The basics of Overvoltage Protection

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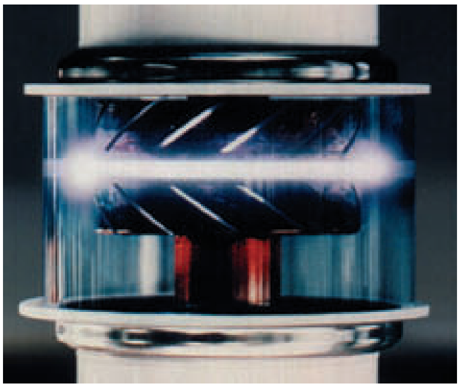
Is Overvoltage Protection worthwhile?

You can rely on luck or take precautions.

The priority you give to overvoltage protection depends on your willingness to take risks! Perhaps you think "it'll never happen to me". Then you won't have lost anything, but will have gained only very little. However, the subject of overvoltage is then a daily worry for you.
But if you wish to be on the safe side, you should include overvoltage protection in your corporate strategy. Such an investment brings you operational reliability and can prove invaluable when disaster strikes.

Disaster comes from the sky

The violent forces of nature in the form of a thunderstorm are a spectacular show. Potentially, this is a dangerous event for human beings and no less dangerous for industrial and commercial premises and equipment.
While a person is mainly exposed to the risk of a lightning strike in his or her immediate vicinity, this is not the case for electrical equipment. Lightning strikes up to 2 km away can damage electrical components.
Apart from this, electrical systems are considerably more sensitive to the indirect effects of the energy of a bolt of lightning. Lightning strikes generate secondary voltages in anything that conducts and therefore endanger the insulation of electrical equipment.
The number of lightning strikes per annum in europe alone are considerable. Lightning strikes are registered worldwide. You can get the latest figures by visiting the Internet address www.wetteronline.de/eurobli.htm.



Electric arc in a 10 kV switch while being switched off

But disaster also comes from inside

And to a much greater extent than from the sky. Wherever electricity is used, it must also be switched on and off. And the physical processes of a switching operation can also cause overvoltages.
These overvoltages are nowhere near as high as those of lightning. But as they are generated directly in the lines, they are also directly in the system and place a stress on the insulation. Although switching operations are not as spectacular as lightning strikes, they do take place more frequently. Added to this are overvoltages caused by electrostatic discharges or faulty switching operations.

Protection would seem to be a matter of common-sense

Our modern working lives would be inconceivable without power supply systems, instrumentation and control equipment, IT networks and much more besides. They have become matter-of-fact and we realise their significance only when they break down. The potential scenarios range from a brief interruption in the work to bankruptcy. Good protection can prevent that.

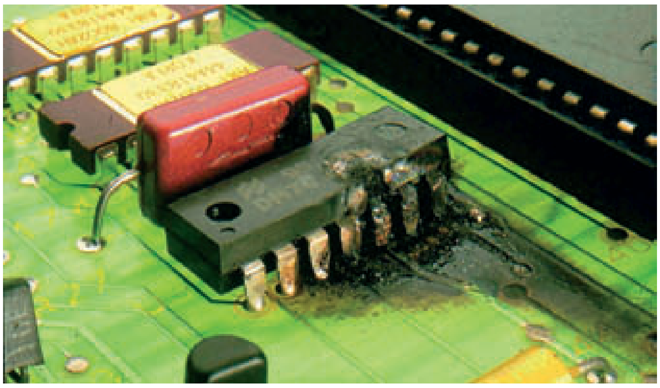
Overvoltage Protection is a topic for today

Overvoltage Protection is an important aspect of electromagnetic compatibility and is required by law. There have been many technical improvements in the field of overvoltage protection over the years. The quality and quantity of overvoltage protection systems have increased. This is also revealed by the statistics of the umbrella organisation for the German insurance industry: the annual total damages for the insurance of electronic equipment has fallen slightly despite the fact that more electronic equipment is almost certainly being used and electrical and electronic systems are becoming increasingly complex with the degree of integration ever higher.
Nevertheless, each year in Germany about 450,000 claims are registered across the whole electronic spectrum.
The total loss in Germany for 2005 amounted to €230m. It is estimated that about one-third of these are due to overvoltages.

Voltages that exceed the limits

Overvoltages are voltages that exceed the normal values. These normal values determine the insulation, which is designed and tested according to the appropriate regulations. The degree of insulation varies depending on the type of electrical equipment. We therefore speak of ”insulation coordination”.

An item for use with 230 V, e.g. an electric motor, is fitted with insulation tested with a few kilovolts. It is obvious that a chip on a PCB operating with 5 V cannot have the same dielectric strength. For this chip 10 V could mean disaster.



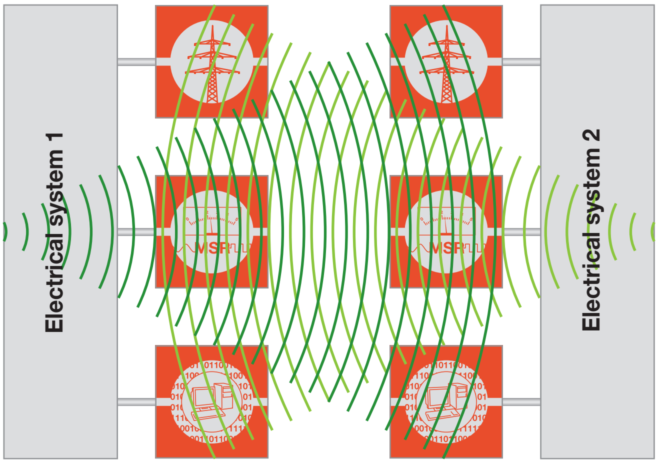
Component destroyed

Overvoltage Protection calls for special knowledge

Overvoltage Protection must differentiate in order to take into account insulation coordination. It must be able to deal with high voltages at high currents just as safely as low voltages at low currents. These could be completely normal in other parts of the system.
Therefore, overvoltage protection is a complex subject.
It comprises of not just one electrical component but rather several functional elements combined in one circuit. This calls for special engineering expertise – not just for the provision of functional overvoltage protection modules, but also for their utilisation, planning and installation.
Therefore, this catalogue does not just present our products but instead provides comprehensive information to help you understand the subject of overvoltage protection.

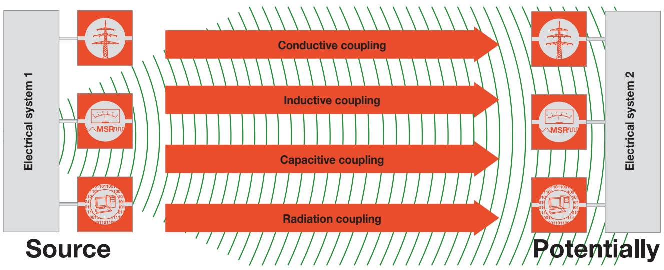
Electromagnetic compatibility

EMC – electromagnetic compatibility – means the trouble-free interaction between electrical and electronic systems and devices without mutual interference. In this respect, any electrical item can act both as transmitter (source of interference) and receiver (potentially susceptible device) simultaneously.



EMC laws and directives

There are a multitude of standards and statutory requirements aimed at controlling mutual interference-free operation. As the Single European Market was set up in 1989, an EEC directive covering electromagnetic compatibility was passed and subsequently ratified by the governments of the member states. In Germany this is covered by the Electromagnetic Compatibility Act, passed on 9 November 1992. There was a period of transition in which the 1992 Act, the Radio Interference Act of 1979 and the High-Frequency Equipment Act of 1949 were all valid. However, since 1 January 1996 only the 1992 Act has been valid. The second amendment to the Act has been in force since 25 September 1998. Electromagnetic influences can be caused by natural processes, e.g. a lightning strike, and also technical processes, e.g. high-speed changes in the status of currents and voltages.



We distinguish between periodic interference (system hum, RF irradiation), transient interference (brief, often high-energy pulses) and noise (broad distribution of interference energy across the frequency range).
The model used in EMC observations designates the transmitter as the **source of interference** emission and the receiver as the **interference drain**. The transmission of the interference takes place via line-bound and/or field-bound (H-field/E-field) coupling mechanisms.
When considered as a source of interference, a device or a system may not exceed emissions thresholds specified in the EMC standards.
When considered as a potentially susceptible device, the same system must exhibit the immunity to interference specified in the standards.
However, the arrangement of various electrical systems within a complex plant or in a room and the many lines for power supplies, inputs and outputs to controls and bus systems give rise to diverse potential influences. Overvoltages can be introduced by lightning, switching operations, etc. via the various coupling paths. This can lead to the following effects:

- reduced functionality
- malfunctions
- failure of functions
- damage

The latter two in this list may lead to shutdown of production plants and high costs.
The following points must be taken into account in order to achieve a system or plant that operates according to EMC guidelines:

- lightning protection
- earthing
- routing of cables
- cable shielding
- panel construction
- sensors and actuators
- transmitters and receivers
- frequency converters
- bus and field devices
- ESD

What are overvoltages?

Overvoltage Protection (OVP) installations

Constructing an electrical or electronic system in accordance with EMC guidelines using suitable components is generally not sufficient to guarantee operation free from interference. Only by employing **overvoltage protection systems** at the appropriate points in a plant is it possible to achieve operation without breakdowns caused by coupled overvoltages. The procedure for the use of overvoltage protection systems is also linked to the model of influences between interference source and potentially susceptible device and be integrated in a comprehensive protective system in conjunction with a lightning protection zoning concept and insulation coordination.

What are overvoltages?

Overvoltages are extremely high voltages that damage or even completely destroy insulation and hence impair or completely disrupt the function of electrical and electronic components of all kinds.

Every electrical component is provided with insulation to isolate the electrical voltage from earth or other voltage-carrying parts. The dielectric strength is specified in IEC/VDE standards depending on the rated voltage and the type of electrical component. It is tested by applying the prescribed voltages for a defined period of time.

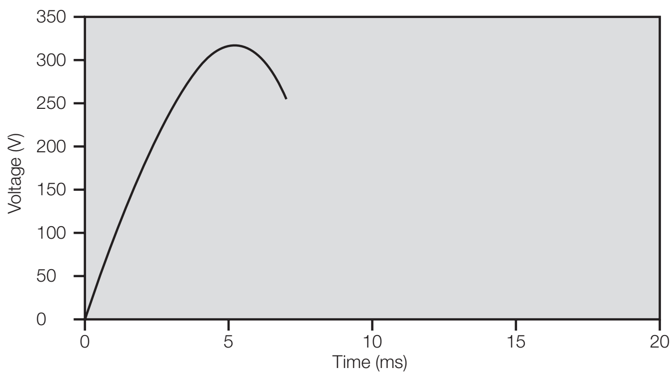
If the test voltage is exceeded in operation, the safety effect of the insulation is no longer guaranteed. The component can be damaged or completely ruined. Overvoltages are the voltage pulses that are higher than the test voltage and therefore could have a detrimental effect on the respective electrical component or system. This means that one and the same overvoltage can be acceptable to components with a high rated voltage but on the other hand extremely dangerous
for components with a lower rated voltage. An overvoltage allowable in an electric motor can spell disaster for an electronic circuit!

Permanently higher voltages also occur with the 50/60 Hz mains frequency. These voltages can be coupled or may occur as a result of faulty switching operations. The resulting continuous interference voltages are then another case for overvoltage protection.

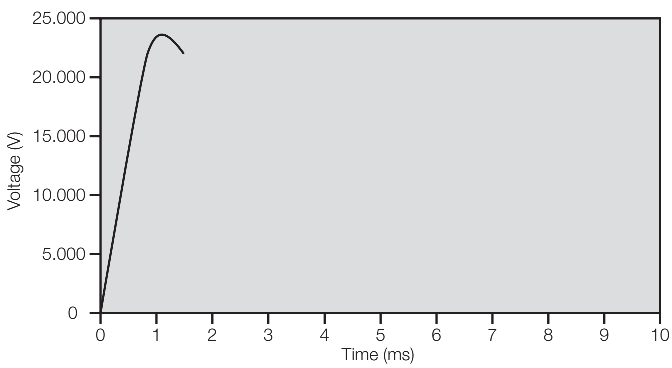
Single overvoltage pulses, which are of a high frequency owing to the nature of their generation, exhibit a current rise which is approx. 10,000 times faster than in the case of a 50 Hz voltage. If the current rise time in the 50/60 Hz range is 5 ms, then for an overvoltage it is around 1 µs.

Overvoltages are designated as ”transient” voltages. This means that they are short-lived, temporary oscillations. Their shape and frequency depends on the impedance of the circuit.

Leading edge of mains voltage



Leading edge of overvoltage pulse



How do overvoltages occur?

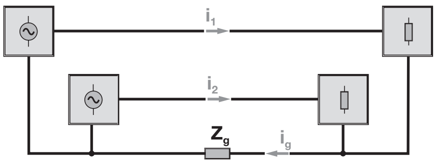
Overvoltages are primarily caused by:

- transient switching operations
- lightning due to atmospheric discharges
- electrostatic discharges
- faulty switching operations

Lightning

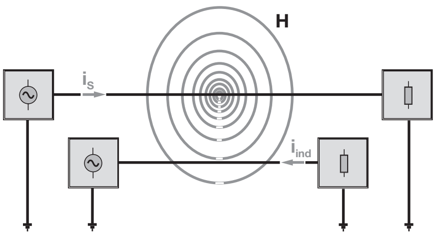
Bolts of lightning exhibit extremely high currents. Therefore, they cause a large voltage drop and, accordingly, a large rise in potential even in well-earthed buildings or systems despite low earthing resistances. This can be coupled in the circuits of electrical or electronic systems by means of conductive, inductive or capacitive processes.

Conductive coupling



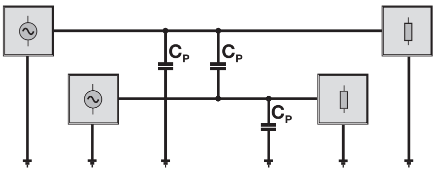
Overvoltages are transferred directly into circuits via common earthing impedances. The magnitude of the overvoltage depends on the amperage of the lightning and the earthing conditions. The frequency and the wave behaviour are mainly determined by the inductance and the speed of the current rise. Even distant lightning strikes can lead to overvoltages in the form of travelling waves, which affect different parts of electrical systems by way of conductive coupling.

Inductive coupling



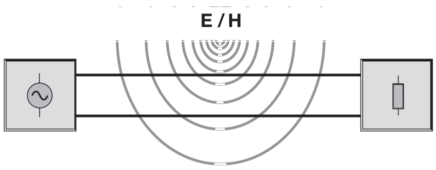
A high-amperage lightning strike generates a strong magnetic field. Starting from here, overvoltages reach nearby circuits by means of an induction effect (e.g. directly earthed conductor, power supply lines, data lines, etc.). According to the transformer principle, the coupling of induced voltages is considerable owing to the high-frequency current di/dt – even when primary and secondary windings consist of only a single winding each, i.e. the inductance is low.

Capacitive coupling



A capacitive coupling of overvoltages is also possible. The high voltage of the lightning generates an electric field with a high field strength. The transport of electrons can cause a capacitive decay to circuits with lower potentials and raise the potential concerned to an overvoltage level.

Radiation coupling



Electromagnetic wave fields (E/H field), that also ensue during lightning (distant field condition, E/H field vectors perpendicular to each other), affect conductor structures in such a way that coupled overvoltages must be expected even without direct lightning strikes. Permanent wave fields from strong transmitters are also able to cause coupled interference voltages in lines and circuits.

Switching operations – transients

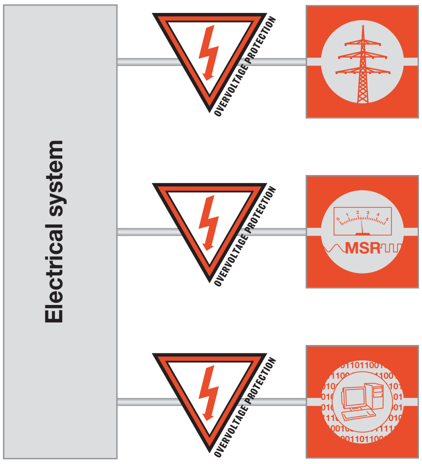
More often, it is switching operations that cause interference rather than lightning. High-amperage shutdowns in the mains in particular can generate considerable overvoltages. Switching operations generate overvoltages because, due to their construction, switching contacts that switch the current on or off do not operate in synchronisation with the current zero of an alternating current. This means that in the majority of cases there is a very rapid change of current, from a high value to zero (di/dt). Owing to the impedances in the circuit concerned, this leads to transient overvoltages with high-frequency oscillations and high voltage peaks. These can reach electrical components by conductive, inductive or capacitive means and endanger or damage them. The situation is similar in the case of short-circuits in the mains because these also represent a rapid switching operation.

Electrostatic discharges – ESD

Electrostatic discharges (ESD) caused by frictional charges are well known. We experience these, for example, when getting out of our cars or walking across a carpet. These charges amount to several tens of thousands of volts. We speak of ESD when these discharge to a lower potential. If such a charge strikes, for example, electronic components, then these can be completely ruined.

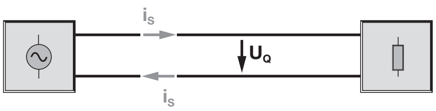
Faulty switching operations

Again and again, we experience faulty switching operations in the 50/60 Hz mains. This can be caused by a failed power supply unit controller or incorrect wiring in a panel. The relatively high voltages that can occur as a result also represent dangerous overvoltages. Protection against these is vital.

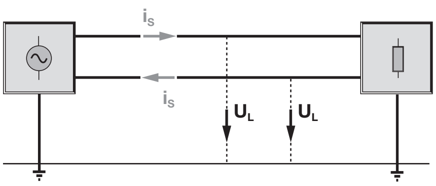


Description of interference voltages

Overvoltages that occur between current-carrying conductors or between a current-carrying conductor and the neutral conductor are designated as transverse voltages or symmetrical interference.



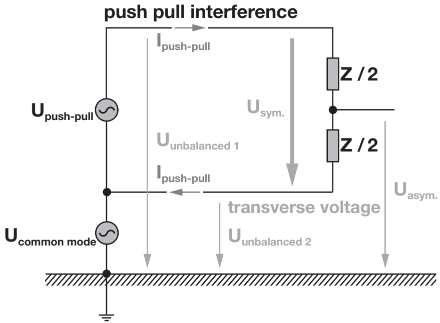
Overvoltages that occur between a current-carrying conductor and the protective earth conductor are designated as longitudinal voltages or asymmetrical interference.



The forms of interference voltage

Basically, coupled transient overvoltages are either normal-mode or common-mode interference measured as a longitudinal or transverse voltage. The interference voltages occur as symmetrical, unsymmetrical or asymmetrical voltages depending on the particular systems involved.

Normal-mode interference (symmetrical interference)



A voltage between supply and return conductor, differential mode voltage/current. Occurs mainly at low interference frequencies in the existing lines. The interference current IS causes an interference voltage UQ directly at the potentially susceptible device (between the input terminals). Series connection of load and interference source, e.g. in the case of inductive (magnetic field) or conductive coupling (common impedance).
In symmetrical circuits (non-earthed or virtual potential earthed), the normal-mode interference occurs as symmetrical voltages.
In unsymmetrical circuits (earthed one side), the normal-mode interference occurs as unsymmetrical voltages.

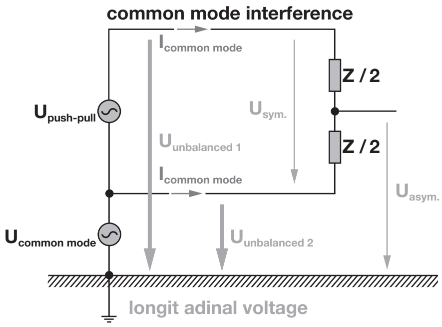
Transverse voltage U_Q (normal-mode voltage)

Coupled transient interference voltage between two active conductors. In the case of unsymmetrical circuits with earth potential, the transverse voltage is equal to the longitudinal voltage.

How do overvoltages occur?

It is limited by twisting groups of associated wires together and providing one or more layers of shielding by way of cable sheathing. This reduces the induction of transverse voltages.

Common-mode interference (unsymmetrical interference)



Voltage between conductor and reference potential (earth), common-mode voltage/current. Mainly caused by a capacitive coupling (electrical field).
Therefore, significant common-mode interference currents only flow at higher interference frequencies. The interference voltage at the potentially susceptible device is caused by different voltage drops at the supply and return conductors (in each case between input terminal and reference earth). Source of interference between signal wire and reference conductor, e.g. due to a capacitive coupling or an increase in reference potential between separate earths.
In symmetrical circuits, common-mode interference occurs as asymmetrical voltages between the d.c. offset of the circuit and the reference earth. Supply and return conductors have the same offset with respect to the reference earth.
In unsymmetrical circuits, common-mode interference occurs as unsymmetrical voltages between the individual conductors and the reference earth.

Longitudinal voltage U_L (common-mode voltage)

Coupled transient interference voltage between an active conductor and the earth potential. As a rule, the longitudinal voltage is higher than the transverse voltage (transverse voltage is lower owing to cable shielding and twisting).
Longitudinal voltages caused by lightning currents on cable shielding can assume quite high values, especially in the case of long lines entering a building from the outside.

Symmetrical, unsymmetrical and asymmetrical interference voltages

The symmetrical interference voltage is measured between the supply and return conductors of a circuit.
$U_{sym.} = U_{unsym.1} - U_{unsym.2}$
The unsymmetrical interference voltage is measured between one conductor and the reference potential (earth) of a circuit.
$U_{unsym.1} = U_{sym.} + U_{unsym.2}$
$U_{unsym.2} = U_{unsym.1} - U_{sym.}$
The asymmetrical interference voltage is measured between the d.c. offset and the reference potential (earth) of a circuit.
$U_{asym.} = (U_{unsym.1} + U_{unsym.2}) / 2$

The effects in ideal and non-ideal circuits

Normal-mode interference in symmetrical circuit

1. Series connection between voltage source and consumer. Circuit designed without reference potential or virtual potential has connection to reference potential. Interference voltage is added to signal because signal currents are, as a rule, normal-mode currents.
2. Symmetrical signal transmissions, e.g. as with a microphone, use two wires with shielding. Virtual potential has connection to reference potential. Symmetrical interference voltage is added to signal and asymmetrical interference voltage occurs between virtual potential and reference potential.

Normal-mode interference in unsymmetrical circuit

Series connection between voltage source and consumer. Circuit designed with connection to reference potential, e.g. co-axial cable. Interference voltage occurs as unsymmetrical voltage between wire of one line and reference potential.

Common-mode interference in symmetrical circuit

Does not cause any interference voltage in ideal (completely symmetrical) circuits.

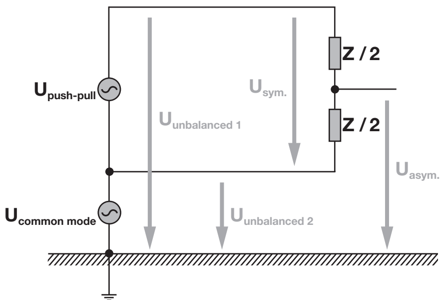
Common-mode interference in unsymmetrical circuit

Does not cause any interference voltage in ideal (completely symmetrical) circuits.

Common-mode interference at higher frequencies

As the frequency increases, so the impedances differ more and have a stronger effect. The common-mode voltage drives common-mode currents through the different impedances of the supply and return conductors and to earth via stray capacitances and back to the source of interference.

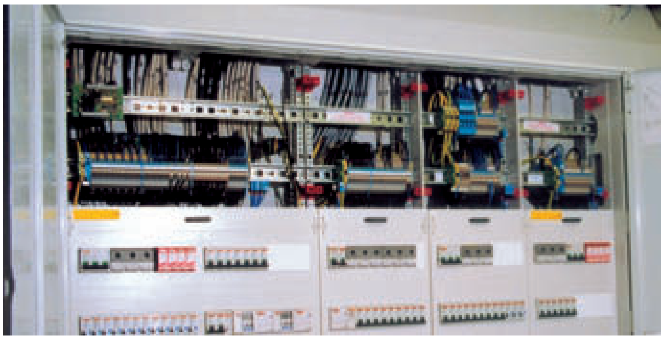
Consequences

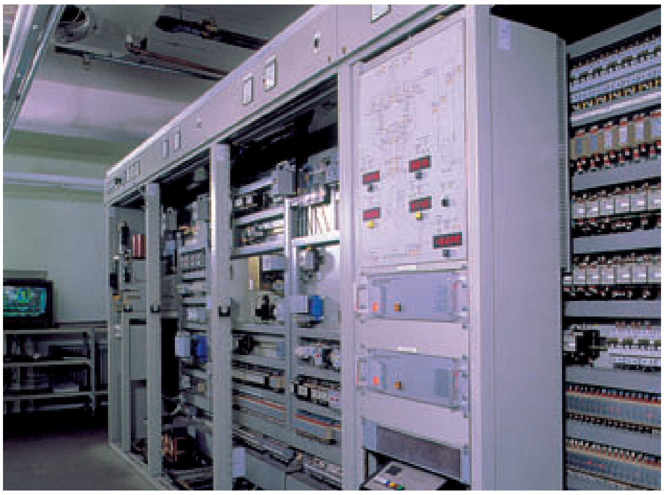


The impedances and stray capacitances are equal in ideal circuits. This means that the currents in the supply and return conductors generated by coupled overvoltages are also equal and so do not generate any interference voltage.
However, in practice the impedances and stray capacitances in the supply and return conductors are different. This results in unequal currents which cause different voltages to earth in the supply and return conductors.

So the unequal impedances lead to the common-mode voltage becoming, for the most part, a normal-mode voltage because of the dissimilarity in the voltages to earth of the supply and return conductors.

Prevention is better than cure





Cause of overvoltage	Protective measures specified in:			Installation of protective devices specified in:
	DIN V ENV 61024-1	DIN VDE 0185-103	E DIN VDE 0100 Teil 443	DIN V VDE V 0100-534: 1999-04
Direct lightning strike	X	X		X
Remote lightning strike		X	X	X
Lightning fields		X		X
Switching operations			X	X

That is also true for the "health" of electrical and electronic components and systems.
Taking economic considerations into account also means investing in overvoltage protection. This investment is only a fraction of the cost of the damage that can occur. Having to shut down a production plant because a control system has failed or the collapse of industrial data transmissions can be expensive experiences. It is not just the disruption or repairs that are expensive, the downtimes, too, have to be taken into account.
The risks caused by overvoltages are considerable. And this is shown not only by the claims statistics of property insurers.
Generally, overvoltages are a threat to all electrical equipment. From an outside high-voltage switching station to the tiniest electronic component.
In the low-voltage range, voltage supplies, instrumentation and control technology, telecommunications and data transmissions are particularly at risk. We can offer ideal overvoltage protection for these applications.
The subject of overvoltage protection has become increasingly important. On the one hand, electrical and electronic components are becoming ever smaller, and on the other, automation in industry and even in consumer electronics is growing.
This means that safety margins in the insulation are decreasing and tolerances are diminishing. Therefore, electronic circuits operating with just a few volts are already endangered by overvoltages of just a few hundred volts.
The legislators have also recognised the significance of overvoltage protection. In Germany, the "Electromagnetic Compatibility of Devices Act" stipulates the design of electrical and electronic devices with respect to EMC considerations.
Overvoltage protection has become one aspect of these EMC measures. The measures necessary to achieve this protection are contained in various IEC/VDE specifications and standards.

The subject of overvoltage protection is rather complicated and requires special knowledge. Therefore, this catalogue provides you with some helpful information. And if you want to know more, simply contact us. We shall be happy to help and advise you.

How do we achieve Overvoltage Protection?

We have to consider Overvoltage Protection from two points of view:

- General protective measures during the planning and construction of buildings and electrical installations.
- Special protective measures realised by the installation of additional overvoltage protection components.

Planning buildings and electrical installations

Much can be done to prevent damage due to overvoltages through the careful planning and construction of buildings and electrical/electronic systems. Although these measures provide only basic protection, they can amount to cost-savings in an effective, complete protection concept. It is vital to include an adequately dimensioned earthing system right from the very first construction phase. Only this guarantees full equipotential bonding in the event of interference.

When planning the electrical installation, care must be taken to ensure that electrical systems with dissimilar rated voltages are kept separate. Corresponding protection zones can then be set up and this leads to cost-savings for the overvoltage protection.

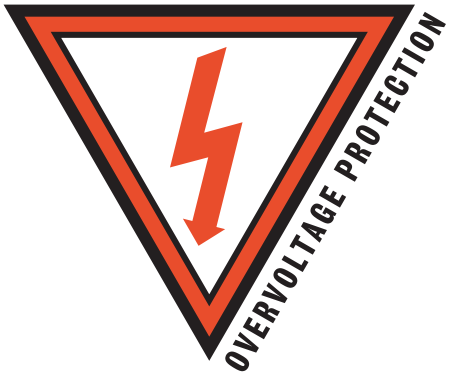
Furthermore, it is advisable to shield lines that could influence or be influenced by others, or route these separately, in order to achieve maximum electrical isolation. Another good option is to split up the individual phases of three-phase systems corresponding to their functions, e.g. one phase only for the supply to instrumentation and control systems.

Of course, all these primary measures do not achieve complete protection. To do this, you must install additional protective components.

Overvoltage Protection components

Overvoltages are prevented from reaching sensitive electrical components by short-circuiting, i.e. quenching, them before they reach that component.

To do this, we use overvoltage arresters that react very quickly. They must respond during the high-frequency rising phase of the overvoltage, i.e. before a dangerous value has been reached, and quench the overvoltage. The response time lies in the nanoseconds range.



It is obvious that overvoltage protection components must be able to withstand very high currents because, depending on the energy source, a short-circuited overvoltage can amount to several thousand amperes. At the same time, no unacceptably high, i.e. dangerous, residual voltage should be allowed to remain, even when the operating current is very high. Therefore, overvoltage protection components must exhibit a discharge behaviour with very low resistance.

Apart from that, it is absolutely essential that the overvoltage protection component is very quickly available again in electrical terms after the overvoltage has been quenched by earthing it. This is necessary to ensure that the function of the circuit is guaranteed.

Good overvoltage protection is characterised by:
- fast response behaviour
- high current-carrying capacity
- low residual voltage
- good reactivation time

Weidmüller can supply protective components that fulfil these criteria. Depending on the application, these usually consist of a combination of individual components, as described in the chapter on overvoltage components. Which combination of protective components is available for the respective application is described in the chapters B, C and D.

Classification and protective zones

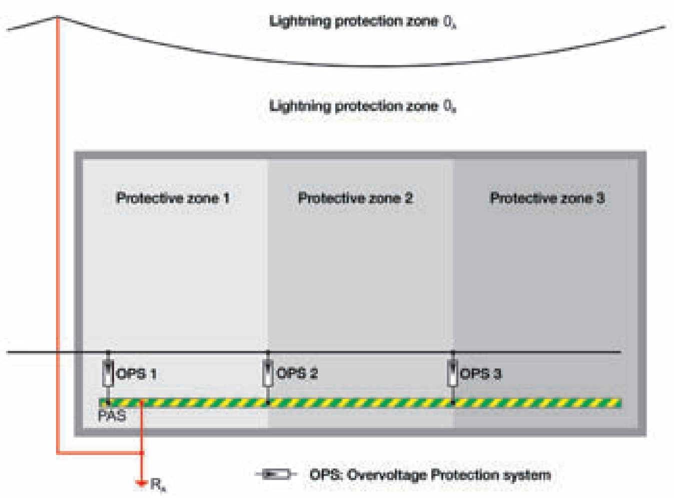
The requirements placed on overvoltage protection and the necessary tests for overvoltage protection components are stipulated by national and international standards.

For rated voltages up to 1000 V AC, the standards apply to manufacturers of overvoltage protection devices and those installing overvoltage protection in electrical sy-stems. This catalogue contains a list of valid standards for your reference.

The insulation coordination for electrical equipment in low-voltage systems to VDE 0110 is critical for the design of overvoltage protection. This specifies different dielectric strengt-hs within electrical systems. Based on this, individual lightning protection zones can be set up according to IEC/EN 62305-3 or VDE 0185.

Lightning protection zones

A protective zone is characterised by a fully earthed envelope. In other words, it has an enclosing shield which enables full equipotential bonding. This shielding can also be formed by building materials such as metal facades or metal reinforcement. Lines that pass through this shield must be protected with arresters in such a way that a prescribed protection level is achie-ved. Further protective zones can be set up inside such a protec-tive zone. The protection level of these zones can be lower than that of the enclosing protective zone.
This leads to a coordinated protection level for the objects to be protected. Not every individual section has to be protected with the maximum protection level (e.g. against lightning). Instead, the individual protective zones guarantee that a certain overvoltage le-vel is not exceeded and hence cannot infiltrate that zone.
This leads to economic protection concepts with respect to the capital outlay for protective components.



Classification

Originally, protective zones were classified according to coarse, medium and fine protection. These protective zones were designated classes B, C and D in DIN VDE 0675 part 6/A1. There was also a class A for external arresters (e.g. for low-voltage overhead lines); however, this class has now been abolished. The IEC 61643-1 (Feb 1998) classifies the protective zones as classes I, II and III.

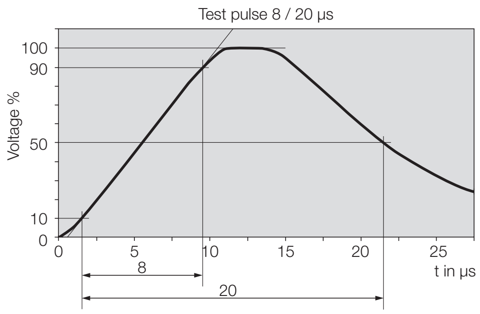
Comparison of overvoltage protection classifications.
Many national standards, e.g. in Austria, are derived from the aforementioned VDE or IEC standards.

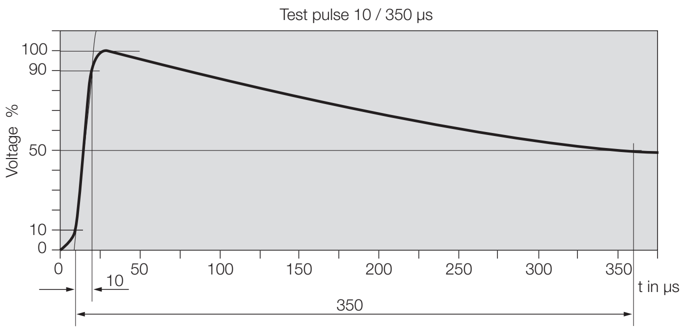
Formerly DIN VDE 0675 part 6 / A1	**Now IEC 37A / 44 / CDV or IEC 61 643-1 (Feb 1998)**
Arresters of requirements class B, lightning protection equipotential bonding to DIN VDE 0185 part 1 (“B arresters”)	**“Class I”** arresters
Arresters of requirements class C, overvoltage protection in permanent installations, surge withstand voltage category (overvoltage cat.) III (“C arresters”)	**“Class II”** arresters
Arresters of requirements class D, overvoltage protection in mobile/permanent installations, surge withstand voltage category (overvoltage cat.) II (“D arresters”)	**“Class III”** arresters

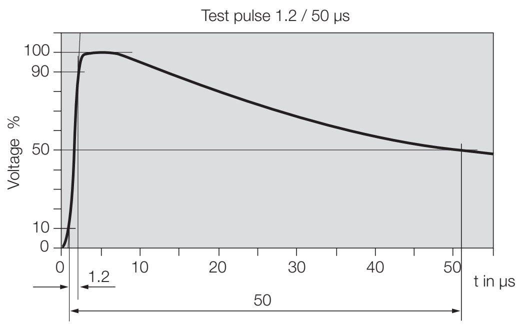
Test criteria

The new classification is based on the experience that "B arresters" can become overloaded in extreme situations, and also on more recent investigations into lightning discharges. This resulted in the new standardised 10/350 µs current curves for the testing of "class I" arresters. The test parameters lie between 12,5 and 25 kA Ipeak.
The term "10/350 µs" means that the surge current reaches 90% of its maximum value after 10 µs and then decays to half that value after 350 µs. The area beneath this curve corresponds to the current energy used in the test.
As in the past, "class II" arresters (formerly "C arresters") are tested with the 8/20 µs current curve. The rated discharge current for our arresters is up to 75 kA for a 2-pole feed and up to 100 kA for a 4-pole supply. "Class III" arresters (formerly "D arresters") are used for protecting equipment. These are tested with a 2 W hybrid surge current generator delivering a maximum charging voltage of 0.1 to max. 20 kV, which during a short-circuit supplies between 0.05 and 10 kA, 8/20 µs.

Classification formerly	VDE 0675	IEC 37A	**Test values**	**Application**
coarse protection	B-arrester	class I	I_{IMP} = 25 kA 10/350µs curve	Protection against direct lightning strike (incoming (supply, main distribution board, etc.)
medium protection	C-arrester	class II	single pole I_N = 20 kA 8/20 µs curve 3 or 4-pole I_N = 100 kA 8/20 µs curve	Protection for permanent installations (electricity distribution etc.)
fine protection	D-arrester	class III	U_{oc} = 20 kV max. I_s = 10 kA max. hybrid generator	Protection for devices (sockets etc.)







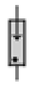
Components for Overvoltage Protection

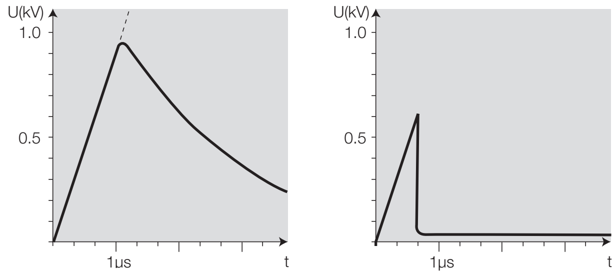
There is no ideal component that can fulfil all the technical requirements of overvoltage protection equally effectively. Instead, we use a variety of components whose different physical methods of operation complement each other; these possess distinct protective effects. Super-fast reaction time, high current-carrying capacity, low residual voltage and long service life cannot be found in one single component.

In practice we use three principal components:
1. sparkover gaps
2. varistors
3. suppression diodes

Therefore, to optimise the overvoltage protection, carefully matched groups of these components are often combined in one protective module.
4. Combination circuits

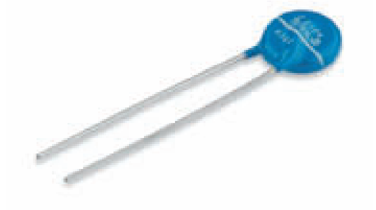
1. Sparkover gaps

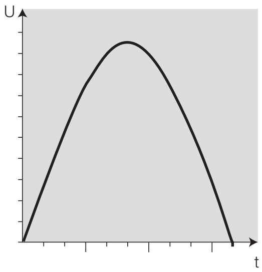


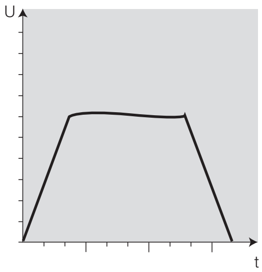


The name says it all. High voltages are discharged to earth via a spark gap (e.g. gas discharge tube) that has been fired. The discharge capacity of sparkover gaps is very high – up to 100 kA.
Gas sparkover gaps are incorporated in insulating glass or ceramic (aluminium oxide) housings. The electrodes of the sparkover gap are made from a special alloy and placed in housings which are vacuum seald and filled with a noble gas such as argon or neon. The shape and spacing of the electrodes of the sparkover gap are such that the applied voltage results in a field strength distribution which has a fairly exact voltage for firing the sparkover gap. Bipolar operation is typical of sparkover gaps. This firing voltage value depends, however, on the steepness of the applied overvoltage.
The characteristic curve for the firing of a gas-filled sparkover gap reveals that the response time shortens as the overvoltage rise becomes steeper. The firing voltage is thus correspondingly higher. The outcome of this is that with very steep overvoltage rises, the firing voltage – i.e. the protection level – is relatively high and can lie considerably higher than the rated voltage of the sparkover gap (approx. 600-800 V).
The problematic quenching behaviour of the fired sparkover gap can be a disadvantage. The arc has a very low voltage and is only extinguished when the value drops below this. Therefore, when designing the geometry of a sparkover gap, care is taken to ensure that – through long distances and also through cooling – the voltage of the arc remains as high as possible and so is quenched relatively quickly. Nevertheless, a longer follow current can ensue. This can draw its energy, in addition, from the incoming supply of the circuit to be protected. One effective solution is to wire a sparkover gap and a fast-acting fusible link in series.

2. Varistors

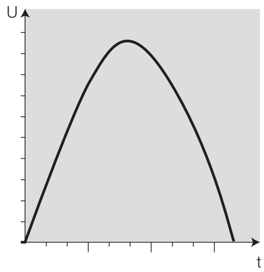


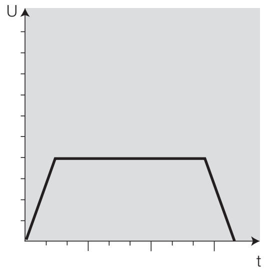




The varistors used in overvoltage protection (MOV – Metal Oxide Varistor) are voltage-dependent resistors in the form of discs of zinc oxide. Just above their rated voltage the resistance becomes so small that they become conductive. The overvoltage is limited by the varistor allowing the current to pass. Bipolar operation is typical of varistors.
Varistors have a medium to high discharge capacity; this lies in the region of 40-80 kA. The response time is less than 25 ns. Residual voltages are significantly lower than those of sparkover gaps. The lower protection level achieves better overvoltage protection and no power follow currents are drawn from the power supply.
However, varistors also have their disadvantages. Their ageing phenomena and relatively high capacitance must be taken into account.
Leakage currents occur over time, depending on the frequency of the triggering, because individual resistance elements break down. This can cause temperature rise or even destroy them completely.
The high capacitance of varistors causes problems in circuits with high frequencies. Attenuation of the signals must be reckoned with for frequencies above about 100 kHz. Therefore, varistors are not recommended for use in data transmission systems.

3. Suppression diodes

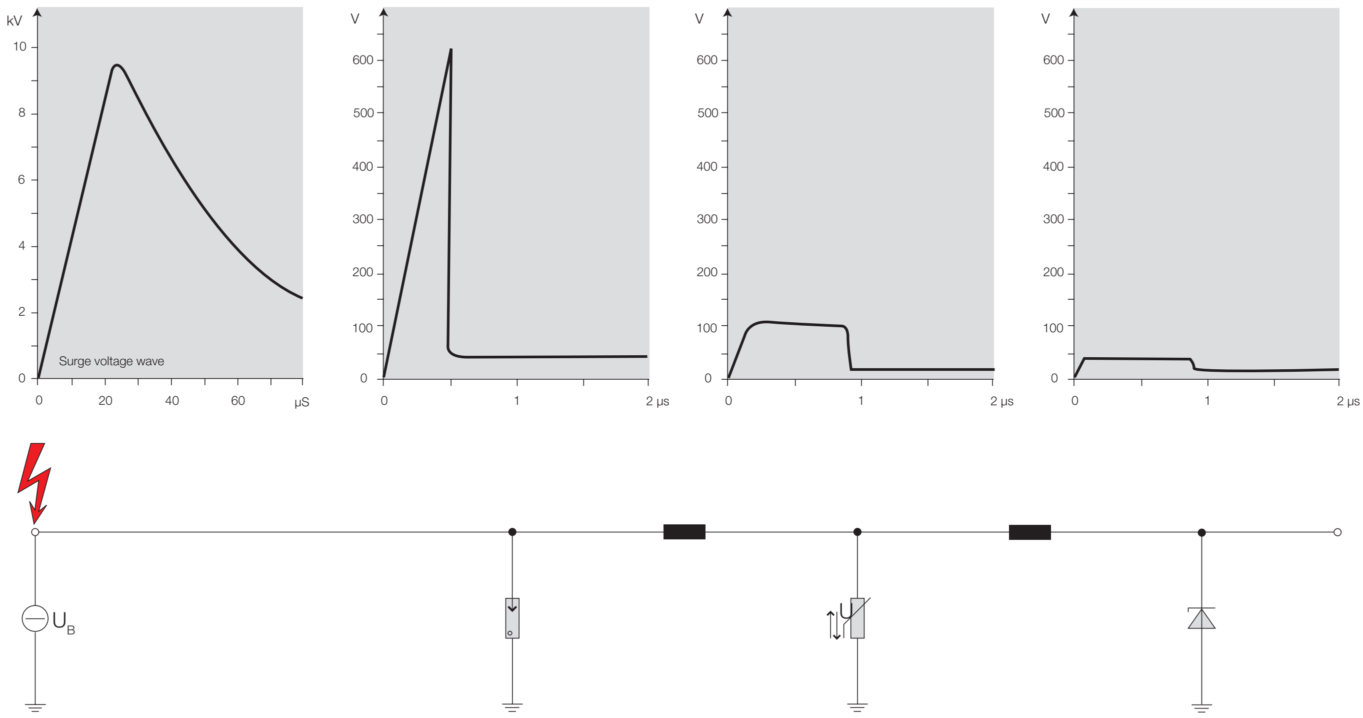




A suppression diode operates in a similar manner to a Zener diode. Unidirectional and bidirectional versions are available. The unidirectional suppression diode is often used in d.c. circuits. Compared to conventional Zener diodes, suppression diodes have a higher current-carrying capacity and are considerably faster. They very quickly become conductive above a defined breakdown voltage and hence short-circuit the overvoltage.
However, their current-carrying capacity is not very high – less than 1800 W/ms. On the other hand, they exhibit an extremely fast response time, lying in the picoseconds range. And the low protection level of suppression diodes is another advantage. Unfortunately, suppression diodes possess a significant inherent capacitance. Therefore, like with varistors, their possible attenuation effect on high frequencies must be taken into account.

4. Combination circuits

Combining the components described above results in overvoltage fine protection products that can match individual requirements.
If a voltage pulse reaches the input of such a combination circuit, then the gas discharge tube is fired and discharges high current. The residual pulse is attenuated by a downstream inductance and subsequently received and limited by the varistor and/or suppression diode. If the gas discharge tube is not triggered, i.e. in the case of a slower voltage rise, then the pulse is discharged by the varistor or the suppression diode alone.
The sequence of the individual components results in an increasing response sensitivity towards the output.
An interference voltage with a rise of 1 kV/µs and a peak value of 10 kV at the input is limited by a gas-filled overvoltage arrester to approx. 600-700 V. The second stage, decoupled from the first by means of an inductance, suppresses this value to approx. 100 V. This voltage pulse is then reduced to approx. 35 V (in a 24 V protective combination) by the suppression diode. Therefore, the downstream electronics need only be able to cope with a voltage pulse of approx. 1.5 x UB.



Network forms to DIN VDE 0100 part 300 (DIN 57100 part 310)

The letters describe the earthing conditions

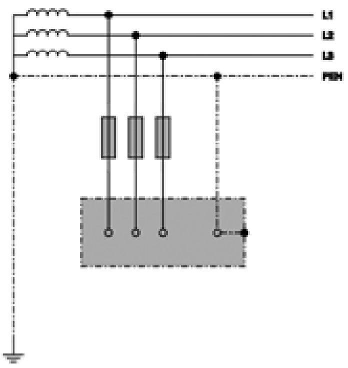
1st letter Earthing at current source	2nd letter Earthing of exposed conductive parts of electrical installation	3rd letter Routing of N and PE conductor (only applies to TN systems)
T- Direct earthing of current source (of transformer)	**T-** Exposed conductive parts of electrical installation are earthed directly	**C-** "Combined" N conductor and PE conductor are routed together as PEN conductor from current source into electrical installation
I- Insulated structure of current source	**N-** Exposed conductive parts of electrical installation are connected to earth of current source	**S-** "Separate" N conductor and PE conductor are routed separately from current source to exposed conductive parts of electrical installation

Four-conductor systems:

Still valid according to VDE but unfavourable for information technology systems from the point of view of EMC (VDE 0100 pt 444 / pt 540 pt 2).

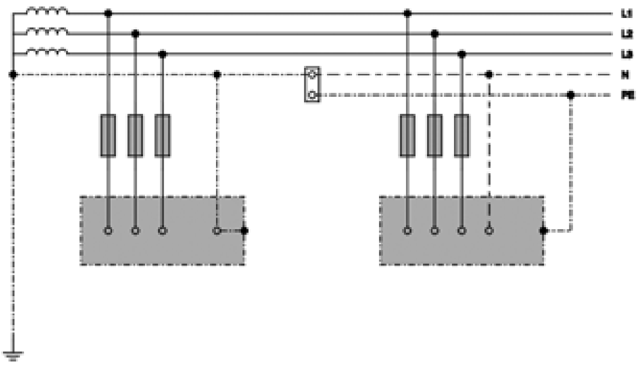
TN-C-System ("classic earthing")

Neutral conductor and protective earth conductor functions are combined throughout the network in a single conductor, the PEN conductor.



TN-C-S-System ("modern earthing")

Neutral conductor, PEN conductor and equipotential bonding system are connected once at the main distribution board or after the incoming supply to the building. Therefore, a TN-C system becomes a TN-S system (TN-C-S system) from this point onwards.

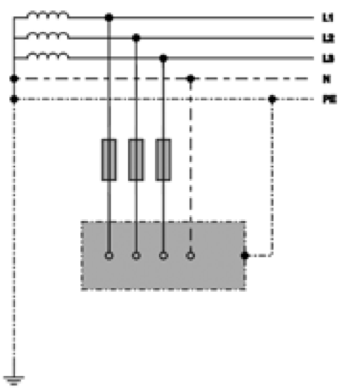


Five-conductor systems:

The neutral point of the supply source is earthed (N and PE). Both conductors must be laid separately and insulated from the incoming supply onwards. In these systems the PE (protective earth conductor) does not carry any operating current but instead only discharge currents.

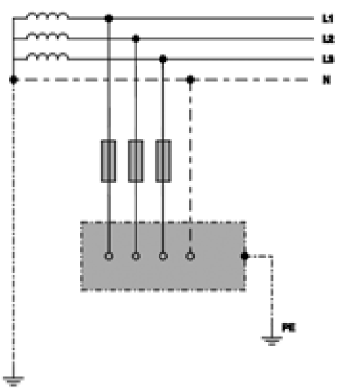
TN-S systems

Neutral conductor and protective earth conductor are separated throughout the network.



TT systems

One point is earthed directly (operational earth). The exposed conductive parts of the electrical installation are connected to earth lines separate from the operational earth.

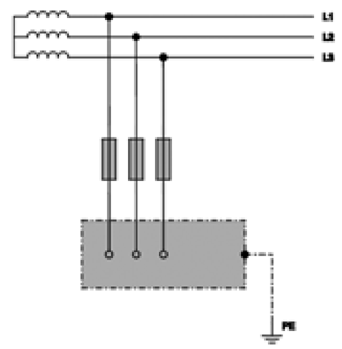


Special system:

Used, for example, in medical applications

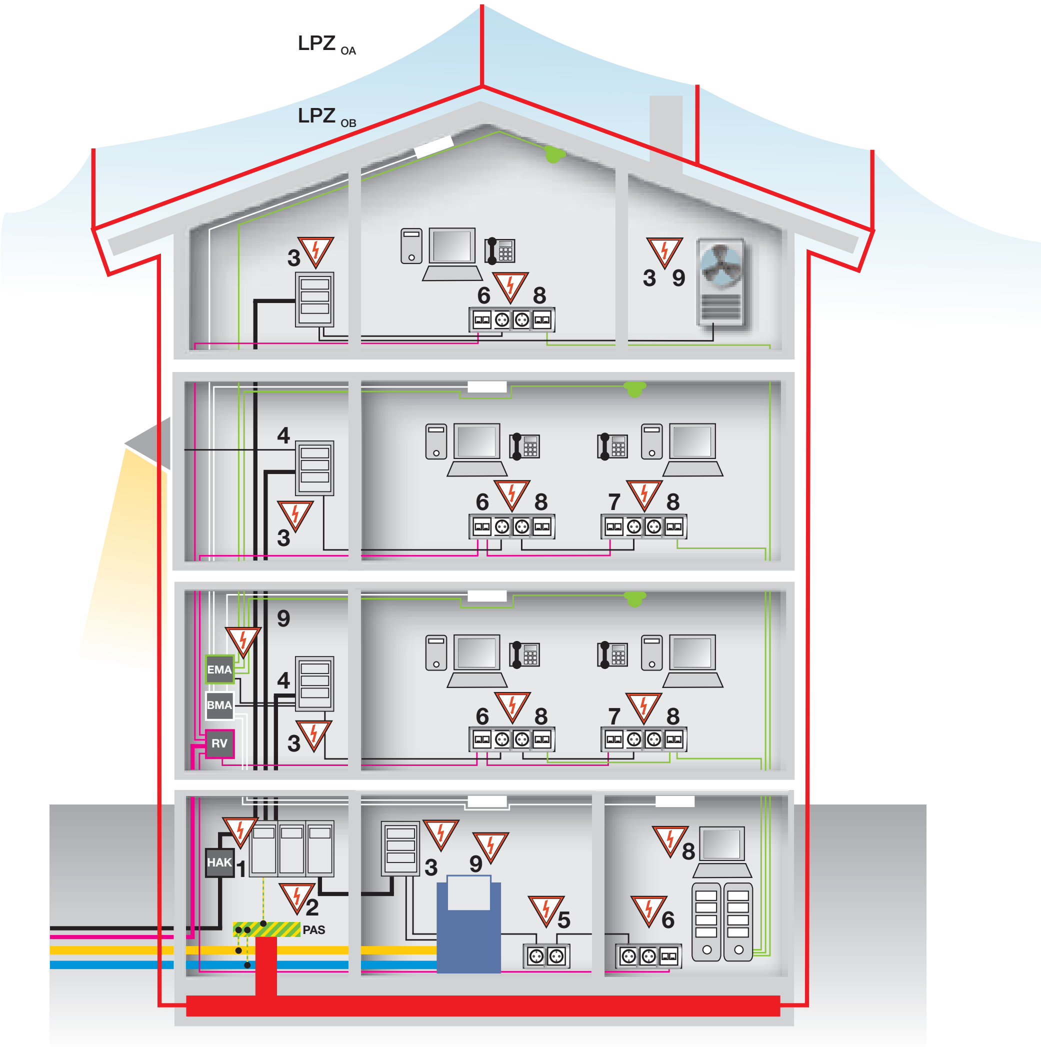
IT systems

There is no direct connection between active conductors and earthed parts. The exposed conductive parts of the electrical installation are earthed.



Office building with lightning protection

Applications, installation positions: Application Office building



Power (low-voltage supply)
1 Class **I** Arresters with sparkover gaps, PU 1 TSG / PU 1 TSG+
2 Class **I** Arresters with high-power varistors, PU BC series
3 Class **II** Arresters with varistors, PU II series
4 Class **III** Arresters for installing in subdistribution boards, PU III series
5 Class **III** Arresters in the form of plug-in overvoltage protectors, PU D ZS

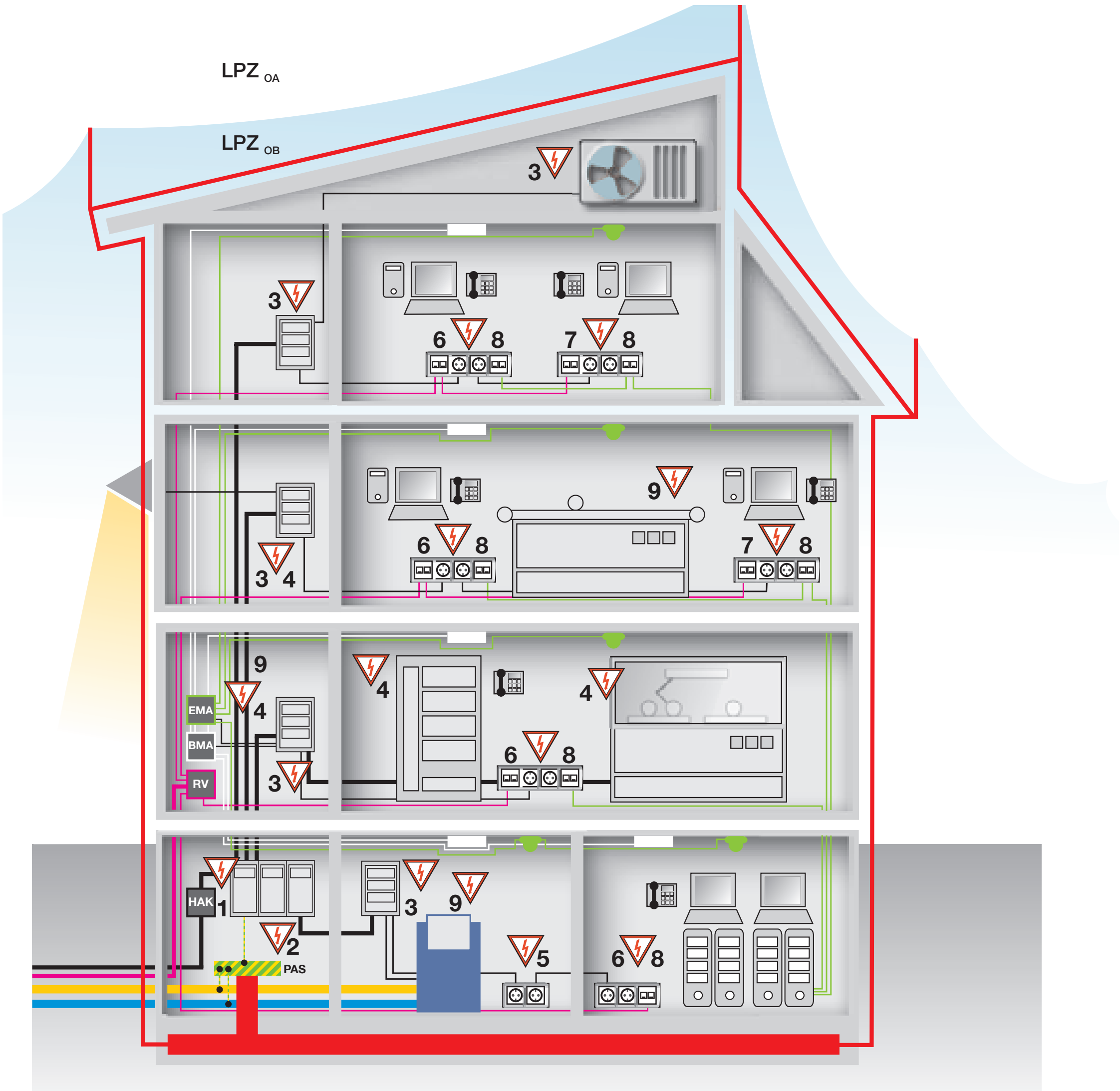
Data
8 Overvoltage protection for data lines, e.g. Ethernet CAT.5

Power and data
6 Class **III** Arresters in the form of plug-in overvoltage protectors with protection for analogue telephone lines, PU D ZS
7 Class **III** Arresters in the form of plug-in overvoltage protectors with protection for digital telephone lines, PU D ZS

Instrumentation and control equipment
9 Overvoltage protection for instrumentation and control circuits, e.g. MCZ OVP series

OVERVOLTAGE PROTECTION

Applications, installation positions: Application Industrial building



Standards
For the user, the availability of electrical and electronic installations and systems is a decisive factor; at times it is of vital importance.
That is why it is important to prevent damage and disruption, a considerable amount of which is caused by voltage surges.

Actual standards
IEC61643-1 Ed.2 2005-03, SPDs connected to low-voltage power distribution systems.

Class I, Class II and Class III products are tested in accordance with this standard.

Regulations for installation
IEC 60364-5-53: 2002-6, Electrical installations of buildings - Part 5-53: Selection and erection of electrical equipment - isolation, switching and control.
This standard is implemented in the international VDE 0100-534. It must be observed when installing low-voltage systems.
Selection and installation of communications electronics is mirrored in the standards VDE 0800, 0843-T5, 0845.

Current
Telecom
Gas
Water

LPZ OA
Unprotected area outside of the building. Direct lightning strike; no shielding against electromagnetic interference.

LPZ OB
Area protected by lightning protection system. No shielding against LEMP.

General installation advices

Many details have to be taken into account during the installation of overvoltage protection and the electrical system in order to achieve optimum protection.

Arrangement and subdivision of electrical panel

Steel cabinets possess good magnetic shielding properties. The following points should be taken into consideration during the installation:

- Avoid unnecessarily long lines (particularly lines with a high volume of data traffic).
- Route sensitive signalling lines separately from lines with a high interference potential.
- Route shielded lines directly to the equipment and connect the shielding there (do not connect via additional terminal in switching cabinet).
- Classify equipment in groups with different sensitivities and place these together.

Place of installation

The overvoltage protection devices should be mounted where the lines and cables enter the cabinet. This is the lowest mounting rail directly above the cable entries. This prevents interference being coupled within the cabinet; interference is discharged right at the entry to the cabinet. When using shielded lines, these can be connected at this point by using Weidmüller clamp straps.

Routing the lines

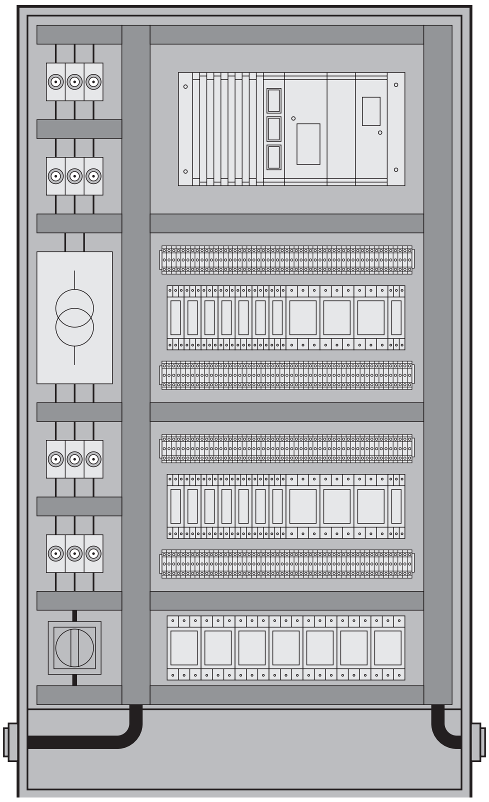
Signalling lines should be laid within the system/cabinet over the shortest route to the overvoltage protection and then continue to the connected equipment. Protected and unprotected lines should be routed separately. The earth line should be regarded as an unprotected line. Metal partitions can be used along cable routes or in cable ducts to achieve this separation. If signalling lines are laid parallel to power lines, a clearance of min. 500 mm must be maintained.

Earthing of products and connected products

All overvoltage protection devices include an earth connection terminal. The earth line of the associated equipotential bonding strip must be connected to this point. The cross-section of this earth line must be as large as possible and the length of the line kept as short as possible; every centimetre of line increases the residual voltage of the overvoltage protection device. In addition to the earth connection terminal, the MCZ ovp module also has a mounting rail contact for earthing directly to the TS 35 rail. The mounting rail should be mounted on an earthed metal back plate in order to achieve optimum earthing. The earth connection terminal of the MCZ ovp should be connected to the equipotential bonding every 600 mm in order to achieve a satisfactory protection level.

Fuse protection

Overvoltage protection devices for instrumentation and control systems frequently operate with a decoupling between the components. This decoupling is achieved with inductors or resistors. Decoupling, besides the types and routes of lines, compels us to employ fuse protection at the maximum level of the rated current for the overvoltage protection devices. Fuse protection for the PU series on the power feed side must be designed in accordance with DIN VDE 0298 part 4 (conductor cross-section, number and type of conductors as well as type of installation). This information is given on a leaflet included with the respective PU module.



Summary of standards and regulations

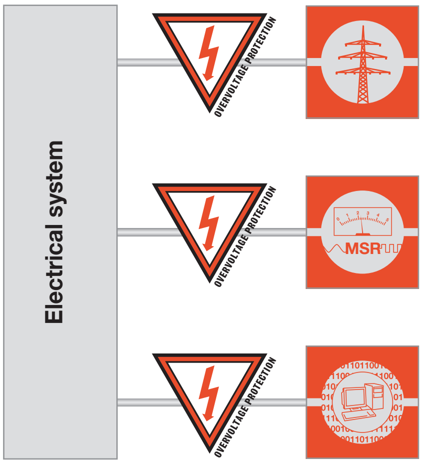
Detailed information and regulations can be found in Chapter E.

In the case of national and international standards and specifications on the same subject, the document with the widest scope takes precedence (e.g. international "IEC", European "CENELEC" or "CNC", national (Germany) "DIN VDE" or (Austria) "ÖVE").

IEC	EN	VDE	others	
IEC 1024-1				Protection of structures against lightning. Pt 1: General principles.
IEC 1312-1				Protection against lightning effect of energy impulse Pt 1: General principles.
	EN 50083-1			Cable networks for television signals, sound signals and interactive services. Pt 1: Safety requirements.
IEC 60364-5-53		VDE 0100 pt. 534		Electrical installations of buildings. Pt 534: Selection and erection of equipment; devices for protection against overvoltages.
IEC 60364-5-54		VDE 0100 pt. 540		Erection of power installations with nominal voltages up to 1000 V; selection and erection of equipment; earthing arrangements, protective conductors, equipotential bonding conductors.
IEC 60664-1	EN60664-1	VDE 0110 pt. 1		Requirements for insulation coordination within low voltage systems; general principles.
		VDE 0110 pt. 2		Requirements for insulation coordination within low voltage systems; design of clearances and leakage paths; Replaced by VDE 0110 part 1.
IEC 60079-x	EN 60079-x	VDE 0165 pt. x		Erection of electrical systems in potentially hazardous zones.
IEC 60079-0	EN60079-0	VDE 0170 / 0171 pt. 7		Electrical apparatus for potentially explosive atmospheres; intrinsic safety.
IEC 62305-1	EN 62305-1	VDE 0185 pt. 1		Lightning protection system; general with regard to installation (VDE Guide).
IEC 62305-2	EN 62305-2	VDE 0185 pt. 2		Lightning protection system; erection of special structures (VDE Guide).
IEC 62305-x	EN 62305-x	VDE 0185 pt. 100		Protection of structures against lightning. Pt 1: General principles.
IEC 62305-3	EN 62305-3	VDE 0185 pt. 103		Protection against lightning electromagnetic impulse. Pt 1: General principles.
IEC 529 1989	EN 60 529 1991	VDE 0470-1 1992		Degrees of protection provided by closures (IP code).
IEC 60099-1	EN60099-1	VDE 0675 pt. 1		Overvoltage arresters with non-linear resistors and protective spark gaps for a.c. networks.
		VDE 0675 pt. 2		Overvoltage protection equipment; valve-type arresters for a.c. networks (VDE GUIDE); Replaced by VDE 0675-5.
IEC 60099-1A		VDE 0675 pt. 4		Overvoltage protection equipment; tests for protective spark gaps for a.c. networks. (VDE Guide)
IEC 60099-5		VDE 0675		Edition 9.00 Overvoltage arresters: instructions for selection and use
IEC 37A/44 CDV 1996 IEC 61 643-1	EN 61643-11	VDE 0675 pt. 6	ÖVE SN 60 pt. 1 + 4	Surge voltage protection devices for use in low voltage distribution networks. 100 V and 1.000 V
	EN 50 081-1 1991 EN 50 082-1	VDE 0839 pt. 81-1 1993 pt. 82-1 1993		Generic emission standards. Pt 1: Residential, commercial and light industrial environment.
		VDE 0845 pt. 1		Protection of telecommunications systems against lightning, electrostatic discharges and overvoltages from electric power installations; provisions against overvoltages.
IEC 38 1983		VDE 0175		IEC standard voltages
			KTA 2206 06.92	Lightning protection standard for nuclear power plants.
			VDE publication 44	Lightning protection systems, explanations to DIN 57185/VDE 0185, published by VDE
			DIN-VDE- publication	DKF publication No. 519: Lightning protection systems 1, external lightning protection, published by VDE.
			DKE publication No 520	Lightning protection systems 2, internal lightning protection, published by VDE.
IEC 60364-5-53		VDE V 0100-534		Electrical connection for building installation - Part 5-53: Selection and installation for electrical equipment.
			ÖVE 8001 §18	Protection of electrical systems against transient overvoltages.

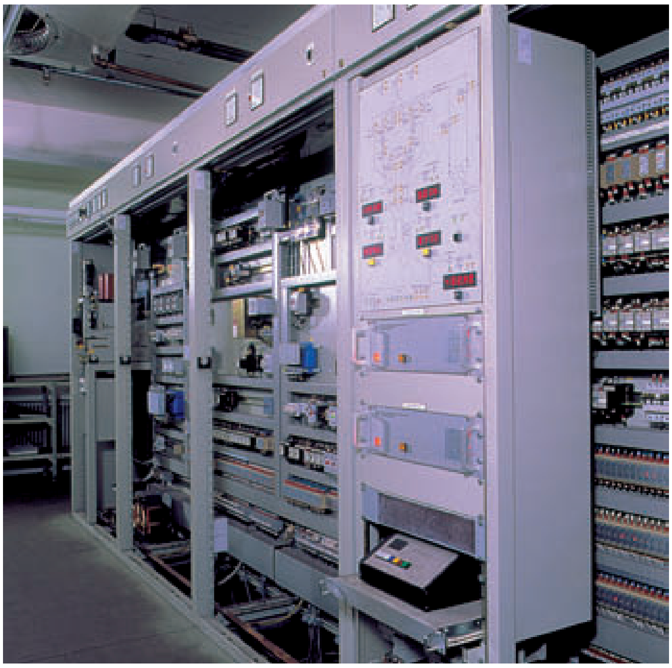
The above list is not exhaustive.

Overvoltage Protection concept



Fundamental concept of protection

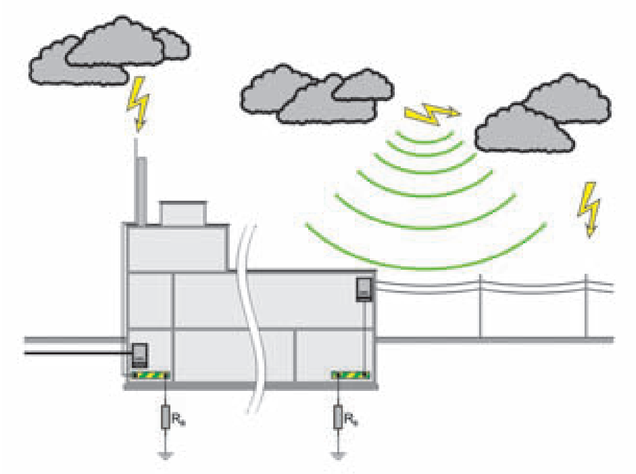
One important aspect of overvoltage protection is the area of power supply and distribution. The procedure is linked to the systematic subdivision prescribed by the protective zones concept and the corresponding coordination of overvoltage arresters. Protection of power supply lines forms the basis for protecting all electrical and electronic equipment right down to the smallest and most sensitive components. A fundamental



requirement for effective overvoltage protection is the presence of properly functioning equipotential bonding to DIN VDE 0100 part 540 in a series, or better still, star or grid arrangement. DIN VDE 0110 (insulation coordination) divides overvoltage protection for power supplies and power distribution into the following three areas:

1. Power supply

The surge voltage strength of the insulation is 6 kV from the incoming supply to the building – by means of underground cables or overhead lines – right up to the main distribution board (backup fuse and meter cupboard). Owing to the lightning protection zoning concept and the physical circumstances, high-energy overvoltages have to be discharged here.



Surge currents exceeding 200 kA can be generated by cloud-to-ground but also cloud-to-cloud lightning discharges.

As a rule, 50% of the current is discharged via the lightning protection system and the remaining 50% is coupled into the conductors and conductive parts in the building and distributed uniformly. The closer a conductor is to the lightning protection system, the greater is the launched voltage (which can exceed 100 kV). The pulse duration can be up to 0.5 ms. These powerful interference pulses are discharged to earth directly at the incoming supply or main distribution board by class I lightning arresters and limited to voltages below 6 kV. Power follow currents and backup fuse values are just some of the aspects that need to be taken into account here.
Depending on the local circumstances and the discharge currents to be expected, sparkover gaps or varistor surge arresters are used, taking into account the type of network.

If a lightning protection system has been installed, or the power supply is via overhead lines, or buildings or plants are spread over a wide area and individual buildings are sited on elevated ground or open areas, high-capacity class I arresters should always be employed.

2. Subdistribution

The surge voltage strength of the insulation is 4 kV from the main distribution board up to and including subdistribution boards. Owing to the coordinated use of arresters, class II overvoltage arresters are used here and, if necessary, decoupled from class I arresters by means of coils. The use of decoupling coils is only necessary when the class I arresters consist of one sparkover gap and the length of the line between the class I and class II arresters is less than 10 m. It is not necessary to decouple Weidmüller class I and class II arresters. The pulse currents that occur here are no longer that high because most of the energy has already been absorbed by the class I arresters. Nevertheless, the line impedances give rise to high interference voltages which must be limited to less than 4 kV by the class II arresters. Class II arresters based on varistors are normally installed in the subdistribution board before the residual-current circuit-breakers.

3. Terminals, consumers, sockets

The surge voltage strength of the insulation is 2.5 kV from the subdistribution board to the electrical consumer. Class III overvoltage arresters are used here. Depending on the application, these consist of individual protective components or combined circuits with gas discharge tubes, varistors, Transzorb diodes and decoupling elements. These arresters are best installed directly before the device to be protected. This can be in a socket or trailing socket (on extension lead) but also in the terminal or junction box of the device itself.
To protect against permanent interference such as “ripples” or “noise” caused by other systems, additional filter circuits are available for the voltage supplies to devices. The insulation of the electrical consumer itself has a surge voltage strength of 1.5 kV.

Principle for selecting arresters according to IEC 664 DIN VDE 0110 part 1