	1570	1620	1650	1880	1820	2080	2200	2550	2450
	B	875	895	920	945	955	975	935	1020	1020	1040	1300	1300	1350
	C	1680	1750	1760	1780	1840	2000	1920	2050	2150	2360	2850	3000	2900
	D	520	520	670	670	670	670	670	820	820	820	1070	1070	1070
	I	520	530	550	560	560	580	580	650	630	640	700	710	850
weights (kg)		960	1150	1360	1580	1810	2060	2120	2620	2990	3750	5340	6340	7900

insulation level ⩽ 24 kV - low voltage 400 V

rated power (kVA) (1) (*)		**160**	**250**	**315**	**400**	**500**	**630**	**800**	**1000**	**1250**	**1600**	**2000**	**2500**	**3150**
dimensions (mm)	**A**	1380	1430	1530	1530	1540	1560	1600	1710	1760	1860	2100	2120	2450
	B	850	865	875	890	910	920	935	1020	1020	1030	1265	1265	1350
	C	1560	1590	1750	1730	1820	1930	1960	2160	2270	2410	2660	2710	2900
	D	520	520	670	670	670	670	670	820	820	820	1070	1070	1070
	I	530	540	550	560	570	570	580	650	640	630	710	820	850
weights (kg)		960	1140	1340	1500	1740	1960	2230	2740	3080	3760	5200	6510	7900

Trihal cast resin transformers

Basic technical specification *Poland* *n° ST-Tri- PL-gb-1a*

Publishing : 29/06/1998

Application:	Industry and tertiary	Customers: All

Standards:	**IEC 76, 726 - HD 538**		
Technical data sheet reference:	No		
Installation:	Indoor		
Cooling:	AN		
Frequency:	**50 Hz**		
Thermal class:	F		
Maximal ambient temperature :	40°C	Daily average: 30 °C	yearly average: 20°C
Maximal temperature of the insulation system:	155°C		
Windings temperature rise:	100 K		
Maximal altitude:	1000m		
Vector group**:**	**Dyn 11 ou Dyn 5**		
Windings material	Aluminium		

HV terminations: on HV pre-drilled terminations from the top
LV terminations: on LV pre-drilled terminations from the top

Standard accessories :
(included in basic price)

Thermal protection (6 PTC + Z electronic converter)
rating plate in english, warning label "electricity danger"
4 flat bi-directional rollers

P (kVA)	pitch (mm)	∅ (mm)	width (mm)
100 à 250	520	125	40
315 à 800	670	125	40
1000 à 1600	820	200	70
2000 à 3150	1070	200	70

2 earthing points without enclosure and 1 earthing point with enclosure
Installation 215000 FT in english (ref-GEa215000)

Additional characteristics:

Terminals marking according to IEC 76
(1U,1V,1W,2U,2V,2W,2N)

Additional accessories and options :
(extra cost)

- Enclosure IP 31
- Antivibration pads
- Copper windings

Rated primary voltage:	**15 or 15.75 kV**	**- Rated insulation: 17.5 kV (95/38)**
	20 or 21	**- Rated insulation: 24 kV (125/50)**
Off circuit tapping links :	**±2.5 %± 5 %**	
Secondary voltage (at no load):	**400 V**	

							IP 00				IP 31			
Power	No load losses	Load losses at 120°C	Load losses at 75°C	Ucc	Lwa	Lpa at 1m	Length	Width	Height	Total Weight	Length	Width	Height	Total Weight
kVA	W	W	W	%	dBA	dBA	mm	mm	mm	kg	mm	mm	mm	kg
100	460	2100	1800	6	59	47	1050	670	1300	690	1430	835	1570	870
160	650	2900	2500	6	62	50	1080	680	1310	790	1530	845	1580	980
250	880	3800	3300	6	65	53	1160	690	1390	1000	1540	875	1750	1200
400	1200	5500	4600	6	68	55	1240	795	1490	1290	1550	890	1760	1500
630	1650	7800	6800	6	70	56	1380	805	1700	1760	1650	925	1980	2000
800	2000	9400	8200	6	72	58	1430	810	1750	2050	1880	945	2060	2310
1000	2300	11000	9600	6	73	59	1560	945	1880	2480	1880	1020	2200	2760
1250	2800	13200	11500	6	75	61	1710	945	1910	3020	2080	1025	2350	3320
1600	3100	16000	14000	6	76	61	1700	945	2130	3470	2080	1025	2540	3840
2000	3900	19000	16600	6	77	62	1900	1195	2170	4550	2130	1255	2640	5010
2500	5000	23000	20000	6	81	65	2050	1195	2400	5400	2450	1270	3000	5940

Tolerances : according to IEC 76
Approximate dimensions. Only the drawings will commit France Transfo

Trihal cast resin transformers

Basic technical specification *Poland* *n° ST-Tri- PL-gb-2a*

Publishing : 29/06/1998

Application: Industry and tertiary Customers: All

Standards: **IEC 76, 726 - HD 538**
Technical data sheet reference: No
Installation: Indoor
Cooling: AN
Frequency: **50 Hz**
Thermal class: F
Maximal ambient temperature : 40°C Daily average: 30 °C yearly average: 20°C
Maximal temperature of the insulation system: 155°C
Windings temperature rise: 100 K
Maximal altitude: 1000m
Vector group**:** **Dyn 11 or Dyn 5**
Windings material Aluminium

HV terminations: on HV pre-drilled terminations from the top
LV terminations: on LV pre-drilled terminations from the top

Standard accessories : Thermal protection (6 PTC + Z electronic converter)
(included in basic price) rating plate in english, warning label "electricity danger"
4 flat bi-directional rollers

P (kVA)	pitch (mm)	∅ (mm)	width (mm)
100 à 250	520	125	40
315 à 800	670	125	40
1000 à 1600	820	200	70
2000 à 3150	1070	200	70

2 earthing points without enclosure and 1 earthing point with enclosure
Installation 215000 FT in english (ref-GEa215000)

Additional characteristics: Terminals marking according to IEC 76
(1U,1V,1W,2U,2V,2W,2N)

Additional accessories and options : - Enclosure IP 31
(extra cost) - Antivibration pads
- Copper windings

Rated primary voltage: **6 kV - Rated insulation: 7.2 kV (60/20)**
Off circuit tapping links : **±2.5 %± 5 %**
Secondary voltage (at no load): **400 V**

							IP 00				IP 31			
Power	No load losses	Load losses at 120°C	Load losses at 75°C	Ucc	Lwa	Lpa at 1m	Length	Width	Height	Total Weight	Length	Width	Height	Total Weight
kVA	W	W	W	%	dBA	dBA	mm	mm	mm	kg	mm	mm	mm	kg
100	440	2000	1700	4	59	47	940	660	1300	650	1360	855	1570	830
160	610	2700	2300	4	62	50	990	665	1330	770	1390	875	1680	960
250	820	3500	3100	4	65	53	1070	680	1370	950	1480	895	1750	1150
400	1000	5200	4500	6	68	56	1260	795	1330	1220	1570	905	1760	1440
630	1370	7600	6700	6	70	57	1320	795	1560	1630	1610	920	1980	1870
800	1700	8800	7700	6	72	59	1380	810	1610	1880	1650	935	1920	2120
1000	2000	10000	8800	6	73	59	1520	945	1670	2360	1880	1020	2050	2620
1250	2500	12000	10500	6	75	61	1590	945	1830	2710	1820	1020	2150	2990
1600	2800	14000	12300	6	76	62	1710	945	1940	3400	2080	1040	2360	3750
2000	3800	17000	14900	6	77	62	1900	1195	2250	4800	2200	1300	2850	5340
2500	4300	21000	18300	6	81	65	2150	1195	2350	5800	2550	1300	3000	6340

Tolerances : according to IEC 76
Approximate dimensions. Only the drawings will commit France Transfo

Trihal cast resin transformers

Basic technical specification — *Czech Republic* — *n° ST-Tri-CZ-gb-5b*

Publishing : 18/06/1998

Application:	Industry and tertiary	Customers: All

Standards: **IEC 76, 726, DIN 42523 - Normal losses**
Technical data sheet reference: No
Installation: Indoor
Cooling: AN
Frequency: **50 Hz**
Thermal class: F
Maximal ambient temperature : 40°C Daily average: 30 °C yearly average: 20°C
Maximal temperature of the insulation system: 155°C
Windings temperature rise: 100 K
Maximal altitude: 1000m
Vector group**:** **Dyn 11 or Dyn 5 or Dyn 1**
Windings material FT's choice

HV terminations: on HV pre-drilled terminations from the top
LV terminations: on LV pre-drilled terminations from the top

Standard accessories:
(Included in basic price)

Thermal protection (2 PTC per phase + Z electronic converter)
rating plate , warning label "electricity danger"
4 flat bi-directional rollers:

P (kVA)	pitch (mm)	∅ (mm)	width (mm)
100 à 250	520	125	40
315 à 800	670	125	40
1000 à 1600	820	200	70
2000 à 3150	1070	200	70

2 earthing points
Installation 215000 FT in english (ref-GEa215000)

Additional characteristics: Terminals marking
(1U,1V,1W,2U,2V,2W,2N)

Additional accessories and options :
(extra cost)

- Enclosure IP 31
- 3 PT100 sensors + TEC 935
- Dial type thermometer with maxima pointer :without contact or 2 contacts
- 3 fixed HV plug-in bushings - 36 kV - 400 A for IP00 or IP31
- 3 mobile HV plug-in connectors - 36 kV - 400 A
- Antivibration pads
- Copper windings
- LV terminations from below or on the small side of the enclosure
- Option LV = 500 to 1000 V - rated insulation : 1.1 kV
- Option rated insulation : 38.5 kV (190/75 kV)

(discount) - Thermal protection (2 PTC per phase + Z electronic converter)

Rated primary voltage: **35 kV - Rated insulation: 36 kV (170/70)** **Normal losses**
Off circuit tapping links : **± 2.5% ± 5 %**
Secondary voltage (at no load): **400 or 420 V**

						IP 00				IP 31			
Power	No load losses	Load losses at 75°C	Ucc	Lwa	Lpa at 1m	Length	Width	Height	Total Weight	Length	Width	Height	Total Weight
kVA	W	W	%	dBA	dBA	mm	mm	mm	kg	mm	mm	mm	kg
100	660	1900	6	59	46	1380	825	1580	1170	1750	1270	1920	1450
160	960	2500	6	62	49	1400	905	1750	1380	1770	1280	2030	1680
250	1280	3500	6	65	52	1400	905	1750	1570	1770	1280	2030	1870
315	1450	4300	6	67	54	1450	910	1800	1750	1800	1290	2060	2050
400	1650	5000	6	68	59	1470	915	1820	1900	1840	1305	2060	2210
630	2200	7000	6	70	60	1620	940	2040	2530	1930	1190	2280	2840
800	2650	8500	6	72	62	1700	950	2110	2890	1980	1205	2340	3200
1000	3100	10000	6	73	63	1700	950	2110	3030	1980	1205	2340	3360
1250	3600	12100	6	75	60	1810	1000	2170	3900	2150	1230	2400	3450
1600	4200	14900	6	76	61	1920	1065	2240	4340	2290	1285	2470	4800
2000	5000	18300	6	78	63	2180	1225	2390	5140	2500	1380	2470	5800
2500	5800	21800	6	81	65	2450	1250	2400	6900	2750	1500	2500	7600

Load losses at 120°C = Load losses at 75°C x 1.14
Approximate dimensions. Only the drawings will commit France Transfo

THE INFLUENCE OF HARMONICS ON DIMEN-SIONING OF TRANSFORMERS

List of contents :

1. Harmonic waves

In electrical networks the real current wave-form is often different from the pure sine wave that characterises alternating current.

The wave-form is modified by other waves, which are also sinusoidal but whose frequency is an **integer multiple** of the fundamental frequency, being superposed on the **fundamental wave** of frequency 50 Hz.

These other waves are called harmonic waves or simply **harmonics.**

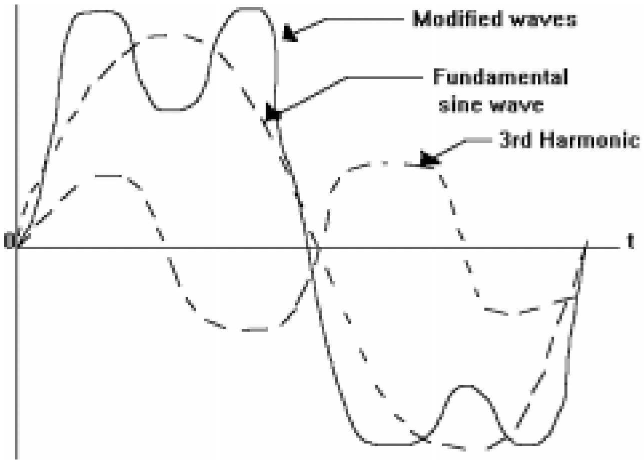


Fig.1 - Waves modified by harmonics

These harmonics are defined by :

- the sinusoidal wave at the base frequency or so called **fundamental component**
-

$$F1 = 50\ Hz$$

- the coefficient giving the frequency (integer multiple of the fundamental component) or the so called **harmonic number** :

$$Hi = Fh / F1$$

- the **harmonic factor** defining the ratio of its intensity to the intensity of the fundamental component :

$$Ti\ (\%) = Ih / I1$$

2. Harmonic generators and their influences

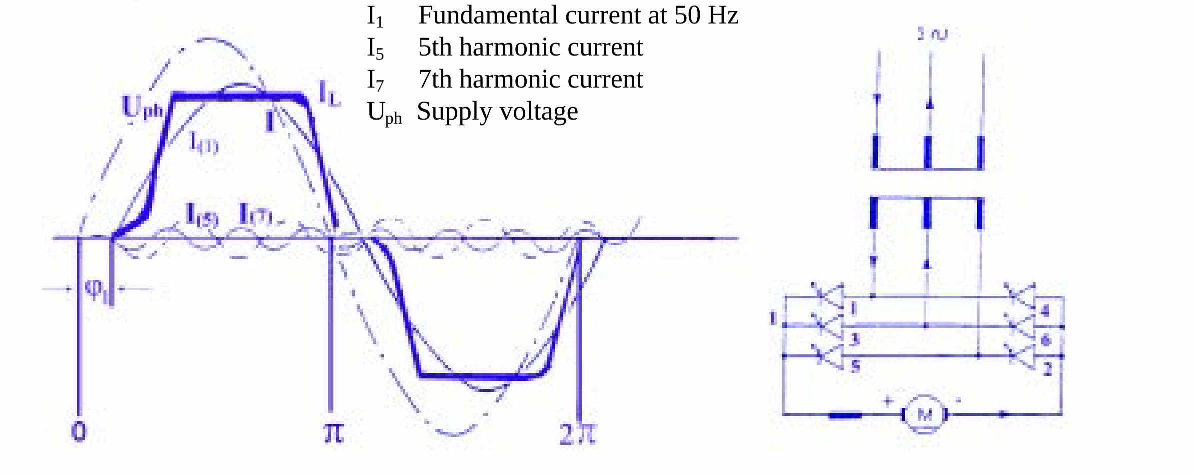
These days, **power electronics** are becoming increasingly used in industry and this constitutes the main source of harmonic "pollution".

The main **harmonic generators** are :

- **UPS inverters** : supplying computers and other sensitive equipments
- **rectifier units** : "alternating - direct" static converter
- **speed controllers** : controlling electric motors
- equipment using **thyristors**
- **ovens** : arc or induction heating

Composition of current emitted by a converter in "fundamental current" and "harmonic currents"

I_L Total current (apparent wave-form)
I_1 Fundamental current at 50 Hz
I_5 5th harmonic current
I_7 7th harmonic current
U_{ph} Supply voltage



These harmonic generators change the electrical quality of the network by giving :

- a higher **true r.m.s. intensity**
- a higher **peak intensity**
- higher **frequencies**

and will cause certain interference effects :
the resulting value of true r.m.s. current is greater than the calculated current values for the required power, which leads to a **risk of premature ageing** of the equipment.

- **resonance** phenomena can occur at certain frequencies, leading to dangerous **overvoltages and overcurrents.**

3. The effects of harmonics on a transformer's behaviour

A transformer is defined by its **rated power** which is equal to the product of **no load voltage** and the **rated current** (times √3 for three-phase) and is calculated as a function of the network **frequency.**
However, as we have seen in the previous chapter, a harmonic generator significantly changes the transformer's dimensioning characteristics :

- **Ohmic losses**

if no account is taken of harmonic currents, the power that the transformer should deliver will be greater than its rated power, leading to an increase in Ohmic losses (RI^2) and therefore to a risk of deteriorating the dielectric qualities of the transformer due to over-heating.

- **Eddy current losses**

Eddy currents are proportional to the **square of the frequency**. However, a harmonic current is of high frequency and could thus, even with a low factor, cause additional losses which can not be ignored.

- **the magnetic core**

in extreme cases, two phenomena can disrupt the correct operation of a transformer :

⇒ at high frequency harmonic currents there are corresponding **harmonic fluxes** which are superposed on the fundamental flux. Depending on the upstream impedance, these fluxes can increase the **resulting peak flux value.**

⇒ a possible **continuous component** will create a shift in the hysteresis cycle relative to zero. For half a cycle, the magnetic core is subjected to a **flux which is too high.**

These two cases can result in the induction level reaching the **saturation peak** for the magnetic core, in an increase in the **ferromagnetic losses** of **magnetis-**

ing current, and in addition, can make the **transformer itself generate harmonics.**

4. Remedies

The existence of **harmonic currents** and their consequences in an electrical network outlined above makes it **necessary** to :

- **quantify the pollution level** by calculation or by measuring harmonic currents and voltages.

- **eliminate any risk of resonance** within the range of harmonics encountered by seeking the lowest possible ratio (technical-economic) between capacitor power and the supply's short circuit power.

- **attenuate harmonic pollution**

  ⇒ **separating pieces of equipment** from one another by assigning **a transformer to each of them** (attenuating interference since the impedance of this part of the network is lower than that of a global supply).

  ⇒ installing **harmonic filters** :
  series filter (also called resonance filter or high-pass)
  parallel filter (also called a stop filter or low-pass).

- **oversize the equipment**

in spite of the above measures it is essential that equipment

  ⇒ **can withstand** overloading due to any harmonics which may be present
  ⇒ **tolerates the nuisance with minimum effect.**

5. Dimensioning the transformer

- **To prevent** the windings overheating :

☞ **The first solution**

involves **oversizing** the transformer or **limiting its load** if it is a piece of equipment which is already installed.
Standards organisations UTE, CENELEC, ...) have adopted or are currently studying **derating equations** such as :

$$K = [1 + 0,1 * (\nearrow Hi^{1,6} * Ti^{2})]^{-0,5}$$

See chapter 1 Hi = harmonic number
Ti = harmonic factor expressed as a % of the transformer's rated intensi ty

- **Example 1**

A 1000 kVA transformer delivers a current which includes the following harmonics :

H5 = 25 % H7 = 14 % H11 = 9 % H13 = 8 %

$$K = [1 + 0,1 * (5^{1,6} * 0,25^{2} + 7^{1,6} * 0,14^{2} + ...)]^{-0,5}$$

The calculation gives **k = 0,91** : the transformer will only supply **910 kVA.**

- **Exemple 2**

We want to determine the size of a transformer needed to supply 1000 kVA with harmonics of number H = 6 x n ⇧ 1, with n = 1,2, ...etc and with a factor of 1/H (typical case of a six-phase rectifier).
By limiting the calculation to number 29, the coefficient K will be **0,87**.

$$K = [1 + 0,1 * (5^{1,6}*0,2^{2} + 7^{1,6} * 0,14^{2} + 11^{1,6} * 0,09^{2} ...)]^{-0,5}$$

The minimum power for the transformer becomes 1000 / 0,87 = **1150 kVA**

☞ **The second solution**

This involves dimensioning of **a transformer which is specially adapted** to supply a harmonic generator, subject to prior agreement between the user and the manufacturer.

- **Against saturation** of the magnetic core :
  when the **extreme conditions** described in § 3 are **specified**, it may be necessary to :

⇒ specify a transformer operating with **a low-flux density** to account for the high harmonic flux.

⇒ specify a **gapped magnetic core** to limit the influence of any possible continuous component.

6. Conclusions

Whatever the configuration and the solution chosen, it is essential that there is dialogue between the user and the manufacturer.

This concise analysis of the influence of harmonic waves shows that the **problem is complex :**

- the consequences on elements of the network due to the **overloads and overvoltages** which the harmonics produce can be dangerous.

- attention must be paid to **controlling and attenuating** harmonic interference effects.

- the influence of harmonics makes it necessary to increase the size of equipment and results in a large increase in cost (up to 50 % in extreme cases).

Bibliography

EDF — Les Cahiers de l'Ingénierie (Engineering Manuals)
Qualité de l'alimentation électrique (Quality of electrical sup ply)

Merlin Gerin — Cahiers techniques