

ITALWEBER

ELETTRA



TECHNICAL GUIDE

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1. GENERAL RULES FOR CHOOSING A TRANSFORMER PROTECTION

The transformers must be protected against possible overloads and short circuits. Our transformers belong to the non-short-circuitproof type and so they must be protected using external fuses. In our labels it is always indicated a rated current of the suggested fuse. Anyway the protection can be obtained also using Miniature Circuit Breakers. The protection of the input winding of the transformer must be choose taking into account that at the starting phase of the transformer, an high value of inrush current is generated, value that can reach 25 times the value of the input rated current, for about 10 milliseconds. Hence, time delay fuses (T or aM type) or MCB having D or K characteristic must be used for a correct protection. The protection of the secondary side can be realized using fuses of F or gG type, or MCB having B or C characteristic.

Here below there is a table with all the suggested protection fuses for the input and output windings (all the values are in Ampere):

SINGLE PHASE TRANSFORMERS						
Rated value of gG or F fuse for secondary side protection					Rated value for aM or T fuse for primary side protection	
Power (VA)	Voltage 24V	Voltage 48V	Voltage 110V	Voltage 220V	Voltage 230V	Voltage 400V
30	1,25	0,63	0,315	0,16	0,5	0,5
50	2	1	0,4	0,2	0,5	0,5
75	3,15	1,6	0,63	0,315	1	0,5
100	4	2	1	0,5	1	0,5
150	6	3,15	1,25	0,63	1,6	1
200	8	4	2	1	2	1
250	10	6	2	1	2	1,6
300	12	6	2,5	1,25	4	1,6
400	16	8	4	2	4	2
500	20	10	4	2	4	4
630	25	12	6	3,15	6	4
800	32	16	6,3	4	6	4
1000	40	20	10	5	10	8
1600	63	32	12	6	16	10
2500	100	50	20	10	20	16

For calculating the secondary short circuit protection it must be considered the most distant

connection point between the transformer and the load. The following formula is used to calculate this protection:

$$I_{cc}'' = \frac{V_2}{\frac{V_2^2}{P} \times \frac{V_{cc}\%}{100} + \frac{2rxl}{S}}$$

V₂ = transformer's secondary voltage

P = Rated power of the transformer (VA)

V_{cc}% = short circuit voltage (%)

r = copper resistivity (value 0,0175 at ambient temp. of 20C°)

l = length of the connection cable between the transformer and the load

S = copper cable section (mm²)

2. MINIATURE CIRCUIT BREAKERS

They can have different time-current characteristics.

The CEI EN 60898 standard defines the three basic ones:

CHARACTERISTIC	MAGNETICAL TRESHOLD	<p style="text-align: center;">I_n = Rated current (Standard CEI EN 60947-2)</p>
B	3:5 I _n	
C	5:10 I _n	
D	10:20 I _n	
K	10:14 I _n	

For transformer's primary side protection, it is suggested to use circuit breakers with D or K characteristic, while on the secondary side B or C characteristic circuit breakers are normally used. In any case the designer must use the type of protection that better fit the transformer's specifications and his specific application.

3. STANDARDS

Exact product standards in relation with their application exist about transformers.

Classificazione <i>Classification</i>	Titolo <i>Title</i>	Applicazione <i>Application</i>	Note <i>Note</i>
EN 61558-1	Sicurezza dei trasformatori <i>Safety of power transformers</i>	Trasformatori, unità di alimentazione e similari di piccola potenza per circuiti di comando e controllo e di sicurezza/isolamento. <i>Transformers, low power supply units and similar devices for control circuits and safety/insulation circuits</i>	Parte generale comune <i>General part</i>
EN 61558-2-2	Requisiti trasformatori di comando <i>Requir. for control transformers</i>	Tensioni adatte per funzionamento delle apparecchiature <i>Adapdetd machinery voltages</i>	Separazione isol. semplice <i>Simple insulation</i>
EN 61558-2-4	Requisiti trasformatori di isolamento <i>Requir. for insulation transformers</i>	Isolamento della rete o apparecchiature con trasformatori di isolamento <i>Line insulation and device separation</i>	Doppio isol. tra i circuiti Secondario > 50V a vuoto <i>Double insulation Secondary > 50V no load</i>
EN 61558-2-6	Requisiti trasformatori di sicurezza <i>Requir. for safety transformers</i>	Isolamento della o apparecchiature con trasformatore di sicurezza <i>Line insulation and device separation with safety transformers</i>	Doppio isol. tra i circuiti /Secondario <= 50V a vuoto/Circuiti PELV e SELV <i>Double insulation/Secondary <= 50V no load/PELV and SELV circuits</i>
EN 61558-2-13	Requisiti per gli autotrasformatori <i>Requir. for safety transformers</i>	Tensioni adattate per funzionamento delle apparecchiature <i>Adapdetd machinery voltages</i>	Non richiesti la separazione e l'isolamento dei circuiti <i>Separation and insulation not necessary</i>
EN 61558-2-20	Requisiti per i piccoli reattori <i>Requir. for small reactors</i>	Circuiti di filtro e spianamento <i>Filtering circuits</i>	Induttanze, reattanze, impedenze <i>Impedance, inductors, reactors</i>
EN 61558-2-23	Requisiti trasformatori di costruzione <i>Requir. for autotransformers</i>	Alimentazione in siti speciali da IEC 60364-7-704 <i>Supply for sites provided in IEC 60364-7-704</i>	Isolamento e sicurezza <i>Safety and insulation</i>
EN 61558-2-15	Requisiti per alimentatori medicali <i>Requir. for medical supply</i>	Postazioni mediche di gruppo II o sistemi IT <i>Supply of medical location of group II ot IT system</i>	Da 3kVA a 10kVA <i>From 3kVA to 10kVA</i>
UL 506	Caratteristiche dei trasformatori <i>Requir. for constr. sites transf</i>	Trasformatori per uso generale <i>Industrial control equipments</i>	Classe 1 <i>Class 1</i>
UL 508	Apparecchiature industriali <i>Requir. for medical supply</i>	Apparecchiature di controllo per uso industriale <i>General purpose transformers</i>	Alimentatori e autotrasformatori <i>power supplies and autotransformers</i>
CSA N.66-1988	Caratteristiche dei trasformatori <i>industrial equipments</i>	Trasformatori per uso generale <i>General purpose transformers</i>	Classe 1 <i>Class 1</i>
IEC 726	Trasformatori di potenza a secco <i>Dry power transformers</i>	Trasformatori di distribuzione e autotrasformatori <i>Distribution transformers and autotransformers</i>	Es: media tensione in resina <i>Ex: Cast resin transformers</i>
EN 60289	Reattori <i>Reactors</i>	Reattori limitatori, di smorzamento, di filtro <i>Filtering, switching and damping reactors</i>	Reattori di potenza <i>Power reactors</i>
IEC 76	Trasformatori di potenza <i>Power transformers</i>	Trasformatori di distribuzione in olio <i>Distribution oil immersed transformers</i>	Es: media tensione in olio <i>Ex: Oil immersed transformers</i>

4. HOMOLOGATION (TYPE TESTING) AND CONFORMITY

On the European market the essential requirements for any product is the CE mark, which is applied on the product to guarantee the compliance with all product-relevant directives and may be applied by the manufacturer himself, who declares under his own responsibility that the product complies with the relevant directives and standards. To offer an additional real warranty, we have chosen to have our products tested and homologated by the certification institute Kema, which released the Quality Marks Kema-Keur and Enec 05. ENEC (European Norm Electrical Certification): it's a new homologation safety and quality mark for electric machinery to guarantee the compliance to all relevant European directives and standards and has a European validity. For North American standards product compliance cannot be certified independently: Csa and UL certification are issued by the corresponding institutes exclusively, after the required verification and controls. The product marketed in North America must be strictly approved. Italweber Elettra s.r.l. has achieved cCSAus (from CSA for Canada and USA) and cURus (from UL for USA and Canada).

5. OPERATING THERMAL CLASS

The operating thermal class is the maximum temperature reachable by the windings during standard working activity and is established during transformer's design. High values of temperature results in a more rapid decay of the materials thus affecting the average life of the product. The EN 61558 standard determines the limits of admissible temperature rise (based on ambient temperature 40°) as follows: Class A = 60°C, E = 75°C, B = 80°C, F = 100°C, H = 125°C

6. INSULATION AND PROTECTION CLASSES

Insulation thermal classes define insulation materials thermal characteristic in relation with their resistance to temperature stress (UL 1446 - IEC 85). The RTI (Relative Temperature Index) is different from the Thermal class and is the result of thermal ageing programme (UL 746B) in which materials are investigated with respect to the retention of certain critical properties after long term thermal ageing. Transformers standard define maxima temperatures for different parts at nominal load and ambient conditions: they depend upon transformers Thermal class, so transformers materials. Best thermal materials and Thermal class normally establish highest transformers temperature. Basic insulation and double insulation: a transformer provide a simple insulation between primary-input and secondary-output circuit to assure protection from direct and indirect contacts. Control transformers provide a simple insulation between windings and between windings and the earth. Safety and safety-insulation transformers provide a double insulation between primary and secondary windings (an independent insulation is applied in addition to basic insulation). Protection class: in class I transformers protection from direct and indirect contacts is not only based on basic insulation, but also on additional safety protection (for example earth connection) to guarantee safety in the case of insulation breakdown (EN 61558). In class II transformers protection between direct and indirect contacts is not only based on basic insulation, but also on additional insulation (for example double insulation), because earth connection or other installation

rules are not possible (right symbol double square). In class II transformers insulation between primary winding-circuit and secondary winding-circuit must be a double insulation (reinforced). Movable transformers with nominal power up to 630VA must be class II transformers. Movable transformers with power over 200VA, but less than 2,5kVA if monophasic and 6,3kVA if polyphasic must be IPX4 minimum. Movable transformers with nominal power over 2,5kVA if monophasic and 6,3kVA if polyphasic must be IP21 minimum (EN 61558). Movable transformers must be short-circuit proof transformers. In class III transformers protection between direct and indirect contact is based on safety extra low voltage (SELV): voltage is limited to 50Vac or 120Vcc between conductors and conductors with the earth and the circuits is separated from the line by a safety transformer. I, II, III protection classification isn't referred to insulation system between primary and secondary windings. Symbols for different series on the catalogue are right standardized for different types of transformers. Insulation voltage: it's the voltage applied between the windings and between the windings and the earth during rigidity test; its value depends upon working voltage and insulation type (basic or reinforced). Highest insulation value is for safety and safety-insulation transformers (5500 Vac for 1 minute, applied between double insulated parts).

7. SHORT CIRCUIT AND OVERLOAD PROTECTION

Not short circuit proof transformers must be protected against short-circuits and overload, according to manufacturer's specifications (EN 60204). For this aim it is necessary to use magneto thermal circuit-breakers or fuses inserted to protect secondary windings. Size, type and time-current feature of the fuse are marked on the identification target; when using a magneto thermal breaker, it is suggested a curve C and size with nominal current same as the one indicated. Protection of the line which supplies the transformer must be a short-circuit protection and in order to avoid out of time switching-off, caused by above mentioned inrush current: when inserting the transformer presents in the primary circuit an inrush current (about 25 times nominal value) for a period of 10ms. In transformers table it is possible to find the coefficient to calculate the inrush current:

- I_n =primary nominal current in A
- P_{ot} =nominal output power in VA $I_n=(P_{ot}+P_{er}) / V_{nom}$
- P_{er} =total loss in W
- I_{pk} =inrush current $I_{pk}=K \times I_n$
- K =inrush coefficient
- V_{nom} =nominal primary voltage

To avoid out of time switching-off protection device it's necessary to compare inrush current with time/current device characteristic (normally delayed fuses or characteristic D circuit breakers). In the case of one transformer and one only line it's possible to obtain a complete protection upstream with a short-circuit device and downstream with an overload device (which can be able to protect also the line). To verify the correct choice of short-circuit device in the worst case (that is at the longest point on the transformer-load line) it's possible to use in first approximation the formula:

$$I_{cc2min}=V_{sec} / [(V_{sec}^2 \times V_{cc}\% / (P_{ot} \times 100) + 2 \times 0,018 \times l / S_{ez})]$$

I_{cc2min} =min. Short-circuit current in A

- V_{sec} =sec voltage in V
- P_{ot} =nominal output power in VA
- $V_{cc}\%$ =short-circuit voltage

- l =line length in mm
- e_z =conductor section in mm²

Final protection must have a work time up to 5 sec. for I_{cc2min} calculated. In the case of different protections, they must be selective that is with different switching time. If the transformer supplies different lines, it's necessary to choose one overload and short-circuit protection devices for every line. It's possible to calculate the short-circuit current:

- I_{ccpri} =short-circuit primary current
- I_{npri} =primary current $I_{ccpri}=I_{npri} / V_{cc\%} \times 100$
- I_{ccsec} =short-circuit secondary current
- I_{nsec} =secondary current $I_{ccsec}=I_{nsec} / V_{cc\%} \times 100$

8. ELECTROSTATIC SHIELD

It's an open copper turn sheet with the right thick and height as the winding, normally wound between primary and secondary and connected to the earth. Shield allows to reduce noise, distortion, overvoltage, which are filtered and discharged to the earth; shield reinforces basic insulation. It's not possible to use the shield (and the other prescriptions about distances) added to basic insulation to realize a double insulation for transformers directly connected to the line with a socket.

9. EUROPEAN VOLTAGES AND REGULATION STEP

CENELEC countries agreed upon voltages standardization; the new voltages limits are:

- $-10\% < \text{monophase voltage} = 230V < +6\%$
- $-10\% < \text{threephase voltage} = 400V < +6\%$

Regulation step on the primary (ex. $\pm 20V / 230V / 400V$) allow to adapt transformers voltages to the line and load voltages.

10. THE POWER

Transformers power must be stated in VA while reactors in VAR (reactive volt ampere). To convert power from kW in kVA it's necessary to know the load $\cos \phi$ and efficiency:

- P_{otva} =output power in VA $P_{otva}=P_{otw} / \cos \phi / \eta\% \times 100$
- P_{otw} =output power in W
- $\cos \phi$ =load phase-difference
- $\eta\%$ =load efficiency

The output power can be calculated also with the product of voltage and current:

- P_{otm} =power in VA monophase $P_{ot}=V \times I$
- P_{ott} =power in VA threephase
- V =voltage in V

$$P_{ot}=V \times I \times 1,73$$

- I =current in A

If the transformer has different secondary windings the total power is the sum of the single power. If the secondary winding has different steps, it's implied not contemporaneous use and maximum powers on highest voltage step. VAR order for reactor and inductor is useful to find out dimensional.

11. INRUSH START TIME POWER (DROP OF VOLTAGE AND NO LOAD VOLTAGE)

To supply control circuits, transformer power depends not only on the maintenance power but moreover on inrush start time power, available to guarantee a maximum drop of voltage of 5% of nominal value (that is to assure right work of contactors).

Drop of voltage%=(Vvuoto - Vcarico) / Vcarico x 100

- Vvuoto=non load sec. voltage in V
- Vcarico=secondary nominal voltage in V

Empirically it's possible to calculate inrush start time requested power at $\cos \varnothing=0,5$ (EN 61558-2-2; the inrush power is available in transformers table):

- Pspunto=inrush power in VA
- Pspunto=0,8 x (\hat{a} potman + Potcon + \hat{a} potutil)
- \hat{a} potman=sum maintenance power
- Potcon=bigger contactors inrush power
- \hat{a} potutil=power sum of continuous load (lamps,cards..)

If we suppose a contemporaneous factor of 70% of supply, previously calculated inrush power must be higher than 70% of the sum of maintenance and continuous load:

Potreg=0,7 x (\hat{a} potman + \hat{a} potutil)

- Potreg=potenza a regime in VA

Between obtained inrush power and maintenance power it's necessary to consider the biggest one. It's possible to use the same calculation procedure for different contemporary factor.

12. CONTROL CIRCUIT CONNECTION EARTH

To supply control circuit it's necessary to use transformers (so with separated winding); they are not mandatory for machines with single motor starter and maximum of two control devices (EN 60204). It's possible to realize the protection from intempestive working for insulation breakdown with connection of one end of the secondary winding to the protective bonding circuit, with control devices connected according to the standard..

13. AUTOTRANSFORMERS AND TRANSFORMERS

The autotransformer is built with an only winding with one or more steps: it doesn't provide an insulated separation between primary/input and secondary/output circuits, but it's useful to reduce dimensions and costs. In star configuration it's not a good solution with not-balanced loads.

Autotransformer dimensional (core) power depends on maximum and minimum voltages:
 $Pot.nucleo (VA) = [(V_{max} - V_{min})] / V_{max} \times \text{nominal output power (VA)}$

- Pot.nucleo=dim. core power in VA
- V_{max} =maximum voltage in V
- V_{min} =minimum voltage in V

Calculation of dimensional power is useful to have an indication of dimensions and costs; the nominal power on the label and for the order is the output power..

14. DERATING: ALTITUDE, TEMPERATURE, WORKING

Frequently transformer working is not nominal one, continuous working and in standard ambient conditions. Transformers type-test (EN 61558) re made at rated load conditions and with input voltage increased of 6%. All the tests, moreover overload test and careful planning, make Italweber Elettra s.r.l. transformers able to sustain overload and overvoltage's normally of 10% (also to support conditions' electric and ambient variability). For switching working with a defined cycle (pause/work) it's possible to calculate a derating coefficient:

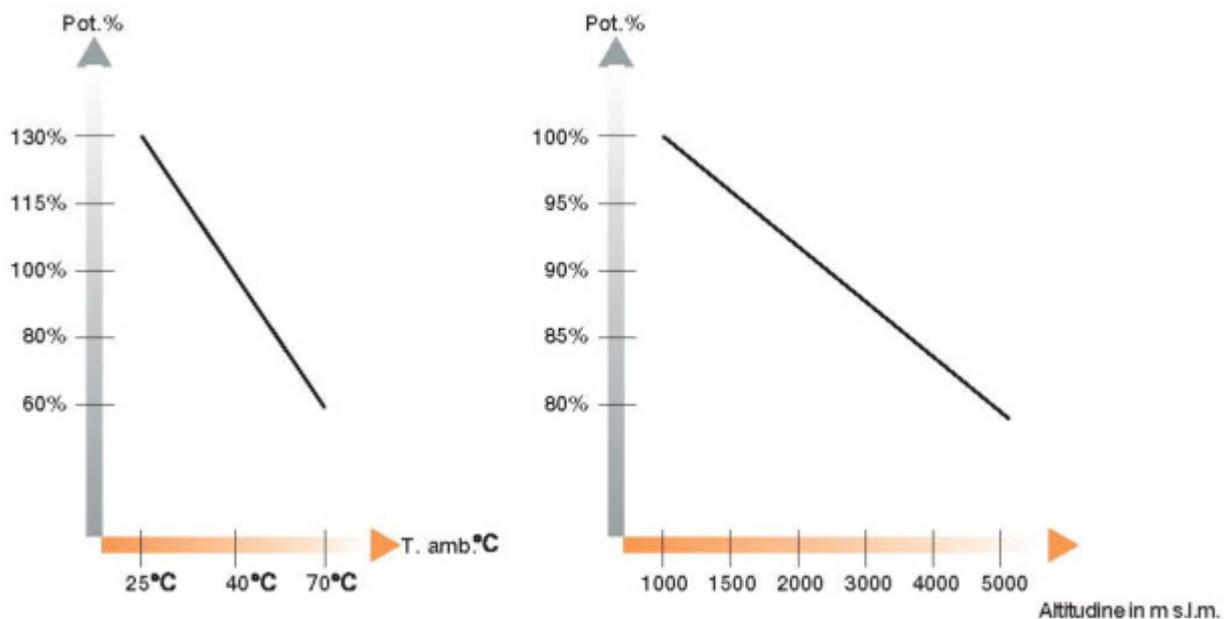
$$P_{dep} = P_{otnom} \times (\text{min. work} / (\text{min. work} + \text{min. pause}))^{1/2}$$

- P_{dep} =derating power in VA
- P_{otnom} =rated output power in VA
-

The calculation is only indicative: it's useful to make test to verify in the worst case right working and protection functionality .Italweber Elettra s.r.l. transformers can sustain temporary overload with right over temperature for not continuous working:

output power in % of nominal power	Maximum overload period in minutes for overload % of output rated power.				
	10%	20%	30%	40%	50%
50%	180	90	90	45	30
75%	150	75	45	30	20
90%	120	60	30	15	10

For higher than 1000 m altitudes and different ambient temperatures it's possible to load other output power than nominal.



15. THREE PHASE CONNECTION AND PHASE DIFFERENT

Three phase winding can be built and connected in different ways: star, triangle and zig-zag. Star connection allows neutral wire (or for monophasic load or for earth connection), triangle allows third harmonic attenuation and better voltage balance for not balanced loads; zig-zag connection is their combination. The use of different connection types for primary and secondary windings establish a phase difference between input and output voltages. For example for Dyn11 the phase difference is of 330° . A way to transform a three phase line in a two phase line (2 monophasic with 90° phase difference) is the Le Blanc / Scott connection: it realizes a balanced current three phase system only if the two loads are identical and contemporary (in this case the system is also reversible)

16. FREQUENCY: 50 AND 60 Hz

The transformer is a static machine and can't modify input frequency, but only voltage. A transformer built to work at 50 Hz works also at 60 Hz at the same voltage, and losses are reduced; on the other hand a transformer built to work doesn't work at 50 Hz (over temperature and losses in the iron are bigger). Italweber Elettra s.r.l. transformers are two-frequency. Reactors are opposite of transformers as regards frequency: it's necessary to specify different from 50Hz working for particular core planning. Very important is also the type of transformers and reactor supply, moreover when it's different from perfect sinusoidal 50 Hz wave (for example in the case of inverters or voltage phase regulators); step wave can saturate the core and produce breakdown and excessive over temperatures.

17. LOSS: COPPER AND IRON

Normally transformer efficiency is high: it's not difficult to obtain efficiency of 95% for bigger transformers. Total loss in W derives from iron dissipated energy for hysteresis and Foucault current and for Joule effect in the winding. Best core and low induction give out less no load current and less iron loss. Iron loss are no load loss: the core achieves its rated temperature also without the load at nominal input voltage. Copper loss (short circuit loss) depend on the loads. With low copper loss normally it's possible to have smaller over temperature and smaller drop of voltage.

18. TROPICALIZATION

Italweber Elettra s.r.l. transformers are impregnated with class H varnish based on alchidic resins with high mechanical and electrical characteristics and with vacuum-pressure immersion, for uniform and complete insulation layer in every part and perfect oven drying process. Materials are selected with best electric, dielectric, mechanics and thermal characteristics and are all type tested; impregnation improves their insulation properties and resistance to unfavourable climate and countries. With this treating Italweber Elettra s.r.l. transformers are suitable to be used at all latitudes and in general at all climate, also in tropical countries if installed in cooling locals and far away external conditions: the humidity permanent limits are 95% at 20°C, 80% at 40°C and 50% at 50°C (without condensation) and temperature limits are normally of +40°C. It's possible to extend the use in very humid ambient conditions.

19. ENVIRONMENT

The technology is to help human beings, but must also be integrated with the ambience and not destroy, which means not only using ecological and long life materials and products, but also using productive processes less destructive for the ambience.