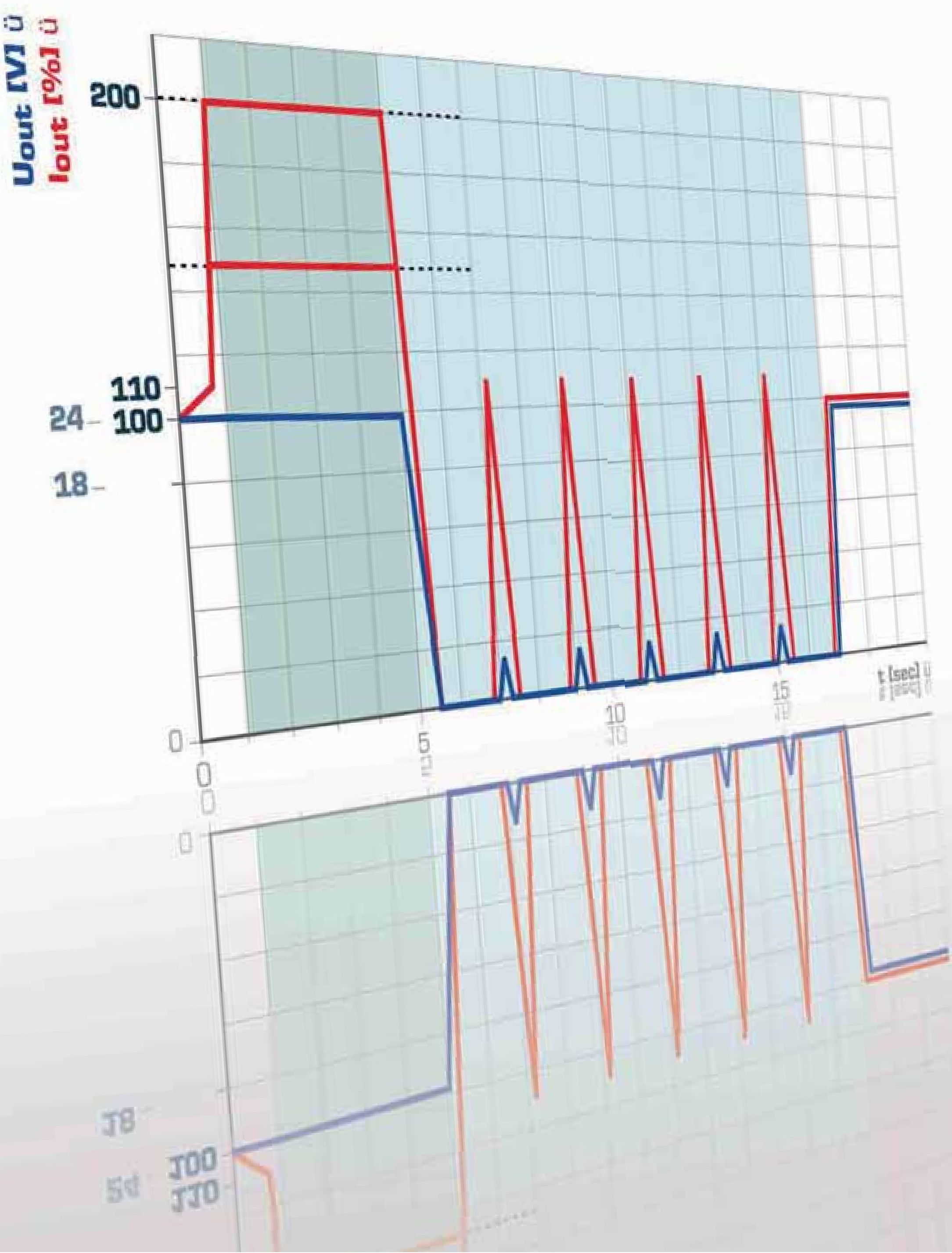
Technical information

Content



Technical informations EMC/Radio interference suppression

Technical informations reactors

General informations

Passive filters and interference suppression components

General technical informations

It is essentially the following components which are utilised for the suppression mains borne electromagnetic interference:

- **Passive filter**
  An assembly of individual parts and inductive, capacitive and resistor elements which are utilised for the reduction of electromagnetic interference caused by electrical or electronic devices or other sources.
- **Reactor**
  An element which exhibits a slight impedance at low frequencies and a high inductively-marked reactance at high frequencies.
- **Capacitor**
  An element which exhibits a high impedance at low frequencies and a low capacitively-marked reactance at high frequencies.

Requirements

The constructive differences between passive electrical filters and interference suppression components, referred to below under the general title "filters", are generally determined by their intended utilisation. Corresponding requirements are established in the installation, device and EMC-standards
(e.g. VDE 0100, VDE 0113/
EN 60204/IEC 60204, VDE 0700/
EN 60335/IEC 60335, VDE 0805/
EN 60950/IEC 60950, EN 61000-6-1 to EN 61000-6-4, EN 61800-3,
EN 62041).

An important selection criterion is the achievable attenuation effect against mains borne interference, depending on the interfering frequency:

Filters against low-band interference

- Power reactors*
- Filtering circuit reactors*

Filters against low and high-frequency interference

- Interference suppression filters
- Motor reactors
- Motor filters
- Sinusoidal filters

Filters against high-frequency interference

- Reactors for the suppression of electromagnetic interference (EMI reactors), current-compensated
- Passive filters for the suppression of electromagnetic interference (EMI filters)

Note:
Proof of whether the limit values of the EMC standards (see "Electromagnetic Interference" and "Electromagnetic Interference Immunity") can be maintained can be obtained only by means of measurement technology as a systems test which takes into account all participating individual components.

*see chapter "reactors"

Standards

Unless otherwise agreed upon with ordering party, we manufacture in accordance with the latest "State of Technology" and with the following standards:

VDE 0565 Teil 3: Passive filter for the suppression of electromagnetic interference

EN 60939/IEC 60939: Passive filter units for electromagnetic interference suppression

EN 60939-1/IEC 60939-1: Passive filter units for electromagnetic interference suppression

VDE 0565 Teil 2: Reactors for electromagnetic interference suppression

EN 60938/IEC 60938: Fixed Reactors for electromagnetic interference suppression

VDE 0570: Safety of power transformers, power supply units and similar, Part 1: General requirements and tests, Part 2-20: Particular requirements for small reactors

EN 61558, IEC 61558: Safety of power transformers, power supply units and similar, Part 1: General requirements and tests, Parts 2–20: Particular requirements for small reactors

Rated voltage

The rated voltage (UR) is either the highest effective operating voltage(1) at rated frequency or the highest operating direct current voltage which can be continuously present at the filter location in conjunction with temperatures between the lower category temperature(2) and the rated ambient temperature (Ref.: VDE 0565 Part 3/EN 60939/IEC 60939).

(1)Supplement: in cases of alternating current systems, the voltage of the external conductor to one another

(2)Supplement: of the lowest permitted ambient temperature, see Test class

Note (Ref.: VDE 0565 Part 3/EN 60939/ IEC 60939): Passive filters for the suppression of electromagnetic interference (EMI filters) must be selected in such a way that their rated voltage is equal to or larger than the rated voltage of the voltage network to which they are connected. It must be taken into account thereby that the network voltage can increase up to 10 % over its rated value(3).

(3)Supplement: see "Conversation of the low-voltage mains".

Note: The specification of the rated voltage with filters often leads to misunderstandings since it deviates from the usual electrical equipment designations which are also in conformance with standard norms.

An example of this: An industry PC, a frequency converter and a passive filter for the suppression of electromagnetic interference is to be operated on a low-voltage mains with the standard norm voltage 230 V (tolerance -10 % to +6 %, which corresponds to 207 V to 244 V) in accordance with VDE 0175/HD 472 S1/
IEC 60038.

A rated voltage of 230 V is to be displayed on the type plates of the industry PC and of the frequency converter. It is established in the standard norms for the device
(Ref.: VDE 0805/EN 60950/IEC 60950 and VDE 0160/EN 61800/IEC 61800) that the industry PC and the frequency converter may be operated continuously up to 110 % of their rated voltage. This means that safe functioning is ensured for these two pieces of electrical equipment, even after the year 2008 (in accordance with VDE 0175/
HD 472 S1/IEC 60038: Tolerance range -10 % to +10 %, which corresponds to 207 V to 253 V), on the 230 V low-voltage mains.

The type plate of the passive filter displays a rated voltage of 250 V. This specification, however, already refers to the upper voltage limit at which the passive filter is permitted to be placed in continuous operation
(Ref.: VDE 0565 Part 3–1/EN 133200). Starting with the year 2008, the passive filter can carry a load of 253 V, which puts it in the limit range of safe functioning.

Passive filters from our company will, in the interests of the greatest possible application security, generally be labelled with rated voltage (as electrical equipment) and with rated voltage (UR) in accorddance with
VDE 0565 Teil 3/EN 60939/IEC 60939.

Voltage range

The voltage range has been assigned to the filter and it is expressed in terms of the upper and lower limits within which the filter is permitted to be placed in continuous operation. Whereas it is true that the lower limit is generally non-critical, the upper limit is determined by the insulation system and the dielectric strength, e.g. of the capacitors.

In a departure from the otherwise usual standard norm-oriented allocation of voltages for electrical equipment, here the upper limit will be marked by the rated voltage of the filter, unless labelled otherwise.

Rated frequency

The rated frequency is the frequency allocated to the filter for the established operating conditions.

Unless other arrangements have been made, radio interference filters will be designed for 50 to 60 Hz.

Rated current

The rated electrical current (Ref.: VDE 0565 Part 3/EN 60939/IEC 60939) is the greatest effective operating current at rated frequency or the greatest operating direct current with which a filter may be operated continuously at its rated temperature (1). It is specified by the manufacturer for one or both of the following conditions:

a) open-air (I_{RO})

b) with a specified heat sink (I_{RH})

[1]Ergänzung: rated ambient temperature

Unless other arrangements have been made, filters will be designed accordingly, mounted on a wooden foundation in position for use, in accordance with Condition b).

Ambient temperature and rated electrical current

The rated electrical current assigned to a filter refers to the surrounding rated ambient temperature of the immediate surroundings. Higher ambient temperatures require an electrical current derating in accordance with the following function:

$$I_{max} = I_B \times \sqrt{\frac{T_K - T}{T_K - T_B}}$$

I_{max} = maximum electrical current at ambient temperature T [A]
I_B = rated electrical current at rated ambient temperature T_B [A]
T_K = upper temperature value of the climate category [°C], z. B. 85 °C
T = ambient temperature [°C]
T_B = rated ambient temperature [°C]

Example: A filter of the test class 25/085/21 is assigned a rated electrical current of 16 A for a rated ambient temperature of 40 °C. With which maximum electrical current may the filter be loaded for an ambient temperature of 55 °C?

$$I_{max} = 16\text{ A} \times \sqrt{\frac{85\text{ °C} - 55\text{ °C}}{85\text{ °C} - 40\text{ °C}}} = 13\text{ A}$$

In cases of lower ambient temperatures than the rated ambient temperature, one is advised against the possibility of using an increase of electrical current over the rated electrical current, since this can then easily lead to saturation phenomena on the parts of the inductances

Leakage current

Leakage current is an undesired flowing alternating current between electrical poles which possesses different levels of voltage potential. An internal wiring of filters with capacitors to earth (PE) is often indispensable for an efficient damping of high-frequency asymmetrical interference. This/these capacity/capacities bring about a leakage current to earth (PE) in terms of the rated frequency of the network.

The maximum limit values for the leakage current are established in several installation and device regulations. The usual values range from 0.1 mA (medical devices) to 5 mA (household appliances).

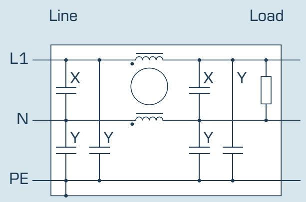
Higher leakage currents with filters are mainly to be encountered in the industrial sector. These filters are equipped with a respective warning and earthing notice. In cases of multiphase systems, the highest leakage current (worst-case scenario) occurs with the connection of only one external conductor to earth (PE). The utilisation of FI safety switches should be dispensed with when filters with a great leakage current are being used, since it can lead to unwanted triggering at the moment of being turning on.

Passive filters for the suppression of electromagnetic interference (EMI filter)

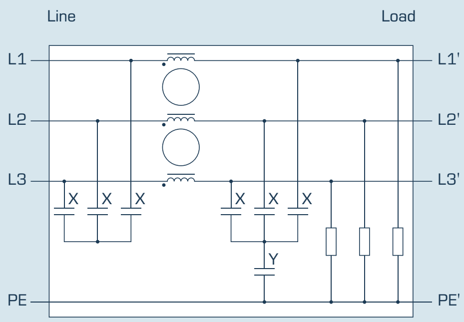
The utilisation of passive filters for the suppression of electromagnetic interference (EMI filters) is the mains borne suppression of interference on the network in the frequency range located between 150 kHz (9 kHz)(1) and 30 MHz. Here are several low-pass principal circuits:

[1] not yet included as part of the EMC standardisation.

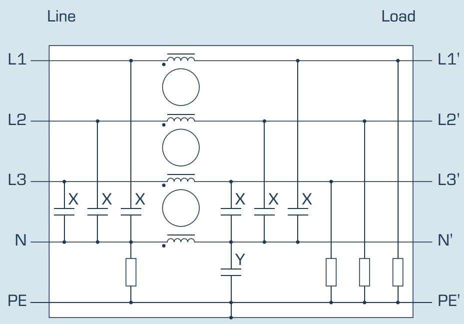
single phase, universally utilisable



three-phase, utilisable for equivalent (symmetrical) current distribution in L1, L2, L3 (e.g. for the individual interference suppression of frequency converters, motors)



three-phase+N, utilisable for equivalent (asymmetrical) current distribution in L1, L2, L3, because the differential current can flow via N (e.g. cumulative interference suppression of entire machines)



Interference suppression components utilised:

- Capacitors Class Y (L-PE, N-PE)
- Capacitors Class X (L-L, L-N)
- Resistance for discharge of the capacitors
- Current-compensated magnetic core reactor

An even more efficient suppression of interference, and with it a greater insertion attenuation, is achieved when additional elements (interference suppression components) are added, thus creating multi stage constructions.

Y-capacitors

In passive filters for the suppression of electromagnetic interference (Ref.: VDE 0565 Part 3/EN 60939/ IEC 60939), designed essentially for the operation of mains alternating voltage, the capacitors need to fulfil the requirements of Class X or Y (depending on the position of the circuit).

Class Y capacitors are suitable for applications where the failure of the capacitor could lead to a dangerous electrical shock. A failure of the Y-capacitor resulting from a short circuit or a disruptive breakdown is thus prevented from occurring during the course of orderly use.

The switching of Class Y capacitors takes place to earth (PE) in relation to the application.

Sub-class	Type of Bridged-over insulation	Rated voltage ranges	Peak value of the surge value
Y1	Double or reinforced insulation	≤500 V	8.0 kV
Y2	Basic or supplementary insulation	≥150 V ≤300 V	5.0 kV
Y3	Basic or supplementary insulation	≥150 V ≤250 V	-
Y4	Basic or supplementary insulation	<150 V	2.5 kV

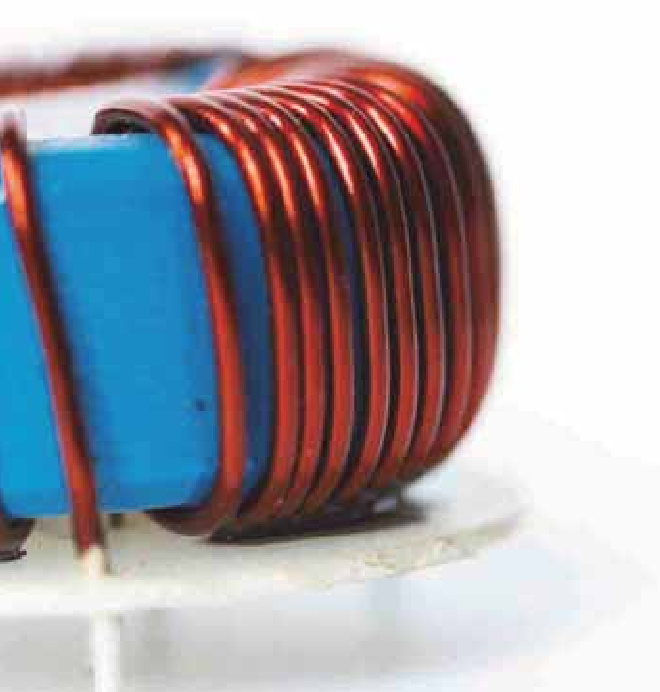
X-capacitors

In passive filters for the suppression of electromagnetic interference (Ref.: VDE 0565 Part 3/EN 60939/IEC 60939), designed essentially for the operation of mains alternating voltage, the capacitors need to fulfil the requirements of Class X or Y (depending on the position of the circuit).

Class X capacitors are catagorised according to the peak voltages of impulses superimposed on the mains alternating voltage to which they are exposed.

The switching of Class X capacitors takes place, depending on application, L-L and L-N.

Sub-class	Impulse peak voltage in operation	Installation category in accordance with IEC 60664
X1	>2.5 kV ≤4.0 kV	III
X2	≤2.5 kV	II
X3	≤1.2 kV	-



Insertion attenuation

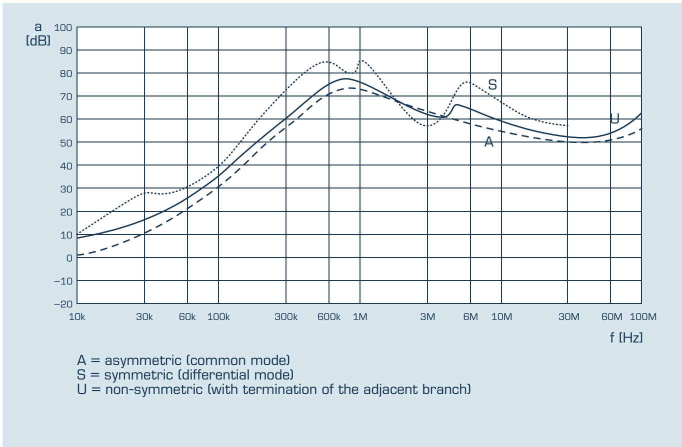
Insertion attenuation represents a
non-system-dependent benchmark criterion for passive filters. The measuring procedure has been standardised (Ref.: CISPR 17) and adapted from communications engineering. It describes the logarithmic ratio U1: U2 of the (interference) voltage before and after the insertion of a filter into a circuit in terms of the frequency, measured at the output.

$a = 20 \times l_g (U_1 : U_2)$ [dB]

Values often applied for U1: U2 include:

0 db = 1 : 1
3 db = 1 : 1,41
6 db = 1 : 2
10 db = 1 : 3,16
20 db = 1 : 10
40 db = 1 : 100
60 db = 1 : 1.000
80 db = 1 : 10.000
100 db = 1 : 100.000
120 db = 1 : 1.000.000
140 db = 1 : 10.000.000

If the filter is terminated on both sides with a real resistor of e.g. 50 Ω during measurement of the insertion attenuation, then one speaks of a 50 Ω insertion attenuation.

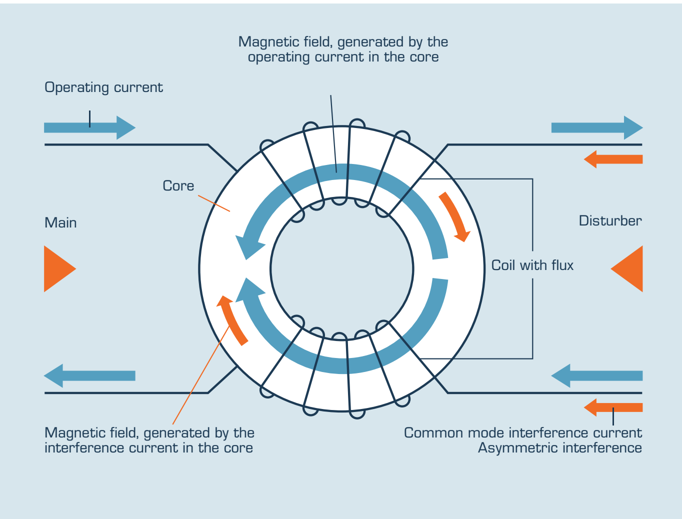


Discharging resistor

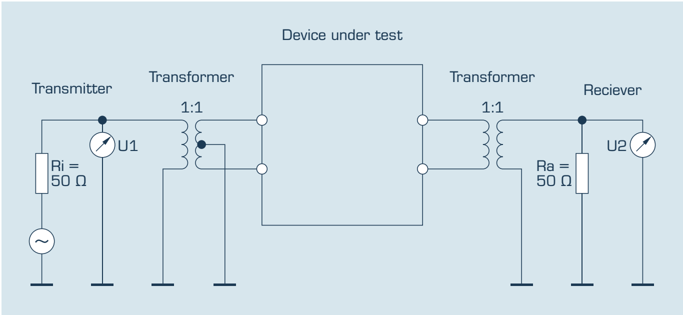
The discharge voltage resistors integrated in a filter aid the voltage degradation of charged capacitors. Capacitors should be discharged down to a voltage of less than 60 V within 5 seconds of the switching-off of the supply voltage in order to avoid the danger of an electric shock.

Current-compensated magnetic core reactor

Current-compensated reactors for the suppression of electromagnetic interference are reactors whose coils are configured upon a normally closed core in such a way that the magnetisation occurring as a result of the (symmetrical) is neutralised. A greater inductive resistor is, however, effective against asymmetrical parasitic currents.



Example of a current-compensated magnetic core reactor

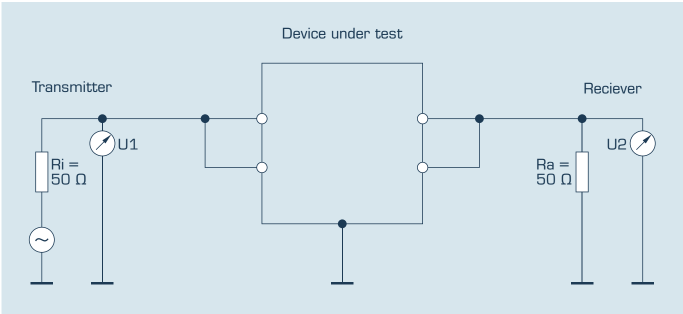


Basic measurement setup for measurement of the symmetrical 50 Ω insertion attenuation (differential mode) of a filter

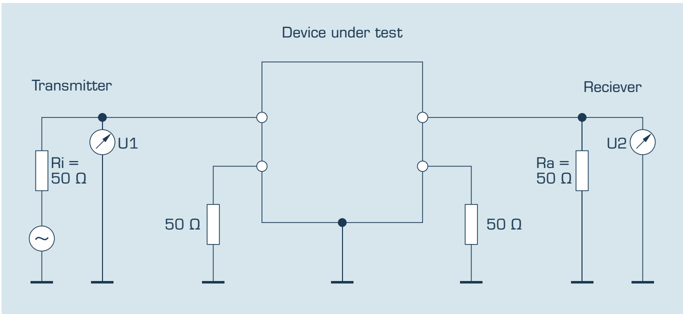
Measurement with unequal real terminating resistors (e.g. 0.1 Ω/100 Ω or 100 Ω/0.1 Ω) can also be carried out. These combinations make it possible to evaluate a filter in case of a mismatch. Even a negative insertion attenuation, meaning an (interference) voltage increase, is thereby possible.

While these measuring procedures do permit a comparison of different filters and make possible a preselection of the desired attenuation characteristics, they do not provide much information concerning the effectiveness of the filter in individual applications. The reason for this is to be found in the fact that neither the source of the interference (interference sink) nor the connected power line system exhibits a real resistor of 50 Ω. In addition to this there is the fact that the measurement of the 50 Ω insertion attenuation takes place in the small signal range (circa 1 V) and that the operating current (non-linear magnetisation characteristic curve, pre-magnetisation) is not achieved for the inductances of the filter. The interference voltage level itself, however, lies once again in the small signal range.

Proof of whether the limit values of the EMC standards (see “Electromagnetic Interference” and “Electromagnetic Interference Immunity”) can be maintained can be obtaines only by means of measurement technology as a systems test which takes into account all participating individual components.



Basic measurement setup for measurement of the non-symmetrical 50 Ω insertion attenuation (common mode) of a filter



Basic measurement setup for measurement of the asymmetrical 50 Ω insertion attenuation of a filter with termination of the neighbouring branch.

Current-compensated magnetic core reactor

The usual utilisation of network interference filters takes place between the network and the input of the consumer (e.g. frequency converters). 1-phase and 3-phase models are available. A network interference filter efficiently brings together the characteristic of a power reactor (see "reactors") and that of a "passive filter for the suppression of electromagnetic interference (EMI-filters)" to make just a single filter which is very effective across a wide band. Optimal tuning of the components makes it possible to have a mains borne suppression of interference from the network frequency up to 30 MHz.

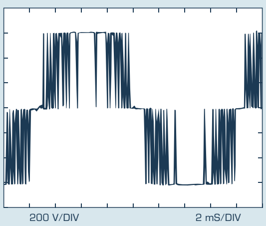
Motor reactor

The problems connected with the operation of alternating current motors at the frequency converter are increased with the utilisation of rapidly-switching power semiconductors. The steep buildup and falloff of the voltage (edge steepness dv/dt up to 12 kV/µs) causes, among other things, the following:

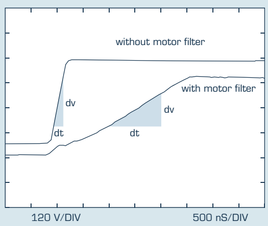
- Problems with the insulation strength and service life of the coil wires in the motor
- Generates harmonic oscillations of greater intensity up into the high frequency range

As a result of the utilisation of motor reactors,

- the edge steepness is reduced to circa 500 V/µs, which protects the motor
- the high-frequency harmonic oscillation share is reduced, which means that electromagnetic compatibility with other systems components is improved



Output voltage of a phase of the frequency converter



Resolution of an edge of the output voltage with and without a motor reactor

Motor reactors represent a minimum degree of protection. A higher level of usefulness can be obtained with motor filters or sinusoidal filters.

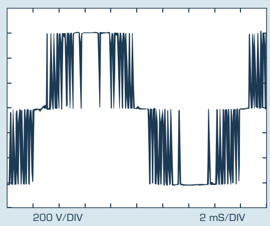
Sinusoidal filters

The utilisation of the sinusoidal filter extends itself to include the mains borne suppression of interference, from the frequency converter output to the shielded motor feed line with the alternating current motor attached to it, for clock frequencies from circa 500 Hz and higher.

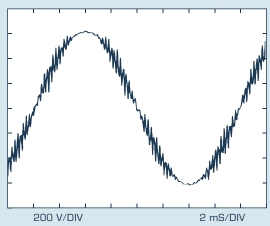
The sinusoidal filter achieves a very high filtering effect as a result of its precise low-pass tuning to the clock frequency of the frequency converter. The wanted signal (the motor operation frequency) up to circa 120 Hz passes the sinusoidal filter with only a slight effective voltage drop, while the clock frequency (typically 8 kHz to 10 kHz) is already being reduced by circa 90%. Harmonic oscillations of the clock frequency are filtered out almost completely.

The special andvantages in summary:

- very high filtering effect throughprecise low-pass tuning
- practically the only edge steepness of the output voltage still remaining is that which is usual for mains
- clock frequency and harmonic oscillation of the frequency converter output voltage become severely attenuated
- long shielded motor feed line possible
- low-noise motor operation through high attenuation of the clock frequency
- reduction of leakage currents



Output voltage of a phase of the frequency converter

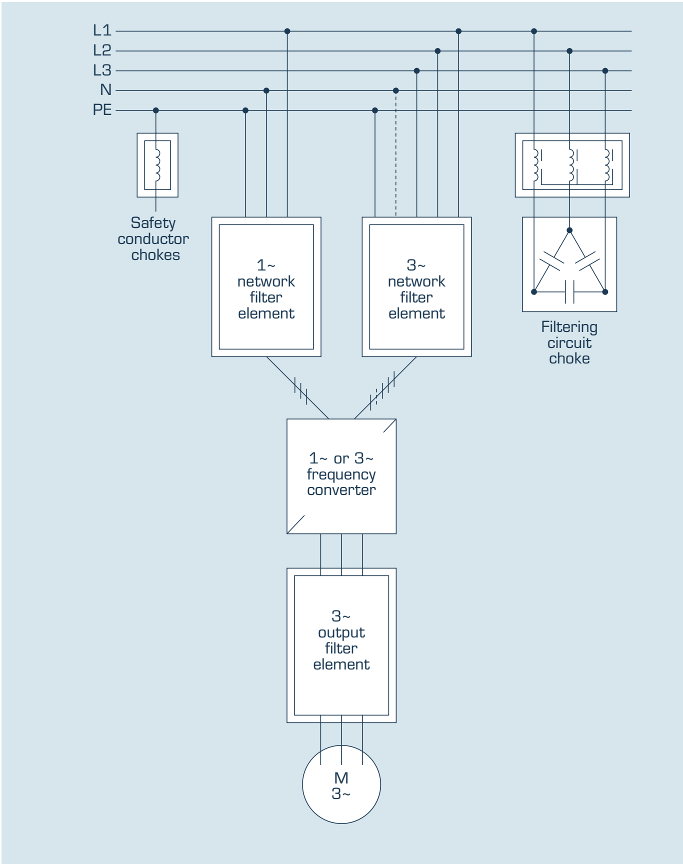


Output voltage of a phase of the sinusoidal filter

It can be seen in the oscillogram that the clock frequency of the frequency converter is present only in conjunction with a low-level amplitude superimposed on the wanted signal (motor operation frequency).

Overview for the utilisation of reactors and passive filters connected with the frequency converter

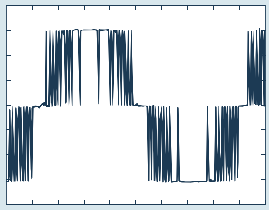
Frequency converters represent the optimal form of general motive power engineering for the control and regulation of motors, both from a technical and from an economic point of view. A typical configuration for this of the pieces of electrical equipment utilised is presented in the illustration:



The problems of modern frequency converters

A distinction is made between I frequency converters and U frequency converters. Both variants have technical advantages and disadvantages in terms of their respective applications. Due to advantages which are conceptional and thus also economic, the U frequency converter is utilised by far the most often – the statements made apply mainly to it.

Large numbers of manufacturing pieces and sophisticated circuit technology make possible the development of ever smaller and ever more efficient devices, qualities which keep them inexpensive. These advantages are achieved through ever-greater clock frequencies and through more rapidly-switching semiconductor switches (IGBT) which are linked to a lower level of power dissipation. The illustration shows the oscillogram of the (pulse width-controlled) clock-pulse controlled frequency converter output voltage of one of the three phases:



The oscillogram is resolved to a period of the "wanted signal" of the alternating current frequency for the operation of the motor (typically up to circa 150 Hz). This alternating current voltage is formed by precisely time-controlled switch-on and switch-off processes of the intermediate circuit direct current voltage with clock frequency of the frequency converter (typically starting from 4 kHz). The steep buildup and falloff of the voltage (edge steepness dv/dt to 12 kV/µs) causes considerable problems, however, with the insulation strenghth of the coil wires in the motor. The stress permitted should not exceed 500 V/µs, since otherwise either a malfunction caused by short circuit in coil will occur or there will be a reduction in the expected service life of the motors. An important additional aspect to be considered is electromagnetic compatibility (EMC) with other system components. The high degree of edge steepness of the clock-pulse controlled voltage generates harmonic oscillations of great intensity extending up into the high frequency range. The elimination of the problems mentioned and the lessened motor noise make it possible to have network filter and output filter elements specially tailored to the operating needs of the frequency converter technology. The power line length of all system components should be structured to be as short as possible in order to avoid a scattering of high frequencies (antenna effect) through the power lines.

Electrical energy is obtained from the 400 V/50 Hz alternating current network via an alternately 1-phase (230 V) or 3-phase (3 x 400 V) network filter element and fed to the alternately 1-phase or 3-phase frequency converter input. Depending on individual requirements, the network filter element can be designed as a power reactor, a network interference suppression filter or an EMI filter (see in this connection "Passive Filters and Interference Suppression components, Requirements").

The rectification of the 50 Hz mains voltage and the storage of the electrical energy takes place in a direct current "intermediate circuit" in the frequency converter. The feeding of the intermediate circuit can take place in 1-phase (usual: B 4 rectifier bridge) or even 3-phase form (usual: B 6 rectifier bridge). The intermediate circuit energy is clock-pulse controlled by means of a targeted switching on and off using six semiconductor switches. This clock-pulse control takes place fundamentally as alternating current voltage with 120° phase displacement and is made available at the output of the frequency converter. The level of the clock-pulse controlled 3-phase-output voltage is oriented to the input voltage of the frequency converter, i.e. 1-phase 230 V devices supply 3 x 230 V, 3-phase 3 x 400 V devices supply 3 x 400 V at the output. Control and regulation functions such as soft start, constant torque, current limitation or modification of the motor operation frequency are realisable through the targeted clock-pulse controlling of the output. The operation of a commercially-available alternating current asynchronous motor then takes place via the (always) 3-phase output filter element via amore or less long cable. Depending on individual requirements, the output filter element can be designed as a motor reactor, a motor interference suppression filter or a sinusoidal filter (see in this connection "Passive Filters and Interference Suppression components, Requirements").

Passive filters in the input range of frequency converters

From the point of view of measuring technology, verification of whether the EMC Requirements of an electrical drive system are being fulfilled in connection with a frequency converter can only be achieved in the form of a system inspection which includes all of the components involved.

EMI filter

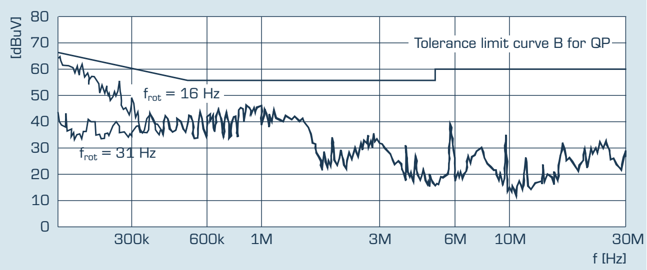
The European standard norm EN 55011: Industrial, scientific and medicinial high frequency devices (ISM devices) is considered the fundamental principle to be applied in connection with mains borne emitted interference in the frequency range extending between 150 kHz and 30 MHz, which is essentially responsible for the dimensioning of the input-side EMI (electromagnetic interference) filter between network and frequency converters. The frequency converter generates HF energy, which is required for internal functioning, and thus becomes classified as an ISM device belonging to Group 1. If it can be assumed that the electrical drive system is not connected exclusively to its own low-voltage supply network (industrial network), but ratherthat a power feed from the public network can also take place, then the frequency converter must be considered to be a Class B device. Class B devices must adhere to the Class B limit values for radio disturbance. If the utilisation of the electrical drive system takes place by means of a low-voltage supply network (industrial network), then the frequency converter is regarded as a Class A device. In such cases, it is then only the less-strict Class A limit values for radio disturbance which must be adhered to.

A passive filter for the suppression of electromagnetic interference in connection with frequency converters must be adjusted to accommodate the different operating states of the electrical drive system. Numbered among the most important operating parameters, the variations of which can lead to aberrant emitted interference, are the following:

- Rotating field frequency (speed of the motors)
- Switching frequency
- Length of the shielded motor line

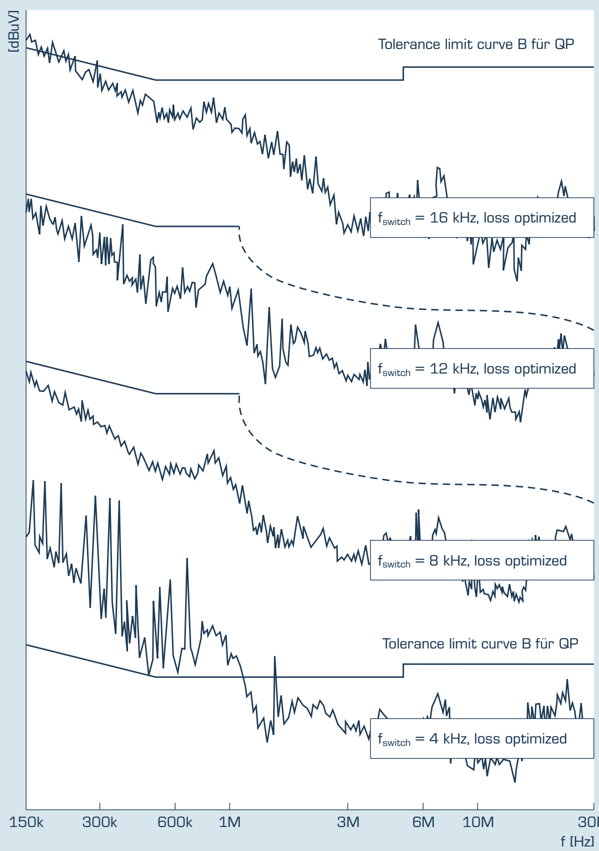
Variation of the rotating field frequency

The ability to carry out simple changes of speed of completely normal, commercially available alternating current asychronous motors is one of the most important reasons for the utilisation of a frequency converter. Even the modification of this operating parameter has an effect on the interference voltage released. Increased emissions were detected in many frequency converters, particularly for the lower rpm range. As a result, the “worst case situation” must be determined for each filter by means of continuous modification of the (output) rotating field frequency as early as in its development stage, the required filtering effect can be dimensioned by extrapolating from this. The following diagram of the interference voltage measurement in accordance with EN 55011 presents typical behaviour:



Variation of the switching frequency

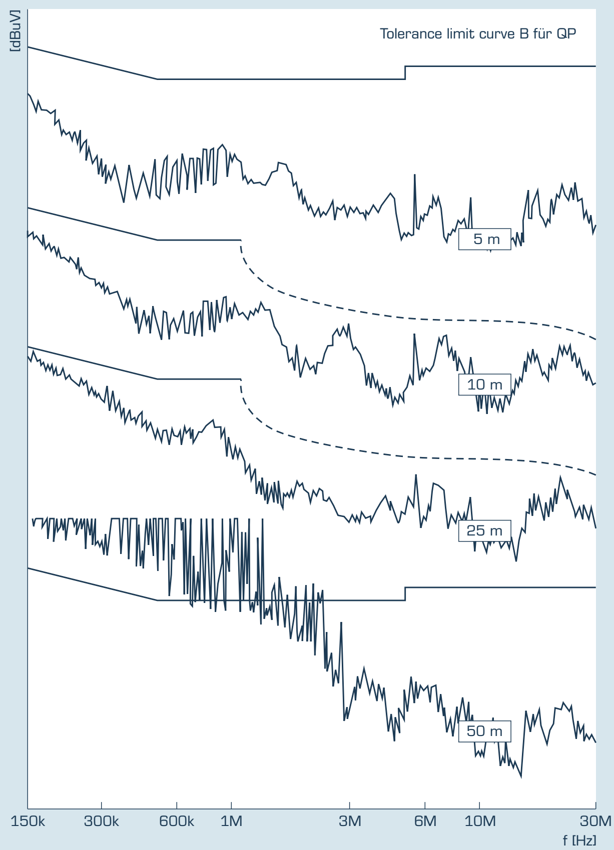
Modern frequency converters with their rapidly-switching IGBT terminal stages permit step-by-step adjustment of the switching frequency within the typical range between 4 kHz and 16 kHz. There are, however, devices on the market which feature automatically changing switching frequency (chopper frequency) for the purpose of avoiding device overheating. When faced with extreme situations, these models automatically reduce the specified high switching frequency to a lower frequency. This variation possibility also exercises a significant influence on the insertion attenuation of the filter which is to be provided. In the following diagram, various switching frequencies were set on the frequency converter in conjunction with the same filter. Whereas the interference voltage measured with the switching frequencies 16 kHz, 12 kHz and 8 kHz was close to and/or just above the limit value curve B, the same filter is completely overwhelmed when faced with a switching frequency of 4 kHz



Variation of the shielded motor line

The length of the motor line connected to the output of the frequency converter, and thereby also the shield area, has an effect on the design of an EMI filter. The dependency of the interference voltage at the input of the frequency converter upon the cable length connected to the output is illustrated in the following diagram.

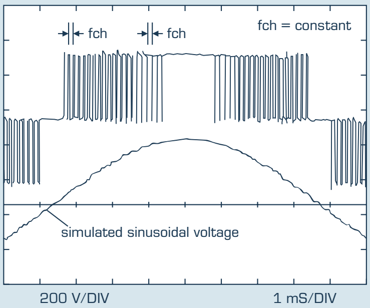
The increase on the mains borne emitted interference in connection with increasing cable length is clearly recognisable. The limit for Class B in the lower frequency range is already exceeded at 25 m, while a 50 m cable length overwhelms the filter.



3.1
3.2
3.3
3.4
3.5

Passive filters in the output range of frequency converters

Frequency converters have the task of propelling alternate current motors forward. This task should be accomplished for the operating behaviour of the almost exclusively-used alternating current asynchronous motor in a way reflecting a high degree of efficiency and user-friendly setting options. For this, it is necessary to supply the three-phase output voltages of the frequency converter with clock pulses. The following illustration shows the oscillographic output voltage of one of the phases of a typical U frequency converter, each of which has been shifted by 120°:

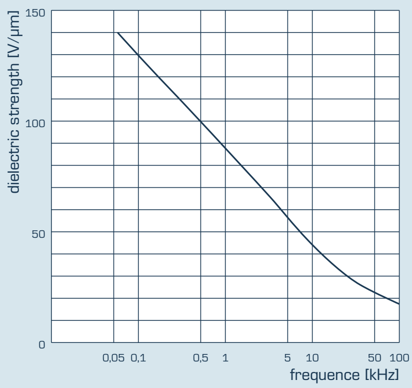


The superimposed sinusoidal semioscillation is intended as an aid to understanding the processes connected with simulation network of the operating voltage. A direct current voltage generated in the frequency converter is split up with unchanging switching frequency (in pre-selectable intervals between 4 kHz and 16 kHz) into individual packets with an unchanging curve summit value. Starting at the first zero crossing of the sine curve, initially very narrow impulse packets with low energy content are to be found, the later progression then witnesses a steady prolongation of the impulse duration up to the amplitude maximum of the shape of the curve to be network balanced. After that, the impulse duration shortens again back to the renewed zero crossing. In the second half-wave, the process repeats itself with reversed polarity.

The control of the connected motor takes place by means of variation of pulse and interlude times in terms of rotating field frequency, torque and startup and braking behaviour. These advantages unfortunately also involve a few disadvantages:

- reduction of the motor service life as the result of steep switch edges
- overvoltages at the motor
- EMC problems
- increasing problems with long power lines
- additional noise development in the motor

Designed for a low-band sinusoidal operating voltage, there have been no problems in the past in terms of insulation strength of the commercially available enameled copper wires used in virtually all electric motors. Whereas in the early days of frequency converter technology frequencies were relatively low and switching procedures were relatively slow, nowadays determined further development of semiconductor components have established ever-shorter switching times and steadily increasing switching frequencies. No development progress of equal import can be recorded for the insulation strength of the enameled copper wires in standard electric motors. In addition to their previous dynamic loads, nowadays the coil wires are also subjected to a frequency-dependent insulation stress which has the effect of reducing expected service life. The dependency of insulation strength on enameled copper wire as a function of frequency is presented in the following diagram:



Varnish insulation, based on modified polyester, layer thichness approx. 75 µm, test voltage increased until voltage breakdown, within 10–20 s.

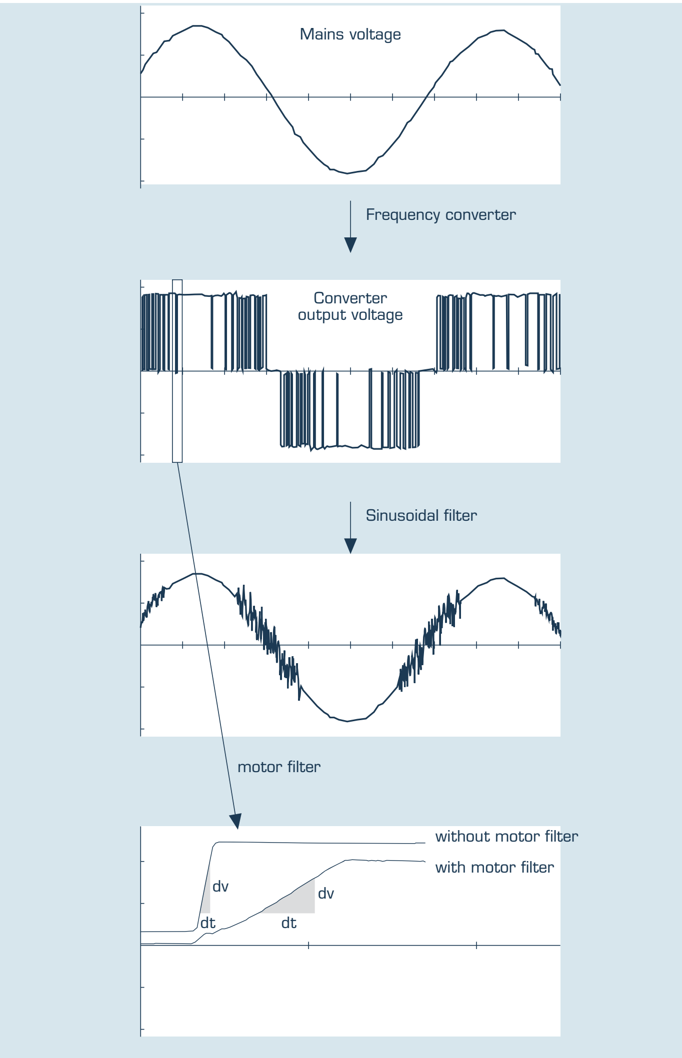
Even in the presence of a sinusoidal voltage with as little as 10 kHz, insulation strength will be reduced by more than a factor of 3. If one considers the quite energetic harmonic oscillation spectrum present in the steep impulse edges of the switching frequency, then the dielectric strength falls to dramatically low values.

The uncontrolled emergence of overvoltages are the result of stationary or wandering harmonic oscillations upon the motor line. The frequency spectrum is not at all constant, it changes with the impulse packets to the control system of the motor. Because the transfer system consisting of frequency converter–motor line–motor needs to be optimised to the power transfer in the rotating field frequency range of the motor, a constant mismatching takes place for the harmonic oscillation spectrum, which promotes the uncontrolled appearance of resonances.

The noise development of the motor, though not important in terms of electrical reliability, is still felt to be extremely disturbing in some areas of use (particularly in the residential sector). It is precisely in the audible range under 16 kHz that the magnetostriction of the sheet steel of the motor occurring with the switching frequency and the mechanical oscillations of the coils in the motor are felt to be particularly disturbing.

In critical cases, a frequency converter with enhanced output power can become necessary. The source of the trouble is an increased frequency converter load caused by parasitic cables and earth currents.

Corrective help for the weak points named can be had from motor reactors, a motor filter and a sinusoidal filter on the output side of the frequency converter.



Whereas motor reactors offer minimum protection against a high degree of edge steepness on the part of the frequency converter output voltage, motor filter are even more efficient. This efficiency can be recognised in the lefthand oscillogram:

Compared to a commercially-available frequency converter with 8 kHz switching frequency, the motor filter reduces the dv/dt value from approx. 12 kV/µs down to a non-critical 500 V/µs. The original expected service life of the motor is thus restored once again. In addition, a low-loss measure for the attenuation of stationary waves on the lines is also integrated into the filter. This installation provides for stable operating behaviour at different power line lengths.

Sinusoidal filters form a sinusoidal voltage with low levels of distortion from the clock-pulse controlled frequency converter output voltage. The ratios in front of and behind a sinusoidal filter are illustrated in the oscillogram. Only a few remaining harmonic oscillations on the sinusoidal fundamental oscillation of the of the rotating field frequency of the motor are indicative of the original progression of the frequency converter output voltage. This is the way the builder of electrical installations avoids the following points of weakness in the area of frequency converter motive power engineering:

- dv/dt loading of the coil wires
- overvoltages at the motor coils
- noise development in the motor caused by the switching frequency
- problems with long motor power lines

The problems outlined are now all to be attributed to the filter utilised, which assumes a key position in the transmission system of frequency converter–filter–motor power line. Only many years of experience and careful selection of materials, coupled with extensive testing techniques makes possible the development and manufacture of reliable filter products for frequency converter motive power engineering.

Installation directions for the frequency converter motive power engineering

The installation of a good filter does not also automatically ensure the successful interference suppression of a switch cabinet.

Basic information concerning service cabinet construction

It is only when the correct concept for service cabinet construction in view of high-frequency interference emissions and immissions has been selected that all EMC efforts will exercise their effective influence. The first step to professional handling of the complex techniques is the recognition of critical components. Included among these in the context of an installation are for example frequency converters, switched mode mains power supplies and SPS devices. Mutual influencing and negative effects upon other consumers are to be assumed when they are connected to a shared network and when they are physically close to one another. Possible points of weakness as well as suitable solution approaches are shown in the following illustration 1:

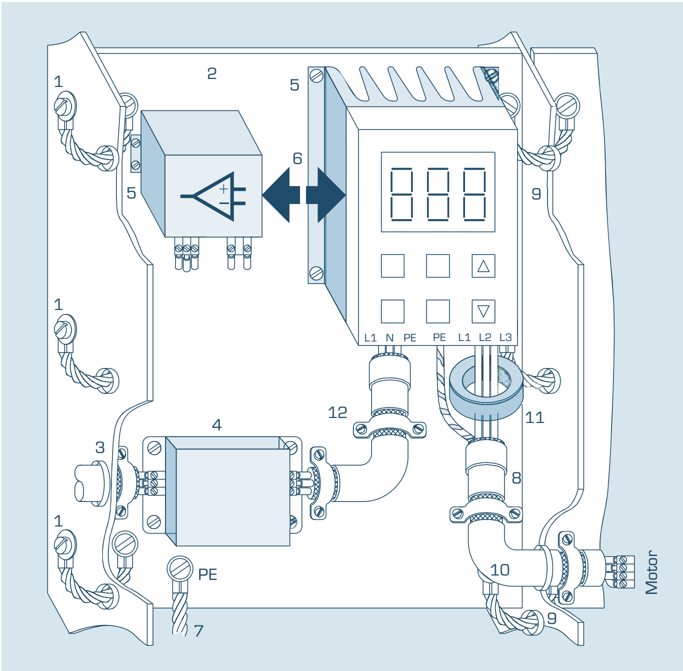


Illustration 1

- Single filters are to be provided for as needed before each source of interference for the purpose of decoupling conducted interference dissemination, thus contributing to the minimisation of its influence. The use of this procedural method leads to the reduction of the conducted interference potential down to permitted values and to the simultaneous improvement of the interference immunity of the shielded component against line-commutated voltage influences.
- In cases of single interferences, the filter is to be placed as close as possible to the emission site. If this is not possible due to space considerations, then a shielded cable is to be selected for the connection (Ill.: 1/12).
- Relays, contactors, solenoid valves, etc., which are located in the same electrical circuit with electronics components are to be provided with corresponding spark extinction combinations and/or overvoltage protection circuits.
- The total sum of suppression filters take over the limiting of conducted interference for the entire installation. Their position is to be as close as possible to the network input (Ill.: 1/3). As a positive side effect, this measure leads to an increase of the conducted immission resistance of the attached product in relation to the spike, burst and surge pulses carried on the network side.
- Suppression filters must channel off corresponding currents against PE for emission suppression. The Y capacities necessary for this allow leakage currents to flow through the protective conductors. For the majority of three-phase filters, only very low levels of leakage current occur during normal operation. This changes however in the presence of non-symmetrical network conditions: then a few 100 mA of leakage current can be expected. For that reason it is absolutely imperative to take care to ensure the presence of a dimensioned PE connection.
- Many manufacturers use the maximum permissible highest value as the basis for the voltage specification for suppression filters. Warning! In such cases, the maximum permitted operating voltage – without any upward tolerances – is to be equated with the printed value.
- An essential part of secure EMC construction is an HF-suitable bonding of all devices and/or installation components. This means that they are bonded in a way which is large-area, of low impedance and protected against corrosion with the PE reference potential (Ill.: 1/5).
- The enhancement of the interference immunity against radiated immission leads to an improved level of operational safety. Adherence to a sufficient spatial separation between sources of radio noise and loaded components is in this connection an effective an inexpensive procedural method (Ill.: 1/6). In cases where spatial opportunities are absent, metallic separating walls are of help (Ill.: 2/7).
- Connect all metallic parts of the switch cabinet, such as rear and side walls, ceiling and floor sheet metal together in a way which is HF-suitable. If this is not done, then the elements will function as junction transistors (Ill.: 1/1). Cross-section-sized fine-wired strands or earthing straps are suitable as connection lines. Solid wire should be dispensed with altogether (Ill.: 1/1). This also applies to the PE connection
(Ill.: 1/7).
- All metallic parts in the switch cabinet (devices, mounting plates, etc.) are to be bonded together in an HF-suitable manner (Ill.: 1/9).
- Unfortunately, coloured lacquered mounting plates are still to be used in switch cabinets. These could hardly be less appropriate for an EMC-suitable construction, since it would take an unacceptable amount of effort to establish an adequate HF bonding. Anodised surfaces are equally unsuitable for good bonding because of the high level of contact resistance in the high frequency range.
- For custom-made structures, one must remember that the only metal surfaces which meet the requirements of HF technology are those which have been permanently protected against corrosion damage.

Selection of cables and their placement

The correct selection and placement of the connecting cable is numbered among the basic prerequisites of a successful EMC setup. Greater problems with installation components accompanied the appearance on the market a few years ago of modern versions of frequency converters, the IGBT final phases of which generate voltage units of up to 12 kV/µs, which means they release a considerable interference potential. Illustration 2 shows typical methods for the placement of connection lines:

- There must be a spatial separation between "hot" and "cold" cables. What is meant here is the placement of interference-prone lines parallel or in the immediate proximity of already shielded or non-interfering lines (Ill.: 2/1). Where necessary, a shielding or metallic separation wall is to be placed between the cable strands (Ill.: 2/7).
- Interference-prone lines should be placed as close as possible to reference potentials such as rear wall, side wall, etc. This will cause a part of the radiated emission to be absorbed by the reference surface (Ill.: 2/6).
- An "orderly" parallel and spatially-narrow arrangement of the wiring between interference-prone and "clean" connections is to be avoided. Each cable has an E-field component which leads to capacitive coupling and thus also to the contamination of the previously interference-free cable (Ill.: 2/2).
- If interference-prone power cables and control cables cross over one another, then this is to be carried out at a 90° angle as much as possible (Ill.: 2/3).
- Cut off "safety lengths" and thus overlong lines, do not roll them up and store them in the switch cabinet. These "coils" act like antennas and "suck up" interference and/or radiate it off.
- The simple measure of drilling unshielded analog lines protects against symmetrical interference couplings
(Ill.: 2/5).
- Connect non-occupied wires with PE voltage. Otherwise they will act like antennas (Ill.: 2/4).
- Only use cables which have copper-mesh shielding, YCY. As for steel mesh or braids, their electric conductance is insufficiently high for HF applications. There is only a very low shield effect. The latest cable shields consist of a synthetic foil with woven-in ferrite material. Cost/benefit considerations are to be pondered in this connection.
- In cases where shield unraveling is required, this should be woven back together again over as large a surface as possible. The free wire ends for the connection clamps should be kept as short as possible.
- Do not place any further lines such as for example control or data cables within a shielded motor line.
- Set up the connection between the suppression filter and the emission source to be as shielded as possible. In cases of extremely short lengths (≤20 cm) this can in some cases be dispensed with.

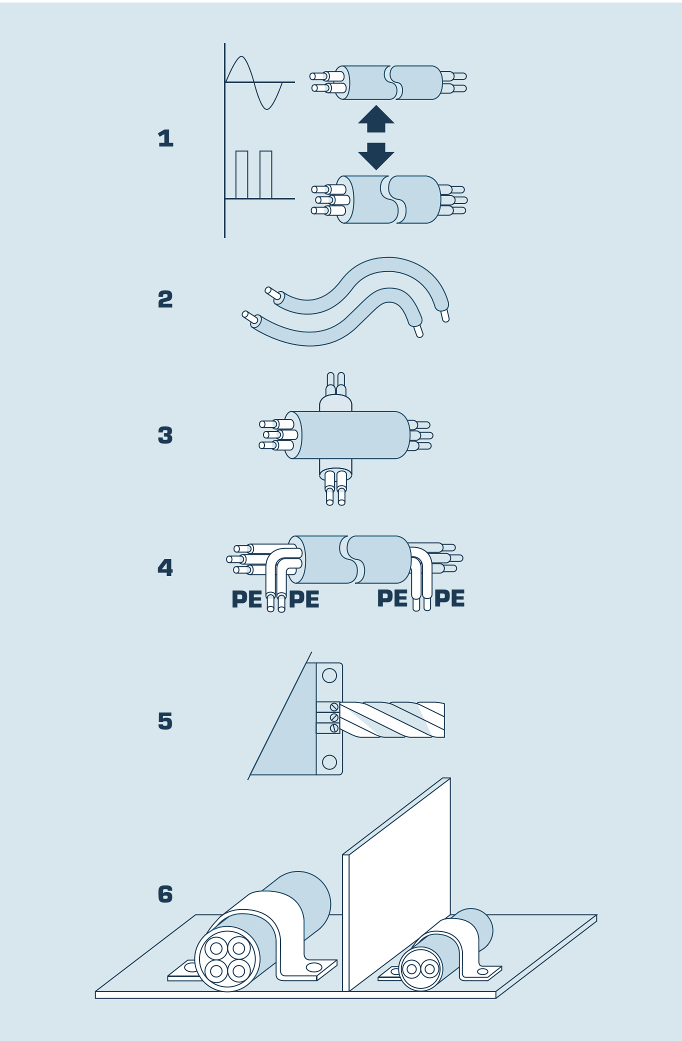


Illustration 2

Proper placement of the cable shield

An opinion widely shared concerning the bonding of a cable shield rests on the state of technology relating to power lines with analogue signals. Here only a single-sided placement of the shield is to be recommended for avoiding humming and earth circuits. This is often also practiced for connections with digital signals (e.g. of the frequency converter output voltage). Unfortunately, this is an unfavourable procedural method. Illustration 3:

- In cases of shielded cables with digital voltage forms, both shield ends must be put on (Ill.: 3/4).
- Always put the shield on over a large surface, e.g. with a cable clip (Ill.: 3/4).
- Completely insufficient is any bonding of the shield by means of simple drilling and subsequent bonding of the thin end with a PE terminal (Pigtail) (Ill.: 3/1).
- Similarly, the shield may not be connected by means of a soldered strand end to a PE clamp (Pigtail) (Ill.: 3/2).
- Connecting the shield weave with a pressure ring and a soldered-on strand end will also yield only unsatisfactory results (Ill.: 3/3).
- The distance between the shield strap and the clamping point is to be kept short (Ill.: 1/8,12). If this requirement cannot be met, then the shield should be carried further up to a position close to the clamping point. The shield end should also be mechanically secured with a heat- shrinkable sleeve as necessary (Ill.: 3/5).
- Use special PG threaded connections for cable bushings use HF-suitable shield layers.
- The motor feed line carries the greatest emission potential. For this reason, do not fail to use shielded cable, particularly in connection with longer connections (Ill.: 1/10).
- A great deal of energy is lost in the shield on long shielded lines. The cause of this is the high speed of voltage increase (dv/dt) of the generated motor voltage. A high dv/dt can, in the case of small frequency converters, lead to a situation where all of the power is extinguished in the cable itself. Motor reactors offer some aid here, as do motor filters and/or sinusoidal filters by means of a flattening of the speed of voltage increase. Besides the EMC problems, there also exists a high dv/dt, in addition to the danger of a rapid shortening of the service life of the motor coil insulation. A useful side effect of the suggested EMC measure is the improvement of the expected service life of the connected motor.
- Sinusoidal filters re-form a sinusoidal operating voltage out of the clock-pulse controlled frequency converter signal. This makes it possible to maintain extremely long shielded motor feed lines. An additional plus point is the noise minimisation at the motor.
- Guide the motor cables of frequency converters as directly as possible out of the switch cabinet. This handling method reduces the internal susceptibility to interference (Ill.: 1/10).
- A ferrite ring over the motor line can under certain circumstances reduce radiated interference as well as the leakage currents to the motor cable shield (Ill.: 1/11).

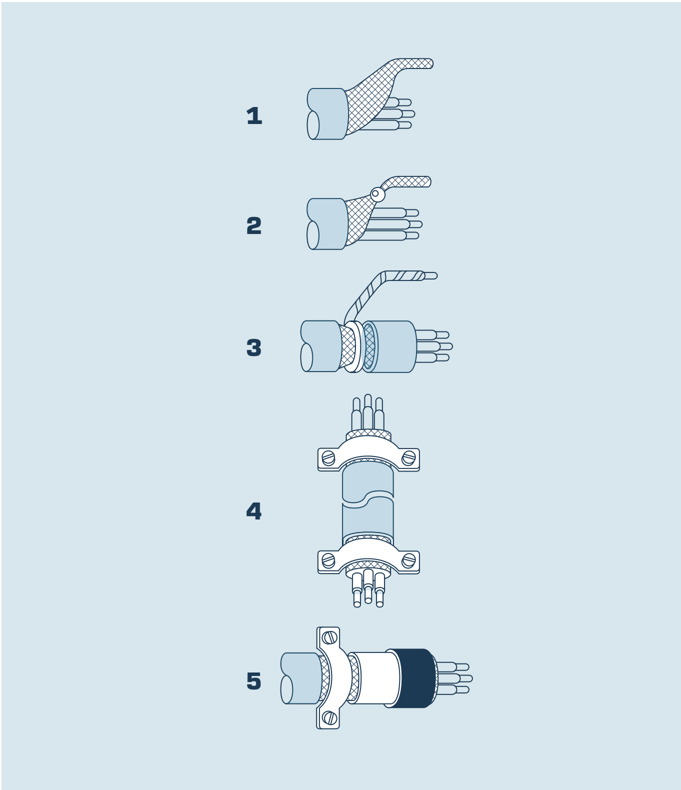


Illustration 3

Reactors

General technical informations

A reactor is a device which is made up of one or several coils with a frequency-dependent impedance and which works in accordance with the principle of self-induction, whereby a magnetising electrical current generates a magnetic field which is directed through a magnetically-charged core or through air (Ref.: Ref.: VDE 0570 Teil 2–20/IEN 61558-2-20/IEC 61558-2-20).

Requirements

The general statements already made concerning such things as protection class, type of protection, insulation material class, rated ambient temperature and (to the extent applicable) transformers also apply to reactors.

Usually, and unless otherwise agreed upon with the ordering party, reactors will be manufactured with basic insulation between voltage-bearing parts and the core.
As a result of the laws of physics, the presence of at least one air gap in reactors causes an operating frequency magnetic leakage field which cannot be ignored and an acoustic noise development which corresponds to twice the operating frequency.
There is a need for providing sufficient clearance to neighbouring electrical equipment and ferromagnetic materials
(e.g. steel switch cabinet).
An important criterion for dimensioning is utilisation of reactors provided for in the low-band range, e.g. as:

- Power reactor
- Smoothing/commutating reactor
- Filtering circuit reactor
- Motor reactor
- Motor filter
- Sinusoidal filter

BLOCK

Standards

Unless otherwise agreed upon with the ordering party, we manufacture in accordance with the latest "State of Technology" and with the following standards:

VDE 0570: Safety of transformers, power supply units and similar devices, Part 1: General requirements and tests, Part 2-20: Particular requirements for small reactors

EN 61558, IEC 61558: Safety of power transformers, power supply units and similar, Part 1: General requirements and tests, Parts 2–20: Particular requirements for small reactors.

Frequency behaviour

Non-dependence on frequency for the inductance can only be expected from ideal inductances and air-core coils. Actual inductances and reactors with a ferromagnetic core exhibit a more-or-less marked frequency dependency, even in the low-band range, which is essentially determined by the core material utilised.

The usual utilisation of reactors in the area of application of VDE 0570 Teil 2–20/ IEN 61558-2-20/IEC 61558-2-20
(see chart).

Harmonic oscillations generate exponentially increasing attenuation in a reactor as frequency increases. These increases will be determined by BLOCK theoretically and optimized for the best possible use in the application. The usual thermal dimensioning (e.g. of a power reactor) on the rated electrical current with rated frequency takes into account only an increase of load through the sum of all harmonic oscillation currents of up to a maximum of 5%. An increase of the core power is required for greater increase of load.

Furthermore, in addition to the rated electrical current at the rated frequency (fundamental oscillation), the effective value of the current of each emerging harmonic oscillation must be known for the thermal dimensioning of the reactor. In critical cases, when a harmonic oscillation current exceeds circa 10% of the fundamental oscillation current, then the phase position of the oscillations to one another is also to be taken into account.

Usual use of reactors within the purview of the standards:

laminated (lamellar) cores	iron powder cores ironres	ferrite fecoresrores
<3 kHz*	**<250 kHz***	**<1 MHz**
Smoothing/ Commutating reactor	Smoothing/ Commutating reactor	Smoothing/ Commutating reactor
Line reactor	Motor reactor	Motor reactor
Filtering circuit reactor	Motorfilter	Motorfilter
Motor reactor	Sinusoidal filter	Sinusoidal filter
		Motor filter
		Sinusoidal filter

*still working on sinusoidal frequence

Tolerance

The voltage drop (Ref.: VDE 0570 Teil 2–20/
IEN 61558-2-20/IEC 61558-2-20) may not deviate by more than 25% from the rated value in the equilibrium state with rated frequency and rated electrical current. For biased reactors and reactors with such additional components as capacitors, rectifiers, etc., the voltage drop may not deviate by more than 30% from the rated value.

Special models of reactors, such as filtering circuit reactors, must be precisely calibrated, which means that they are subject to considerably lower tolerances.

Proportional to rated voltage drop, inductance is calculated to:

$$L = \frac{U_{rated}}{I_{rated} \times 2 \times \pi \times f_{rated}}$$

Linearity

The linearity of the inductance of a reactor can be influenced within certain limits by constructive design. The illustration A shows a common layout, e.g. as a power reactor (with a linear air gap).

Inductance proceeds in an almost linear manner up to the rated electrical current (thermal dimensioning) and falls off in the presence of over-current in a relatively undefined manner as the result of the magnetic saturation of the core. As a rule, the only way to avoid loss of linearnetic saturation of the core. As a rule, the only way to avoid loss of linearity in the over-current range is to increase core power.

If a greater initial inductivity of up to a current of circa 10–20% of the rated current is required, this can be realised by means of a nonlinear air gap. The disadvantageous effect of this, however, is a relatively undefined curve progression and the associated greater inductance tolerance.

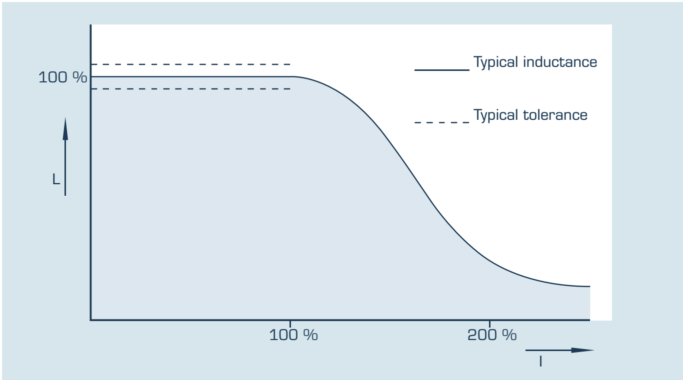


Illustration A

3.1
3.2
3.3
3.4
3.5

Bemessungsleistung

The rated power (Ref.: VDE 0570 Teil 2–20/IEN 61558-2-20/IEC 61558-2-20) of a reactor is the sum of the products of rated voltage drop and of rated electrical current with rated frequency. The specification of the reactive power is given in kVAR or VAR (Volt Ampere Reactive).

$$W = U \times I \times t = \frac{L \times I^2}{2}$$

with W = energy in Watt seconds (Ws)

U = voltage drop in Volts (V)

I = current in Amperes (A)

t = time in seconds (s)

L = inductance in Henry (H)

Note concerning magnetic energy of the rated power

Smoothing/Commutating reactors

These reactors are often utilised as storage reactors for electrical energy in direct current circuits. The core is thereby often biased with a direct current, which is either superimposed upon an alternating current characterised by the most eccentric curve progressions and frequencies or used for current direction changes (commutation). Dimensioning is highly dependent on circuits and applications.

Line reactors

These reactors are usually used in the mains in series connections to the user. Single phase and 3-phase models are available. They provide the following important safety functions:

- Attenuation of harmonic oscillation currents resulting from frequency-dependent inductive resistance
- Starting current limitation for the user and thus reduced module stress, e.g. for rectifier circuits
- Guarantee of the short circuit voltage UK of 4% to the network frequently demanded by the EVUs (electric supply companies)

Example: With rated electrical current (e.g. 4 A) and rated frequency (e.g. 50 Hz) of a reactor with UK = 4 %, 96 % of the mains voltage (3 * 384 V) is still available to the consumer (ohmic resistance) on a 3-phase network of 3 * 400 V/50 Hz. The rated voltage drop of each phase at the reactor amounts to 16 V * 1/w3 = 9.2 V and the rated inductance is calculated to

$$L_{rated} = \frac{U_{rated}}{I_{rated} \times 2 \times \pi \times f_{rated}}$$

$$= \frac{9{,}2\ V}{4\ A \times 2 \times 3{,}14 \times 50\ Hz}$$

$$= 7{,}3\ mH \text{ per phase}$$

For the rated frequency (fundamental oscillation), the inductive resistance is calculated to

$$XL = ❷ \times \pi \times f_{rated} \times L_{rated}$$

$$= 2 \times 3{,}14 \times 50\ Hz \times 7{,}3\ mH$$

$$= 2{,}3\ \Omega \text{ per phase}$$

an idealised point of view, harmonic oscillation currents are reduced in relation to fundamental oscillation (1st harmonic = 50 Hz) by the factor of the ordinal number (e.g. 3rd harmonic = 150 Hz = factor 3). However, the statements made concerning the “frequency behaviour” of reactors should be taken into account for this.

3.1 3.2 3.3 3.4 3.5

Filtering circuit reactors

Power converters and frequency converters are used nowadays with increasing frequency on the network. This leads to harmonic oscillations on the network, which causes additional attenuation, especially in the capacitors of reactive current compensation installations. Among the advantages offered by filtering circuit reactors are:

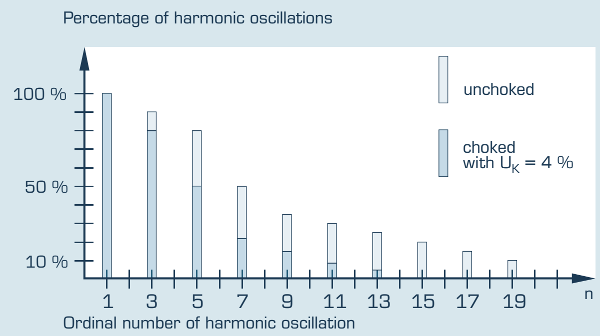
- less attenuation and no overloading of the capacitors of a reactive current compensation installation,
- the impedance behaviour of the network becomes improved.

Filtering circuit reactors require special dimensioning for safe and long-lasting operation:

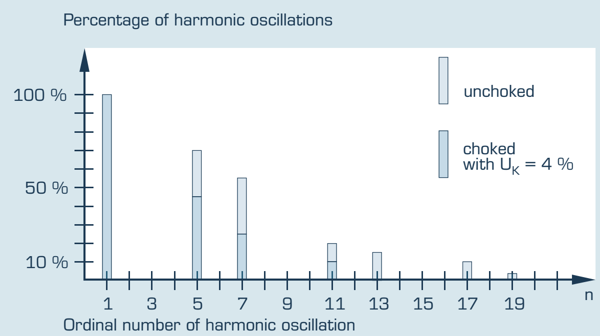
- low inductance tolerance,
- linear inductance progression extending far beyond the rated electrical current and with harmonic oscillations,
- thermal design construction for continuous operation for network frequency and harmonic oscillations.

The series connection to the capacitors is carried out almost exclusively in 3-phase design, which means that it has an effect upon the entire alternating current network.

Typical effect for consumers with direct current intermediate circuit (rectification and filterung of the mains voltage):



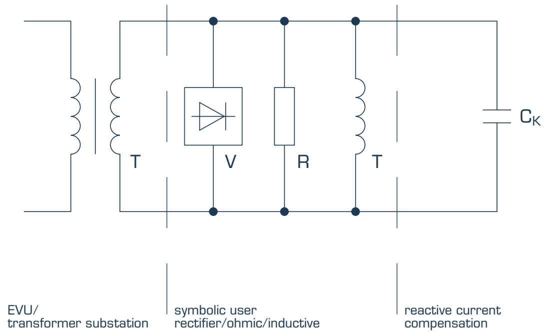
1-phase user



3-phase user

The normal reactive current compensation

The illustration shows the basic construction of a reactive current compensation at a network which is loaded with harmonic oscillations:



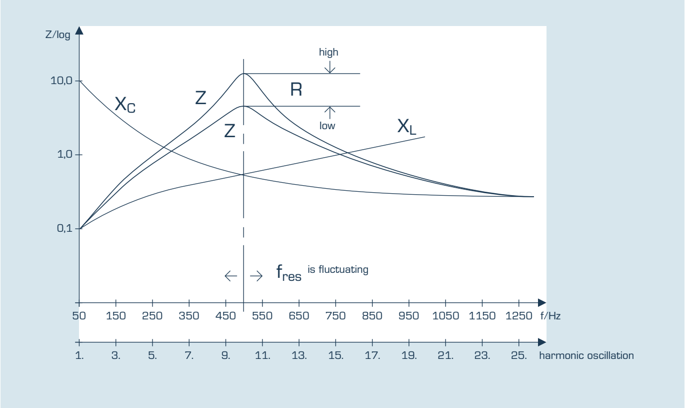
Filtering circuit reactors for reactive current compensation installations

An economic operation of inductive consumers such as motors, transformers and fluorescent lamps is possible only through appropriate measures involving reactive current compensation. A capacitive reactive current has a compensating effect to counter the inductive reactive current of consumers. This means that it becomes possible to approach the desired power factor cos 0.9 ind. up to 1. Reactive power costs will continue to be minimised and the load on the networks of the electric supply companies (EVUs) will be lightened.

Networks with harmonic oscillations

Harmonic oscillations on the mains occur, for example, as the result of the operation of power converters and frequency converters. The frequency spectrum of the harmonic oscillations that arises is dependent on the generator of the harmonic oscillations and extends well up into the Kilohertz range. Generally speaking, however, an assessment which extends up to the 25th harmonic oscillation (in terms of the network frequency) is sufficient. Installations and components are usually designed for compatibility levels in accordance with the VDEW guidelines "Fundamentals for the evaluation of network reactions".

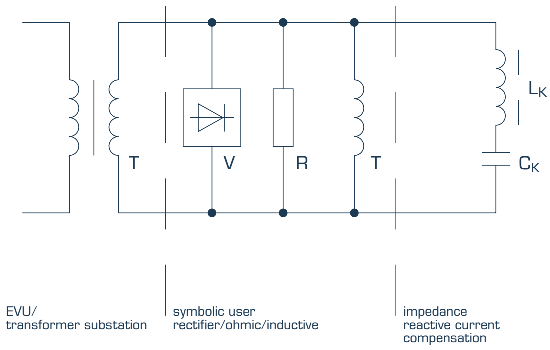
The harmonic oscillations are caused by the user V. Even just a relatively low share of harmonic oscillations leads to additional losses in power lines, transformers, switching elements and in the capacitor of the reactive current compensation, which is to be regarded as particularly critical. To this is added an undefined impedance behaviour on the part of the mains. The following illustration shows a typical impedance behaviour:



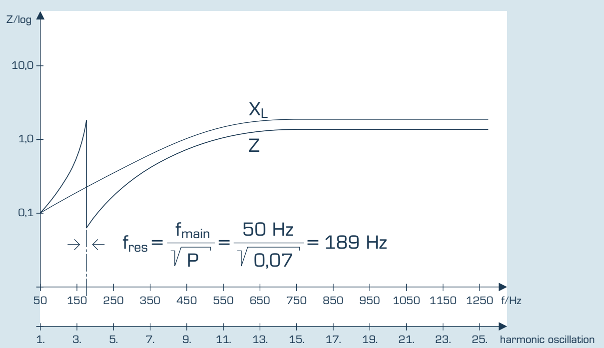
Depending on the load and the effect of the existing parallel oscillation circuit, which consists of the sum of all inductances and the capacitor of the reactive current compensation, resonance increases occur. The resonance frequency which arises can fluctuate and, in conjunction with the generated harmonic oscillations, can lead to the destruction of individual components of the network being observed.

The impedance reactive current compensation

The following illustration shows the basic structure of an impedance reactive current compensation:



Defined network conditions are created through the addition of a filtering circuit reactor LK in series connection to the capacity CK of the reactive current compensation. Generally speaking, an impedance becomes absolutely mandatory when the apparent power of the consumer generating harmonic oscillations amounts to more than 1/5 of the rated power of the feeding transformer. By adjusting the series oscillation circuit (LK, CK) to match a non-critical frequency, undefined resonance increases are avoided and the capacitor of the reactive current compensation, which is to be regarded as critical (particularly in conjunction with high frequency harmonic oscillations), is protected. The following illustration shows in this connection a typical example of network impedance behaviour in conjunction with the most frequently selected impedance of 7% (p = 0.07):



The impedance factor p is expressed as the ratio of the reactive impedances:

$$p = \frac{X_{LK}}{X_{CK}}$$

The ensuing resonance frequency of the series oscillation circuit is

$$f_{res} = \frac{f_{mains}}{\sqrt{p}} \text{ (Hz)}$$

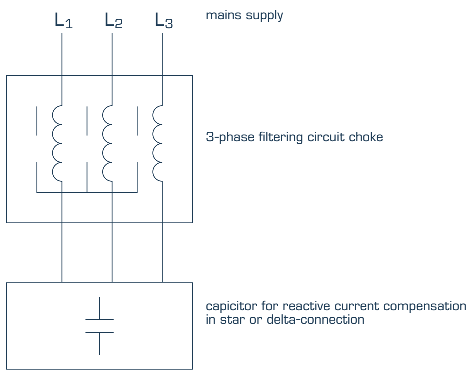
This means the resonance frequency in a
50 Hz network calculates out to 189 Hz. This resonance frequency, which is considered to be non-critical, lies clearly above the network frequency of 50 Hz on the one hand, but below the base frequency of the harmonic oscillation-generating consumer and below the audio frequency multi-station control system of the electric supply company (EVUs) on the other.

The compatibility is, however, to be individually adjusted in conjunction with the local electric supply company (EVUs).

Filtering circuit reactors have special requirements to fulfil as a result of their utilisation, e.g.:

- low inductance tolerance
- linear inductance progression extending far beyond the rated current
- linear inductance progression with harmonic oscillations
- thermal design construction for continuous operation with network frequency and harmonic oscillations

Filtering circuit reactors are utilised almost exclusively in 3-phase models:



In cases of regulated reactive current compensation installations, each capacitor group is to be allocated to a filtering circuit reactor which is adjusted for this purpose.

the EU-Symbol (Communautés Européennes)

The CE marking

General Note

The technical explanations contained here represent points of departure for many areas of application, a number of rules apply in addition to special and exceptional cases. The intention here is to provide a brief introduction into the complex subject field.

EC Designation

EU guidelines have been issued by the Council of the European Union, based upon the Treaty for the Establishment of the European Economic Community (EEC), particularly under Article 100. These EU guidelines are for the purpose of establishing conformity among the legal and administrative regulations of the different member states of the European Union (EU) in cases where differences among national regulations lead to trade restrictions or otherwise hinder the functioning of the internal market of the EU. The guidelines are to be adopted by the national lawmakers within prescribed time periods for the respective national legal system.

The manufacturer is required to attach the EU designation to products which fall under the authority of certain EU regulations as a sign of conformity with them. The products affected are those which are covered by the guidelines made in accordance with the "New Concept" (issued 07.05.1985) which contain requirements governing the technical quality of different products.

EU guidelines are binding legal directives of the European Union. That means that the fulfillment of these requirements is a **precondition for the marketing of the products in Europe. This does not affect the rest of the world trade market.** The attachment of the EU designation confirms product conformity with the corresponding fundamental requirements of all (applicable) guidelines affecting the product. As the documentation of conformity with directives, the EU designation is solely intended for monitoring government agencies. It is, however, often misinterpreted as a "Quality Seal". Because of this, it is unfortunately often demanded in cases where there is no legal requirement for it.

For this reason, our company dispenses with any advertising display of the EU symbol in our catalogue and prospectus pages, since the placement of the EU designation on products is done solely to satisfy a legal requirement which all manufacturers and importers are obligated to adhere to.

Although the EU declaration of conformity on the part of the manufacturer is kept on file only for the purposes of the monitoring agencies (for at least 10 years following the last bringing of the product into circulation), respective copies of it can be made available to customers upon request.

The determination of which guideline(s) is (are) to be applied can be deduced from the EU Declaration of Conformity for the respective product. The directives and their changed directives most commonly applied to our company's range of products are:

1. The Low Voltage Directive (72/23/EEC) for electrical equipment to be used with a rated voltage of between 50 Vac and 1000 Vac and between 75 Vdc and 1500 Vdc.

Title: Directive of the Council for the Establishment of Conformity among Legal Directives of the Member States with respect to Electrical Equipment for Use between Certain Voltage Limits 73/23/EEC of 19. 02. 1973

Almost all of the products in our manufacturing program fall under the area of application of the Low Voltage Directive. The conformity of each piece of electrical equipment, every device, every system and every installation with the safety requirements of the directive is to be certified by

2. The EMC directive (89/336/EEC) for devices which could cause electromagnetic interference or whose operation could be impaired by this kind of interference.

Title: Directive of the Council for the Establishment of Conformity among Legal Directives of the Member States with respect to Electromagnetic Compatibility 89/336/EEC of 03. 05. 1989

Legal basis:
For the purpose of establishing conformity among the legal directives of the member states, the Council of the European Community issued a binding directive for its members on 03. 05. 1989, which was in turn put into effect on 09. 11. 1992 by the Federal Republic of Germany in the form of a federal law governing electromagnetic compatibility (EMVG). The Bureau of Directive for Telekommunikation und Post (RegTP) and its external offices were charged with responsibility for the implementation (monitoring) of the EMC law.

Definition, in accordance with the following extract from Article 1:
Electromagnetic compatibility is the ability of an apparatus, equipment or a system to operate satisfactorily in the electromagnetic environment without itself causing electromagnetic interference while doing so which would be unacceptable to any of the devices, installations or systems present in this environment.

Area of application, in accordance with the following extract from Article 2:
This directive applies to all devices which could cause electromagnetic interference or whose operation could be impaired by such interference.

Note: "Devices" (in accordance with Article 1) consist of all electrical and electronic apparatuses, installations and systems which contain electrical and/or electronic modules.

Fundamental procedural methods:
Starting 01. 01. 1992 (with transition grace period until 31. 12. 1995), only those electrical and electronic devices, systems and installations may be brought into circulation or put into operation in the European Union which are in conformance with the established EMC safety requirements contained in the directive. The conformity of every device, every system and every installation with the safety requirements of the directive is to be certified by the manufacturer by means of an EU Declaration of Conformity and to mark the product with the EU Sign of Conformity.

Modules which are not required to carry the designation of conformity:
For the purposes of the EMC directive, a module is defined as any element which is used for installation in a device but which possesses no function of its own and which is not intended for use by an ultimate consumer. In accordance with Article 1 of the EMC directive, modules are therefore not devices and from the onset do not fall under the jurisdiction of this directive.

Examples:

a) **Modules (for circuit boards, devices, control cabinets)**, which as built-in components are not required to bear the EU designation sign, such as resistors, capacitors, inductance, integrated switching circuits.

b)**Modules** which are required to bear the EU designation sign **(with housing and with protection against accidental contact)**, which are to be operated autonomously and/or are to ultimate consumers, such as plug-ready power supply units, battery charging sets, personal computers, testing and measuring apparatus, isolating transformers for construction sites or service, transformers for halogen lights.

Electromagnetic compatibility

Definition

According to the definition contained in the EMC Regulation 89/336/EEC, electromagnetic compatibility is the capability of a device to be able to work satisfactorily in the electromagnetic environment without itself causing electromagnetic interference while doing so which would be unacceptable to any of the devices, installations or systems present in this environment.

A distinction is made between

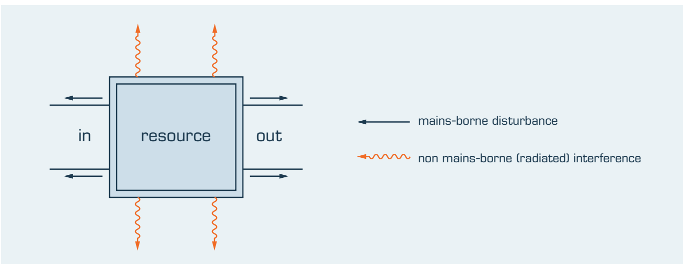
1. Electromagnetic interference (EMS)
2. Electromagnetic immunity (EMI)

Electromagnetic interference (EMS)

Electromagnetic interference (emitted interference) is every kind of electromagnetic event (e.g. noise, unwanted signal), which could impair the functioning of a device, an installation or a system.
The basic specification for emitted interference is

- EN 61000-6-3 (Residential, business, trade areas and small-scale enterprises)
- EN 61000-6-4 (Industrial area)

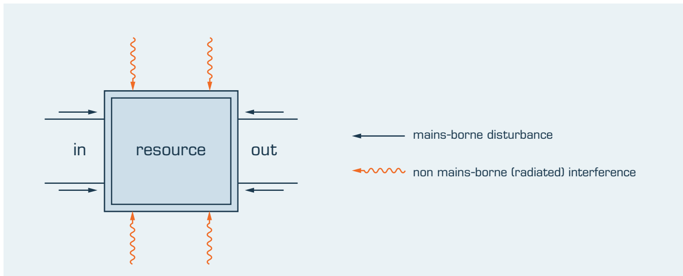
A large number of basic standards (IEC 61000, CISPR) and product standards are also to be taken into consideration as required.



Electromagnetic immunity (EMI)

Test standards are:

- EN 61000-4-2:1995 +A1:1998 +A2:2001
  Electrostatic discharge immunity test
- EN 61000-4-3:2006 +A1:2008
  Radiated, radio-frequency, electromagnetic field immunity test
- EN 61000-4-4:2004
  Electrical fast transient/burst immunity test
- EN 61000-4-5:2006
  Surge immunity test
- EN 61000-4-6:2007
  Immunity to conducted disturbances, induced by radio-frequency fields
- EN 61000-4-8:1993 + A1:2001
  Power frequency magnetic field immunity test
- EN 61000-4-11:2004
  Voltage dips, short interruptions and voltage variations immunity tests

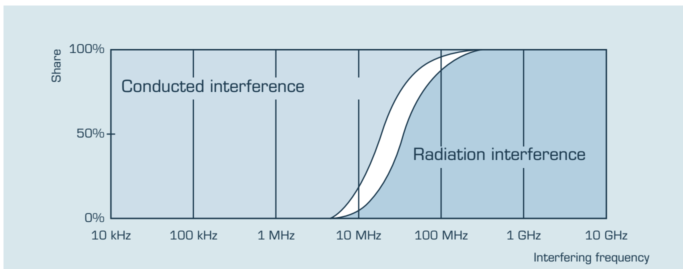


Shielding from interference

There are many opportunities for interference to be transmitted:

- by means of metallic contact as electrical current and voltage, carried by power mains
- as a magnetic field
- as an electrical field
- as an electromagnetic wave or radiation

Propagation of mains borne and radiated interference generally behaves as follows:

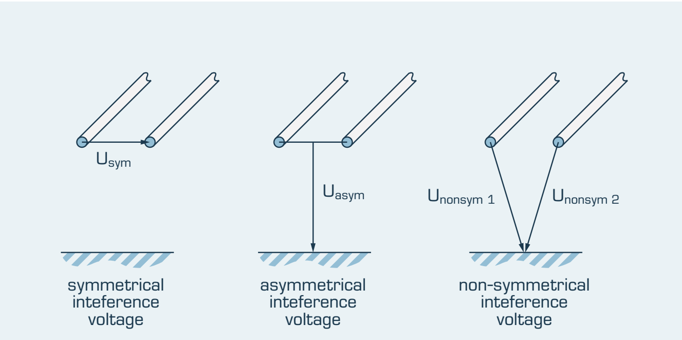


The attenuation of interference is achieved by construction which takes EMC into consideration, involving such things as low-impedance earthing, filters, shielded lines, metallic housing and spatial clearance. The EMC measures to be carried out, however, are highly dependent on the components utilised and on the operating parameters of the system, which means that it is almost impossible to make universally valid statements.

Mains borne interference

Interference voltage often occurs on electrical lines, between conductors and between conductors and the earth, in intensities which can range up to a frequency of circa 30 MHz. A distinction is made between symmetrical, asymmetrical and non-symmetrical interference voltage.

Reactors, capacitors and filters are particularly suitable for the attenuation of mains borne interference, as are – indirectly – shielded cables. As a rule, additional protection measures (radio links, varistors) are necessary against energy-rich interference, e.g. caused by lightning bolts.



EMC Standards

The fundamental principles for EMC standardisation are generally compiled by

- CISPR, founded in 1934 (International Special Committee on Radio Interference, Comité international Spécial des Perturbations Radioélectriques)

and

- IEC TC77, founded in 1974 (International Electrotechnical Commission Technical Committee 77, Comité d'études 77 de la Commission Electrotechnique Internationale)

in coordination with the IEC Regulation Guide 107 (EMC-Guide to the drafting of electromagnetic compatibility publications).

The purpose of Guide 107 is to ensure that identical procedures and points of view are applied during the course of EMC standardisation and to keep everything as conclusive as possible. Observations are carried out on line-borne and radiated phenomena occurring in the frequency range between 0 Hz and 400 GHz, in which electromagnetic compatibility is to be achievable.

Generally speaking, four categories of EMC standards are defined, whereby each EMC standard is, as a whole, assigned to only one of the four categories.

1. Basic publications (Basic Standards) e.g.

- IEC 61000-2, -3, -4, -5 etc.
- CISPR 11, 13, 14, 15, 16, 22

The Basic Standards can have the status of a standard or even that of a technical report. They contain the respective measuring procedures, classification of environmental conditions and testing techniques for EMC, but no measurement limiting values for individual products or product families. Constant reference is made to the Basic Standards in the basic specifications, product family standards and product standards. It should be clear from the title alone that it is a Basic Standard (Basic Norm) which is being dealt with.

2. Basic specifications (Generic Standards)

- Residential and small-scale business enterprises field:
  EN 61000-6-3 (Emitted Interference), EN 61000-6-1 (Interference Immunity)
- Industrial field:
  EN 61000-6-4 (Emitted Interference), EN 61000-6-2 (Interference Immunity)

The basic specifications are to be applied to products for which neither product family standards nor product standards exist. There is always a distinction made between the environmental conditions of industry (supplied by industrial networks) and those of residential, business and trade areas and small-scale enterprises (supplied by public electricity networks). While limited number of EMC tests specify minimum interference limit values and maximum interference emission limit values, they do not address certain product characteristics.

3. Product Family Standards, e.g.

- EN 55011 (Emitted Interference), Industrial, Scientific, Medicinal (ISM) Devices
- EN 55013 (Emitted Interference), EN 55020 (Interference Immunity), Audio, TV, Radio devices
- EN 55014 (Emitted Interference), EN 55104 (Interference Immunity), Household Appliances

The product family standards are tailored to specific product families and contain particular specifications (e.g. limit values, test design, operational criteria and criteria for complaints). Concerning measuring procedures, Basic Standards are referred to and limit values are coordinated with the basic specifications. Product family standards for EMC can exist as independent standards, but also as (autonomous) parts of standards which govern the other aspects (e.g. electrical safety) for the product family.

4. Product standards (Dedicated Product Standards), e.g.

- EN 61800-3, Frequency Converters
- EN 50199, Electric Arc Welding Devices

The product family standards are intended for special products, they enjoy the highest application priority and are therefore the only ones to be applied for ensuring the EMC of the product. In terms of the inclusion of Basic Standards and basic specifications, the rules which apply to the product family standards are the same as those for the product standards.

Classifications

Protection class

The protection class 0, I, II or III (Ref.: VDE 0140/EN 61140/IEC 61140) is a **construction feature** for the classification of electrical equipment for the purpose of security against dangerous fault or leakage currents (electrical shock), e.g.:

- Protection class 0:
  Device with basic insulation as a precaution for basic protection, but without provision for fault protection
- Protection class I:
  Device with protective conductor connection and (at least) basic insulation
- Protection class II:
  Device without protective conductor connection and double or enhanced insulation
- Protection class III:
  Device supplied with SELV (Safety Extra-Low Voltage) and in which no voltages higher than the SELV are generated.

Electrical equipment intended for installation in devices have no safety class and can only be "prepared for" one of these. Electrical equipment which has been prepared for utilisation in protection class II devices can also be utilised in protection class I devices.

Type of protection

Specification of the type of protection (Ref.: DIN VDE 0470, EN 60 529, IEC 60529) describes the protection of electrical equipment by means of housing, covers, enclosures and similar.

The type of protection is specified by letter symbols (IP Code), whereby the first code number (0 to 6) offers information concerning protection against contact and against the penetration of foreign objects. The second code number (0 to 8) provides information about protection against the water penetration.

Common types of protection in use:

- IP 00
  No special protection against accidental contact or against the penetration of foreign objects. No special protection against water. **Constructions of the "open design type" are manufactured for the IP 00 type of protection.**
- IP 20
  Protection against contact and against the penetration of solid foreign objects larger than ø 12 mm. No special protection against water.
- IP 23
  Protection against contact and against the penetration of solid foreign objects larger than ø 12 mm. Protection against water spray falling at any angle of up to 60° to the vertical, so that such jets will have no damaging effects.
- IP 40
  Protection against contact and against the penetration of solid foreign objects larger than ø 1 mm. No special protection against water.
- IP 44
  Protection against contact and against the penetration of solid foreign objects larger than ø 1 mm. Protection against water spray so that no spray hitting the equipment from any direction will have any damaging effect.
- IP 54
  Complete protection against contact. Protection against damaging dust deposits. While dust penetration is not completely prevented, the dust which does enter may not amount to quantities which will impair working procedures. Protection against water spray, so that no spray hitting the equipment from any direction will have any damaging effect.
- IP 65
  Complete protection against contact. Protection against dust penetration. Protection against water spray. Protection against water jets from spray nozzles directed at the equipment from all directions to the extent that no spray will have any damaging effect.
- IP 67
  Complete protection against contact. Protection against the dust penetration. Protection against the effects of temporary immersion in water. Water shall not be permitted to penetrate in a quantity which will would cause damaging effects when the housing is temporarily immersed in water under standardised pressure and time conditions.
- IP 68
  Complete protection against contact. Protection against the dust penetration. Protection against the effects of immersion in water for an indefinite time. Water shall not be permitted to penetrate in a quantity which will would cause damaging effects when the housing is immersed in water under standardised pressure conditions.

Note: The specification of the type of protection refers to the condition at the time of delivery and to the established or usual method of setting up the equipment. The type of protection can change as the result of a different setup or installation method.

Insulation material class

The regulations (Ref.: VDE 0301/ HD 566S1/IEC 60085) in addition to (Ref.: VDE 0304/HD 611.1S1/IEC 60216) describe among other things the thermal resistance of electrical insulation materials. The different insulation material classes are assigned temperatures in reference to their periods of thermal resistance.

Common Insulation material classes:
A (105 °C), E (120 °C), B (130 °C), F (155 °C), H (180 °C)

Unless other arrangements have been made, transformers and power reactors are designed in accordance with the specifications of the insulation material classes E or B.

Insulation system (EIS)

An electrical insulation system (EIS) is an insulating arrangement made up of one or more insulation materials (electrical insulation materials) which is installed together with the associated conduction parts in one piece of electrical equipment (Ref: VDE 0302 Teil 1/ EN 60505/ IEC 60505 sowie VDE 0302 Teil 11/ EN 61857-1/ IEC 61857-1). A judgement is made under thermal stresses of whether or not the combination of insulation materials is suitable for operation in the respective insulation material class.

Ambient air temperature for measurement

The ambient air temperature for measurement is the highest ambient air temperature at which a piece of electrical equipment or an electrical device or an installation component (e.g. transformer, reactor, filter) can be operated continuously under normal operating conditions. It is the air temperature of the immediate surroundings. Electrical values often refer to the ambient air temperature for measurement and they can change with different temperatures! Special attention is to be paid to the installation of components in housings with a higher type of protection. Possible deficient cooling can lead to non-authorised high temperatures in the housing. A reduction of the expected service life of the component is possible in this case (see “Insulation material class”).

The ambient air temperature for measurement is specified using a shortened notation form (Ref.: VDE* 0570, EN 61558, IEC 61558).

Example:
ta=25 °C or ta=40 °C

Unless other arrangements have been made, the rated ambient temperature used for the design of components intended for installation is set at 40 °C and at 25 °C for (table) devices which are to be operated independently.

*Association of german electrical engineersBemessungsumgebungstemperatur ausgelegt.

Test class

The test class indicates climate category (Ref.: DIN EN 60068/EN 60068/ IEC 60068) as the key to the designation of the climatic usability of component parts.

Example:

25/085/21
25 = –25 °C, Test A: coldness, 085 = + 85 °C, Test B: dry heat,
21 = 21 days, Test Ca: moist heat constant

The individual tests are defined in different parts of the standard.

Characters and symbols

VDE 0570 Part 2–6/EN 61558-2-6/IEC 61558-2-6
Safety transformer, short circuit-proof,
double or increased insulation between PRI and SEC, PRI max. 1000 V, SEC max. 50 V AC voltage (effective value) and/or 120 V smoothed DC voltage, frequency max. 500 Hz

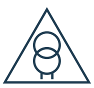
VDE 0570 Part 2–6/EN 61558-2-6/IEC 61558-2-6
Safety transformer, not short circuit-proof,
double or increased insulation between PRI and SEC, PRI max. 1000 V, SEC max. 50 V AC voltage (effective value) and/or 120 V smoothed DC voltage, frequency max. 500 Hz

VDE 0570 Part 2–4/EN 61558-2-4/IEC 61558-2-4
Isolating transformer, short circuit-proof,
double or increased insulation between PRI and SEC, PRI max. 1000 V, SEC max. 500 V AC voltage or 708 V smoothed DC voltage, frequency max. 500 Hz.

VDE 0570 Part 2–4/EN 61558-2-4/IEC 61558-2-4
Isolating transformer, not short circuit-proof,
double or increased insulation between PRI and SEC, PRI max. 1000 V, SEC max. 500 V AC voltage or 708 V smoothed DC voltage, frequency max. 500 Hz.

VDE 0570 Part 2–15/EN 61558-2-15/IEC 61558-2-15
Isolating transformer for supplying medical areas, not short circuit-proof, double or increased insulation between PRI and SEC; windings installed one above the other; windings-core; windings-shield; shield-core; PRI max. 1000 V, SEC max. 250 V, frequency max. 500 Hz

VDE 0570 Part 2–12/EN 61558-2-12/IEC 61558-2-12
Magnetic voltage stabiliser acting as isolating transformer, short circuit-proof, double or increased insulation between PRI and SEC, PRI max. 1000 V, SEC max. 500 V, frequency max. 500 Hz (30 kHz internally)



VDE 0570 Part 2–2/EN 61558-2-2/IEC 61558-2-2
Control transformer, not short circuit-proof, basic insulation between PRI and SEC, PRI max. 1000 V, SEC max. 1000 V AC voltage or 1415 V smoothed DC voltage, frequency max. 500 Hz

VDE 0570 Part 2–1/EN 61558-2-1/IEC 61558-2-1
Mains transformer, not short circuit-proof, basic insulation between PRI and SEC, PRI max. 1000 V, SEC max. 1000 V AC voltage or 1415 V smoothed DC voltage, frequency max. 500 Hz

VDE 0570 Part 2–13/EN 61558-2-13/IEC 61558-2-13
Autotransformer, not short circuit-proof, no insulation between PRI and SEC, PRI max. 1100 V, SEC max. 1000 V AC voltage or 1415 V smoothed DC voltage, frequency max. 500 Hz

VDE 0570 Part 2–20/EN 61558-2-20/IEC 61558-2-20
Small reactor, not overload-free, max. 1000 V, frequency max. 1 MHz

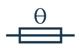
6,3 AT

Specification for the fuse assigned in the case of transformers that are not short circuit-proof; here, 6.3 A time-lag

20 A

Thermal overcurrent release; here, 20 A miniature circuit breaker

Temperature fuse

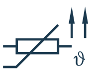


Temperature fuse

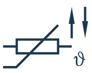
Self-resetting thermal relay
, e.g. thermal time delay switch

Non-self-resetting thermal relay Reset by switching off the mains connection, e.g. thermal time delay switch with locking function, PTC

Non-self-resetting thermal relay Manual reset (e.g. thermal overcurrent release, miniature circuit breaker)



PTC thermistor



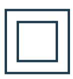
NTC thermistor

ta 40 °C
ta 40

Rated ambient temperature; here, 40°C

CL.B
CL.130
class 130

Class of insulation; here, B



Safety class II, total insulation

Protective conductor, earth

Connection for mount or core

Suitable for use with fitments whose flammability properties are not known, e.g. wood, furniture, intermediate ceilings. Sign in acc. with VDE 0710 Part 14.

Sign for domestic use, only for dry rooms, general

Voltage warning, general

Heat source warning: hot surface, general

~ **AC current**, also spelled A. C. or ac (alternating current)

⎓ **DC current**, also spelled D. C. or dc (direct current)

cetification marks

CE mark, legal mark of conformity in Europe (stands for Conformité Européenne)

ENEC mark of conformity, Europe; in Germany: certification by VDE (10), European Norms Electrical Certification

VDE mark of conformity, Germany, VDE Testing and Certification Institute

UL mark of conformity (recognized component), USA and Canada; in Germany: certification by UL, Underwriters Laboratories Inc.

transformer only

UL mark of conformity (recognized component), USA and Canada; in Germany: certification by UL, Underwriters Laboratories Inc., only relates to the integrated transformerr.

UL mark of conformity (recognized component), USA, Underwriters Laboratories Inc.

UL mark of conformity, (Listed) USA, Underwriters Laboratories Inc

CSA mark of conformity, Canada, Canadian Standards Association

GL mark of conformity, certification by Germanischer Lloyd

AS-Interface mark of conformity, certification by AS-International Association

Special signs by BLOCK

XtraDenseFill: XtraDenseFill from BLOCK, a casting technique that ensures cavity-free filling of the transformer's entire internal structure thanks to high vacuum and pressure phases. It significantly reduces creepage distances and clearances and enables the electrical equipment to enjoy long-term protection against the effects of its environment. A more compact design can also be used.

BLOCK ImpEx: Ensures the winding material is covered evenly, thus providing extensive protection against external influences. The resin developed specifically for BLOCKImpEx, together with our in-house-developed impregnation process, seals as many cavities as possible and creates a temperature reserve to ensure efficiency during long periods of operation.

The BLOCK logo: a sign of quality

The old BLOCK logo: our original logo