



TRABTECH Basics

Fundamentals for Surge protection

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TRABTECH – The comprehensive surge protection concept by Phoenix Contact

Surge voltages originating from switching operations in electrical systems or from lightning discharges destroy or damage electronic equipment. Electrical systems and equipment are effectively protected from destruction by surge voltages by the professional TRABTECH surge protection.



Fig. 1a: IC destroyed by surge voltages



Fig. 1b: Destroyed residual current circuit breaker (RCD)



Statistics of electronics insurers indicate that anything up to 25 percent of damage occurs due to surge voltages. Although operators of electronic systems are compensated by their insurance company for damage to the hardware in most cases, software damage and system failure frequently remain uninsured with great financial loss.

The more highly integrated electronic systems are, the less resistant they are to surge voltages. The frequency of damage is increasing as a result of this and because of the rapidly growing number of sensitive electronic systems.

Each circuit works with its own specific voltage. When a voltage increases beyond the upper tolerance limit, it becomes a surge voltage for the circuit. The transient voltages observed here are very short events in which many times the nominal voltage is reached. They are described as "transients" as are the briefly occurring surge currents.

In many cases, they damage the circuit and its components (power supply, load etc.). The extent of the damage largely depends on the dielectric strength of the components and – if you look at it further – on the energy that can be converted without damaging the circuit concerned. A coupled transient voltage of 500 V resulting from a switching process on inductive consumers, for example, will not result in destruction in a power supply for 230/400 V, since it does not even assume 2.5 times the value of the rated voltage and only very briefly occurs in the μs range. The dielectric strength of such devices is 1.5 kV or 2.5 kV depending on the area of application: building installation or industrial installation.

The situation is different in a 5 V DC circuit linked to an IC. The identical coupled surge voltage here reaches 100 times the nominal voltage and definitely causes damage. The destruction resistance of an IC is less than that of power supply components by several powers of ten (Fig. 1). Transient surge voltages have very brief rise times of a few μs and then drop again relatively slowly in a range from several 10 μs to several 100 μs . To prevent these surge voltages from damaging sensitive electrical systems, the conductors in which such high voltages occur must be short-circuited with the equipotential bonding as rapidly as possible.

During a surge arresting process, discharge currents of many thousand amperes can occur. At the same time, a protective module is often expected to limit the output voltage to a minimum despite the high discharge current. For this reason, components such as air spark gaps, gas-filled surge arresters, varistors and suppressor diodes are available individually or in combined circuits. The combination is logical, since each of the components has specific characteristics, which vary according to the following criteria:

- Surge arresting capacity
- Operating behavior
- Extinguishing behavior
- Voltage limitation

The protective circuits are integrated into a surge protection device that also guarantees the mechanics for easy installation. The range of surge arresters from Phoenix Contact goes under the name TRABTECH (Transient Absorption Technology). A suitable protection module can be selected from the wide TRABTECH arrester range to suit the respective application and the performance requirements for the surge protection.

The surge protection is one element of the entire technical field of electromagnetic compatibility (EMC)++.



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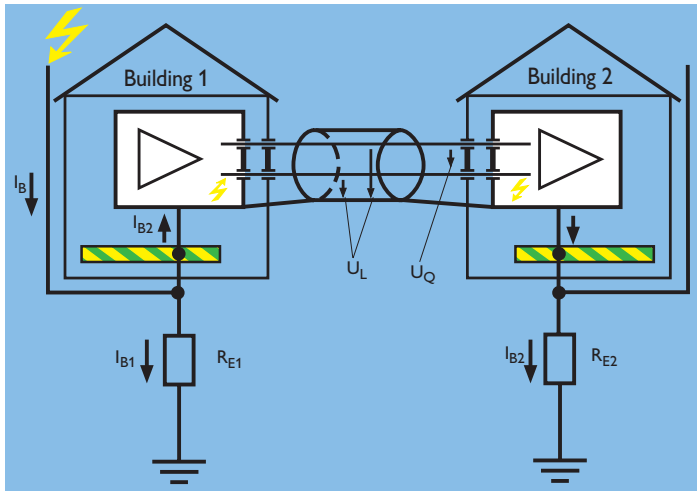


Fig. 2.0-2:
Common mode and normal mode voltage

A surge voltage between two operating cores and ground is described as "common mode voltage U_L " (Fig. 2.0-2), a surge voltage between two operating cores that are not grounded, is described as "normal mode voltage U_Q " (Fig. 2.0-3). The amount of an induced surge voltage increases along with the edge lengths of the induction loops.

When the first computer centers with mainframes went into operation, little or no thought had been given to the electromagnetic compatibility of the computers with the environment. This was also hardly necessary because the first generation of computers still had a very sturdy construction – in relation to possible interferences. From today's perspective, the computers had a very large volume but a relatively small capacity.

This large volume allowed a sufficient spacing or a sufficient insulation of two current-carrying lines or conducting paths inside the computer. Therefore, "flashovers" between two points with different electrical potentials were not expected.

Flashovers due to high potential differences do not occur in the normal operation of a system but as a result of surge voltages coupling from external interference sources.

In the meantime, computer technology has advanced so much that the same memory size and computing speed that was found in a room-sized computer many years ago is now achieved with a PC, including peripherals, that are also miniaturized. It is therefore understandable that in such a PC, large distances no longer exist between two conductor paths on a PCB. The surge voltages that can couple from external interference sources still have the same high values as a few decades ago.

Since the dielectric strength between two points with different electrical potentials decreases when the distance becomes smaller, modern computers are no longer able to function without interference and damage unless measures such as interference and surge protection are implemented.

Fortunately, very few operators of computer centers or other sensitive electronic equipment still believe that they have sufficient protection from an "outdoor lightning protection system".

Apart from the fact that lightning protection systems have to be fitted with indoor lightning protection in accordance with DIN VDE V 0185 Part 4 or IEC 62305 Part 4 to be functional, an outdoor lightning protection system also causes EMC problems for the electrical equipment inside the building. When lightning surge currents are intercepted and discharged by the lightning protection system, electromagnetic interfe-

rences occur and cause surge voltages to couple into data lines and conductor loops on the PCB of electrical equipment. Interferences are coupled to conductor loops in the same way when lightning strikes into the ground through the natural lightning current channel in the close or general vicinity of an electronic system (Fig. 2.0).

All lines that run parallel and diagonally to the lightning current path are influenced in this way. Couplings of several 1000 V into the power supply or data lines to a computer are not unusual. Surge voltages are not only caused by lightning discharges, though. Whenever a current changes very quickly, surge voltages will be produced in the connected electrical lines according to Faraday's law. This can happen, for example, with switching operations and short circuits in power installations or with electrostatic discharges. In these cases, one must also reckon with very high surge voltages that can destroy the electronics.

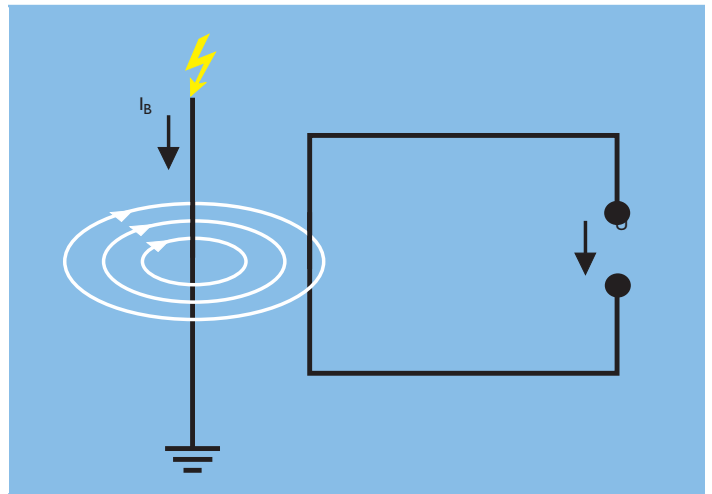


Fig. 2.0-3:
Coupling of lightning currents in a conductor loop

Danger from surge voltages normally does not announce its arrival. There are, however, indications that a system is not sufficiently protected from interferences. One indication could be, for example, when the electronics "drop out" at a given time for no reason or interferences continually occur during a particular season of the year, on a particular day of the week, or always at the same time of day. In such a case, measures should be immediately implemented to protect the affected system.

3.0 Measures to protect against surge voltages

3.1 Primary and secondary measures

There are two basic possibilities for creating an efficient surge protection:

- absolute electrical isolation, which must be done in such a way that no more interference is possible or
- a consistent equipotential bonding between all active and passive system components

Both options, the electrical isolation as well as the equipotential bonding, can only function if they are fully implemented. Absolute electrical isolation, which also has to withstand an inductive and capacitive interference, is practically impossible.

Complete equipotential bonding requires the inclusion of all active conductors such as power supply and data lines, for example. This requires surge arresters that produce a short circuit between two points with different potentials. This short circuit functions as a "predetermined breaking point" for a very short time when surge voltages occur.

During normal operation, these arresters can be treated as open switches that do not influence the power circuit. The short circuit is generated within nanoseconds and only maintained for a period of microseconds depending on the duration of the surge voltage.

The fuse of the circuit only operates in rare cases, and then it is generally only due to line follow currents from low-impedance current sources – proof that fuses are not suitable for the tasks of surge protection.

Primary measures against surge voltages are shielding, grounding, equipotential bonding, and separate installation of lines that may interfere with each other. These measures include improving the EMC characteristics of electrical installations as well as using an uninterruptible power supply (UPS).

Ideal conditions in accordance with the above-mentioned primary measures cannot be produced in practice. It is therefore also necessary to install surge protection devices if surge voltages might couple. The use of surge protection devices is considered a secondary measure against surge voltages. Such surge protection devices reduce the transients to a safe level for the electronic systems. The arresters are able to discharge the surge currents often and also with a high frequency. Both the surge voltages discussed here the discharge surge currents occur as transients.

3.2 Ensuring surge protection when planning

It is best to begin with the surge protection as early as the planning stage, when it is possible to minimize the costs of an effective protection concept the most.

The correct functioning of the surge arresters requires a complete equipotential bonding that has a corresponding connection to the grounding system and is designed according to the valid standards. The grounding system should be created in the very first building phase during the excavation and foundation work. For this reason, it must be taken into account in the construction planning.

The environment of the sensitive electrical and electronic systems must be divided into EMC protection zones. These protection zones must be determined according to the dielectric strength of the systems that are operated inside (see also the chapter "The installation of arresters").

Equipment and systems with approximately the same dielectric strength should be kept together in the same place and arranged in a common

EMC protection zone, or a common EMC protection zone should be formed around these systems and equipment.

"Comprehensive surge protection" means that an effective protection concept always takes into account all interfaces of the incoming or outgoing circuits of an electrical or electronic system. The use of surge protection devices that conform to the system prevents destructive surge voltages from reaching the sensitive interfaces of electrical and electronic systems.

A surge protection device has protective circuits and uses familiar components: air spark gap, gas-filled surge arrester, varistor and suppressor diode. Between one and three of these component types are used in a surge protection device that is generally also called arrester. The word "arrester" already indicates that something is arrested or stopped here. What is stopped are the currents that result when a surge voltage connects with the existing complex resistance "X". The arresters are not responsible for converting electrical energy (e.g. into heat). They are the "gate" for the discharge of the currents to the ground. They are the most important factor for the remaining residual voltage of a current path in relation to ground is therefore a low resistance (a low impedance) of the entire discharge path, thus of the surge protection device and the connected down conductors. Since this path runs over the equipotential bonding of the affected building, the objective is to keep the resistance of the equipotential bonding low. The surge voltages are transient events and thus concern the discharge of high-frequency currents. This means that it is not the ohmic but the inductive resistance that is of primary importance. According to Faraday's law, surges are again generated when surge currents are discharged to the ground potential.

$$\hat{u} = L \cdot di/dt$$

\hat{u} = Voltage along the conductor in V

L = Inductivity in H

di/dt = Increase in the current

The inductive resistance can only be influenced by changing the length of the cable or by connecting cables in parallel. For this reason, a mesh-shaped equipotential bonding that is as finely meshed as possible is the best technical solution to keep the total impedance of the discharge path and thus the residual voltage low.

One generally distinguishes between line, star and mesh-shaped equipotential bondings. In the case of an existing building, a line-shaped equipotential bonding will have to suffice in most cases. However, it is sometimes possible to achieve a star-shaped equipotential bonding by laying additional equipotential bonding cables. A mesh-shaped equipotential bonding can only be implemented in places where corresponding measures have already been taken in the building planning phase.

3.3 Different protection requirements

The necessary surge protection for the power supply and data lines is divided into three protection stages.

Interfaces in the area of data, telecommunications, and MCR technology are significantly more sensitive than the power supply input of terminal equipment. Fine protection for the data interfaces is therefore very necessary. The protective circuit is generally designed in two or one stages.

The first protection stage for the power supply is created with a lightning current arrester either at the entrance to the building, in the main distribution or in the meter board, as necessary. Since the remaining residual voltage is still too high for the downstream system areas, further protection stages have to be installed. These depend on the definition of the protection area. In downstream distributions, such as floor distribution boards or the connection boxes of large electronic systems, surge protection devices should be installed as the second protection stage. The third device protection level involves the installation of surge protection devices immediately in front of the device. A normal grounding outlet, for example, can be replaced by a grounding outlet with integrated surge protection or equipment protection that can be adapted to each range of sockets/switches

(Fig. 3.3-1). In addition, surge protection devices are available in many other designs such as plug-in adapters, socket strips or modules for rail mounting.



Fig. 3.3-1:
MAINS-PRINTRAB
Universal equipment protection for installation in cable ducts or in flush-type installations

Surge protection devices for applications in data lines have to fulfill the electrical and mechanical requirements of the corresponding interface. Examples of such protective devices are shown in Fig. 3.3-2. They contain matching coarse protection elements and fine protection elements. The decoupling resistors that are necessary for the commutation are in the protective circuits. These surge protection devices are installed in the particular protection area at the entrance of the data line. In contrast to the parallel connection method of the arresters in the power supply, the surge protection for MCR systems and for data processing equipment is connected to the transmission line in series. The corres-



Fig. 3.3-2:
Arrester for protection in data lines

ponding arresters must therefore be installed on both sides, at the transmitter as well as at the receiver of data. After the equipment and systems with the same protection requirement have been arranged together in an EMC protection zone, all of the electrical connections that enter into the protection zone are connected to protective devices that allow a residual voltage level in accordance with this protection requirement. In addition – as already mentioned as a basic prerequisite – equipotential bonding must be created between all conductive connections within each protection area.

4.0 Structure and principle of arresters

4.1 Arresters for the power supply

In surge protection for power supplies, one distinguishes between:

- Lightning current arresters (type 1 / class I)
- Surge arresters, (type 2 / class II) and
- Arresters as equipment protection (type 3 / class III)

Lightning current arresters have the strongest protection element – preferably a spark gap – which allows them to control discharge surge currents, e.g. occurring from direct lightning strikes.

Encapsulated spark gaps and open spark gaps are used as lightning current arresters (see sectional drawing 4.1-1). The arc chopping technology of an open spark gap is presented in Fig. 4.1-2. In addition to the surge arresting capacity of a lightning current arrester, the level of the line follow current (short circuit current from the current source) that an arrester can quench by itself without triggering a fuse is also especially important. Diverging electrodes (spark horns) such as those shown in the sectional drawing Fig. 4.1-2 provide very good conditions for quenching the line follow current. Line follow currents of 25 kA and more are also automatically extinguished with the technology of the encapsulated spark gap. Even fuses with very low nominal values do not respond.

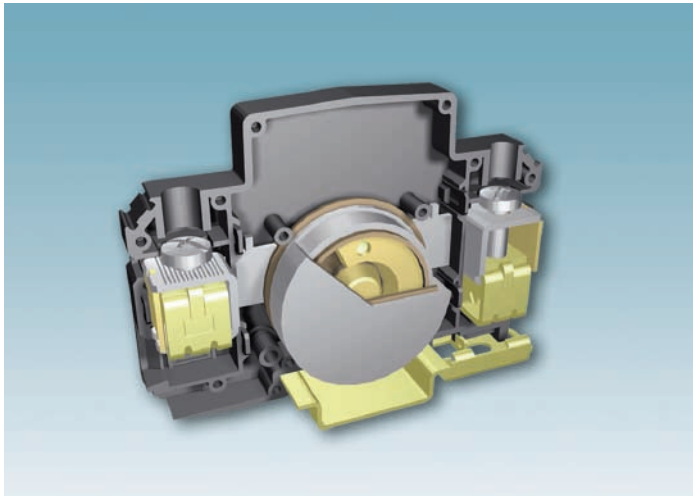


Fig. 4.1-1:
Sectional drawing: Encapsulated spark gap

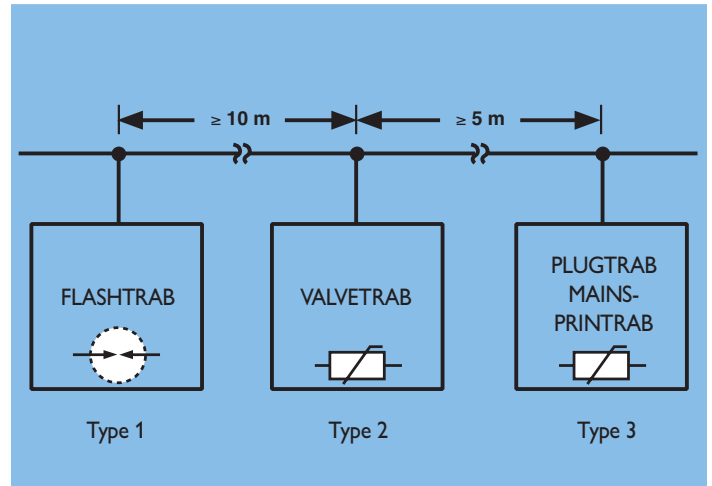


Fig. 4.1-3
Cable as decoupling element

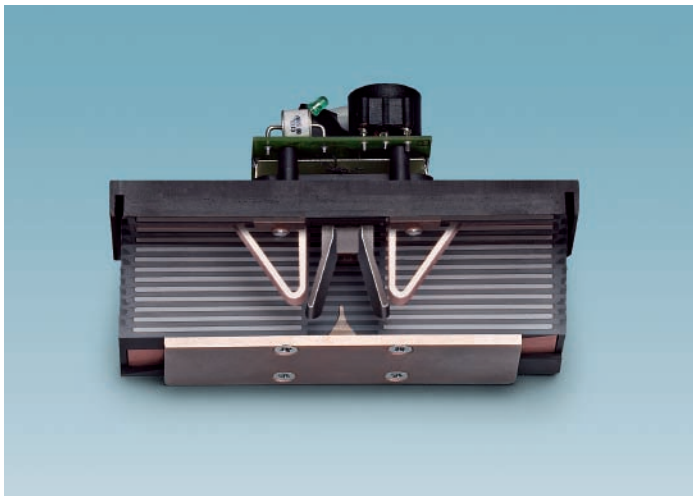


Fig. 4.1-2:
Sectional drawing: Open spark gap

Surge arresters for installation in main distributions or subdistributions have powerful varistors as surge arresting components.

Combination circuits of varistors or of varistors and gas-filled surge arresters are used in type 3 equipment protection arresters.

The gas-filled surge arresters are in series with the varistors and are jointly connected with these between L and PE or N and PE. According to various national and international standards, varistors that are operated in powerful circuits must be permanently checked for temperature increases, i.e. for flowing leakage currents. For this reason, varistors for the protection of power supplies are always equipped with thermal fuses.

Arresters for equipment protection are placed immediately before the volume/equipment to be protected. To effectively protect the power supply from surge voltages, it is necessary to position lightning current arresters, surge arresters and equipment protection decoupled from each other. Lightning current arresters and surge arresters are connected parallel to the power supply lines, i.e. between the phase conductor and ground. This prevents the power supply from being interrupted in the case of a fault in this arrester or in the fuse immediately upstream.

The arresters of various protection stages must be coordinated. Modern coordination methods enable an immediate installation of type 1 and type 2 arresters. The original coordination method requires you to adhere to the defined minimum lengths of the cable path. The distance between lightning current arresters with an operating voltage of approx. 4 kV and surge arresters with a rated voltage 275 V should not be less than 10 m. A cable path of at least 5 m is recommended between surge arresters and device protection. The required decoupling lengths are given in Fig. 4.1-3. If the conductor path is affected by surge currents, a voltage is built up in the conductors due to the self-inductance. The sum of this voltage and the arrester threshold voltage, e.g. of a surge arrester, results in the necessary operating voltage for the arrester in the upstream protection stage, e.g. a lightning current arrester. In this way, the discharge current commutes from the weaker arrester to the more powerful arrester. If the spark gap has been triggered in the lightning current arrester, it takes over the surge current completely. The discharge current is commuted in the same way as described later in "Combined protective circuits". The energetic coordination between the surge arrester and the lightning current arrester can be implemented in a particularly advantageous way with controlled spark gaps. The technology that is used is called AEC and is described in the chapter "Interaction of the installation of the surge protection in the power supply" on page 17. In addition to the protection for power supplies, protection must also be supplied in data, MCR and antenna lines. Surge arresters for these applications usually have multi-stage protective circuits with components of various capacities and different protection levels.

4.2 Component for multi-stage protective circuits for Information technology conductors

4.2.1. Surge arresters filled with inert gas

Surge arresters filled with inert gas (gas-filled surge arresters) are used as a coarse protection element. The most commonly used types can discharge transient currents up to 10 kA (8/20) μ s (Fig. 4.2.1-1).

However, there are also arresters filled with inert gas with nominal discharge currents of up to 100 kA (10/350) μ s.

Discharge currents greater than 10 kA (8/20) μ s are also not to be expected in such information technology lines; the connected cables have relatively small cross-sections that often have no more current carrying capacity for the transients. The gas-filled surge arrester, which has operating times in the middle nanosecond range and has been in use in the telecommunications field for several decades, not only has advantages. One disadvantage is the time-dependent ignition behavior (Fig. 4.2.1-2). Transients with long rise times (e.g. $du/dt \sim 100$ V/s) intersect the characteristic ignition curve in the area that runs almost parallel to the time axis. A protection level that is roughly as high as the nominal voltage of the gas-filled surge arrester is therefore to be expected. Especially fast transients, however, intersect the characteristic ignition curve at a point at which the voltage can be ten times the amount of the nominal voltage of the gas-filled surge arrester. In the case of 75 V, the smallest nominal voltage of a gas-filled surge arrester, this fact would still

mean a residual voltage of 750 V. Another disadvantage is a potentially occurring line follow current. If the gas-filled surge arrester has ignited, a low-impedance circuit in particular, with voltages over 24 V is able to maintain the short circuit, which is actually only desired for a few microseconds, through the gas-filled surge arrester. As a result, the gas-filled surge arrester would explode within fractions of a second. In surge protection circuits where gas-filled surge arresters are used, it is therefore necessary to connect a safety fuse upstream that interrupts the circuit without delay.

4.2.2. Varistors

The use of varistors causes the remaining residual current to decrease further after the high currents have been discharged.

Varistors that are approximately the same size as a gas-filled surge arrester are not able to discharge such high currents. However, they react faster, with operating times in the bottom nanosecond range, and do not have the problem with line follow currents. In protective circuits for MCR circuits, varistors are used with discharge currents of around 2.5 kA to 5 kA (8/20) μ s. These varistors, however, have larger dimensions than the gas-filled surge arresters with 10 kA (8/20) μ s discharge current. More significant disadvantages are the aging of varistors and the relatively high capacity. Aging refers to the failure of diode elements within the varistor. Since the pn transitions cause a short circuit in most

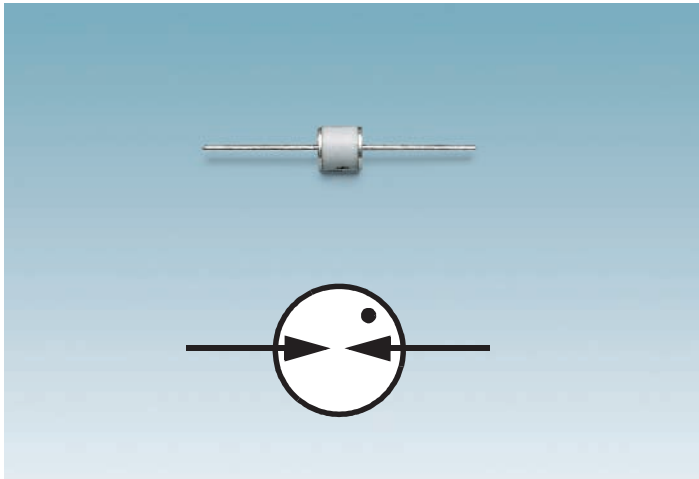


Fig. 4.2.1-1: Gas-filled surge arrester

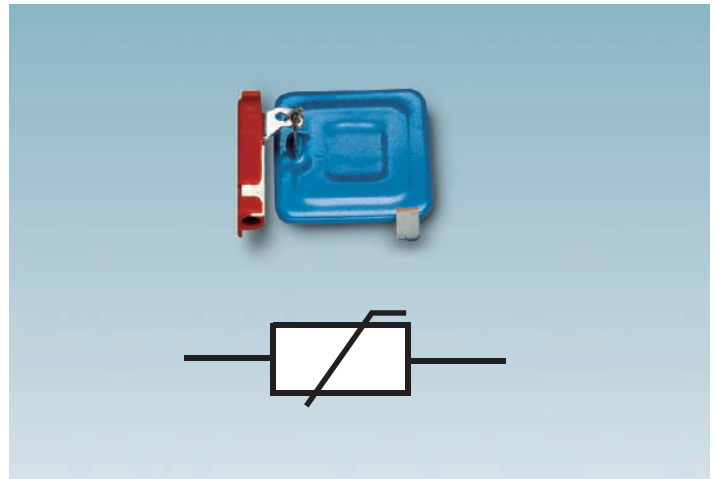


Fig. 4.2.2-1: Varistor

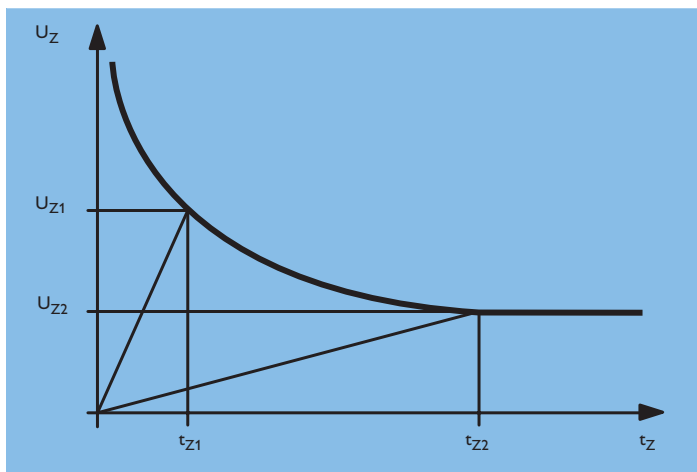


Fig. 4.2.1-2: Characteristic curve of a gas-filled surge arrester

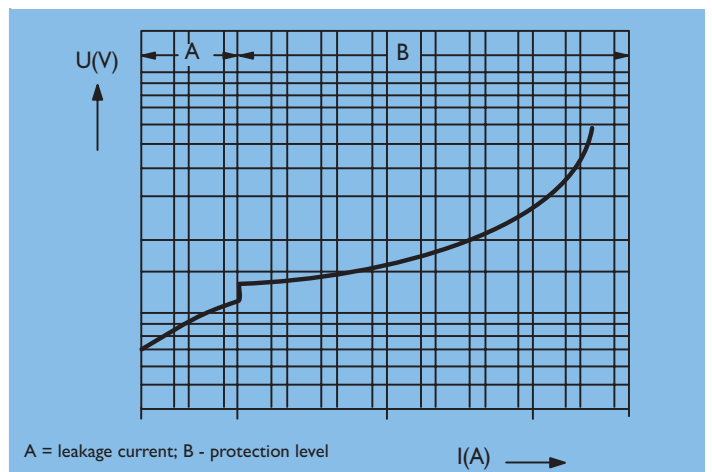


Fig. 4.2.2-2: Characteristic curve of a varistor

cases when an overload occurs, a varistor will begin to draw leakage currents depending on the frequency of its loading. These leakage currents can cause distorted measurement data in measurement circuits and – particularly in the case of circuits in the power supply – a high rise in temperature. The high capacitances of varistors rule out their use in data transmission lines with high frequencies in many cases. Together with the inductance of the conductor, these capacitances form a low pass, which then leads to high attenuation of the signals. However, at frequencies up to around 30kHz, this attenuation is almost insignificant.

4.2.3. Suppressor diodes

Due to the low dielectric strength of sensitive electronic circuits, the protection level that is achieved with a gas-filled surge arrester or a varistor is still frequently too high. For this reason, an additional stage has to be included in the protective circuit. Suppressor diodes that react very fast are used as a fine protection element (Fig. 4.2.3-1 and Fig. 4.2.3-2). The response times extend into the picosecond range. The voltage threshold, which is around 1.8 times the nominal voltage, is also advantageous. Nevertheless, these diodes also have disadvantages: the low current carrying capacity and the relatively high capacitance. In the case of nominal voltages of 5 V DC, the maximum discharge current is

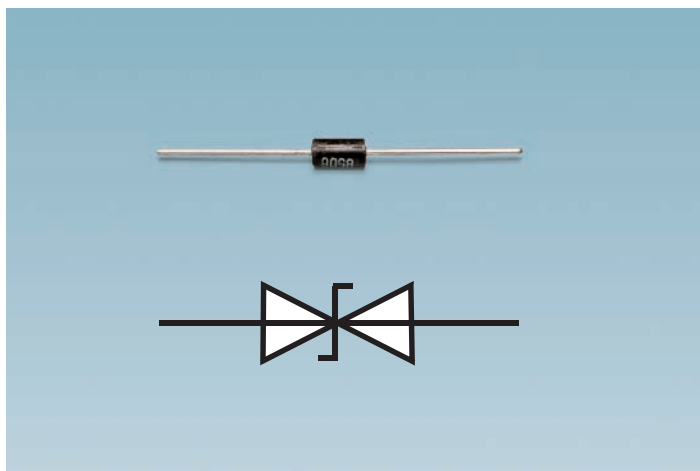


Fig. 4.2.3-1: Suppressor diode

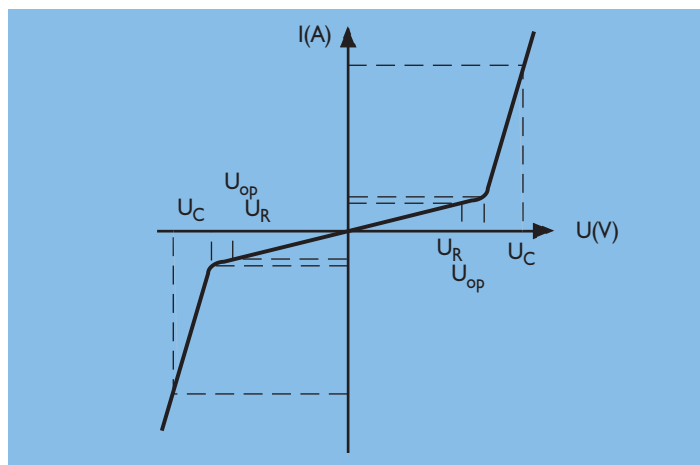


Fig. 4.2.3-2: Characteristic curve of a suppressor diode

around 600 A; with special diodes, it can even be up to 900 A (8/20) μ s. Higher nominal voltages only allow currents of a few 10 A. Suppressor diodes also have self-capacitance. This increases with a decreasing nominal voltage. In connection with the inductance of the connected cables, a low pass is formed here as well. Depending on the signal frequency of the connected circuit, the low pass has a damping effect on the data transmission.

4.2.4 Combined protective circuits

The aim is obviously to exploit the advantages of the individual components – gas-filled surge arrester, varistor, suppressor diode – and eliminate the disadvantages. To do this, indirect parallel circuits of these components are used with decoupling impedances. Such a circuit, which can be found in specialist literature as well as information material on the Phoenix TRABTECH arrester range, is shown in Fig. 4.2.4-1.

When a surge voltage occurs, the suppressor diode operates first as the fastest component. The circuit is designed so that when the amplitude increases, the discharge current commutes to the upstream discharge path, i.e. to the gas-filled surge arrester, before the suppressor diode can be destroyed.

$$u_S + \Delta u \geq u_G$$

u_V Voltage over the suppressor diode
 Δu Differential voltage over the decoupling inductance
 u_G Operating voltage of the gas-filled surge arrester

If the current increases and the discharge current remains smaller, then the gas-filled surge arrester does not operate.

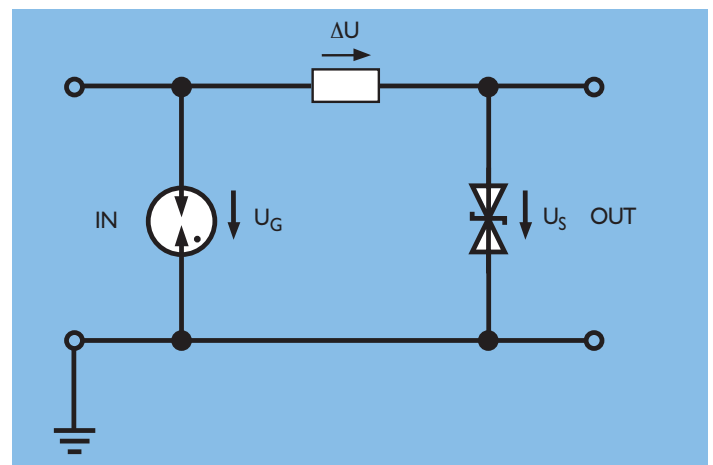


Fig. 4.2.4-1: Block diagram of an arrester

This circuit provides the advantages of fast operating surge arresters with a low voltage threshold as well as a high surge arresting capacity at the same time. The disadvantages of overloading the suppressor diode and frequent disconnection of the circuit by the fuse when a line follow current occurs have been eliminated. Circuits for higher frequencies use ohmic resistors as decoupling impedances and work with low-capacity bridge circuits. In the case of surge arresters that are to be connected in series, such as in measured-value and data processing, the input and output of the protection module are marked. This is accomplished with the words "IN" and "OUT". During installation, make sure that "IN" points in the direction from which the surge voltage is expected. The cables to the volume to be protected are connected on the "OUT" side.

4.2.5 Designs with numerous advantages

The entire protective circuit is then arranged in a housing that provides the user with numerous advantages for installation and maintenance. Such advantages are:

- Two-part design consisting of base element and connection plug. If the surge arresting elements in the plug are overloaded, they can be replaced without interrupting the circuit.
- The component can be conveniently tested with a special test device to prevent lengthy laboratory tests.
- Arrangement of the decoupling impedances in the base to keep the measuring circuits impedance-neutral even during the test process or during replacement.
- Polarization of the plugs and base elements to prevent confusion of "IN" and "OUT".
- Use of a grounding foot that simultaneously creates the connection to the ground during installation.

A surge arrester that combines these and other advantages and can be used for measurement or information processing circuits depending on the internal circuitry is shown in Fig. 4.2.5-1. Other arrester designs are characterized by the fact that they use the same physical connection technique as the equipment that must be protected. This is generally the case, for example, with surge arresters that are inserted in the cable like an adapter. Surge arresters with familiar connectors are shown in Fig. 3.3-2.

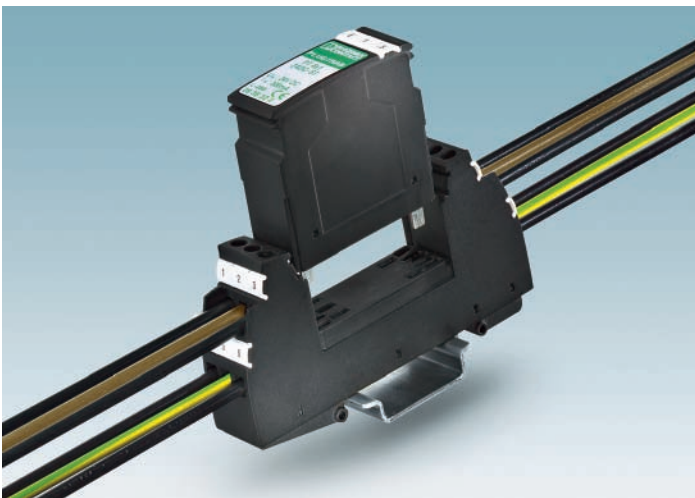


Fig. 4.2.5-1:
MCR-PLUGTRAB

5.0 Protection concept and selection of arresters

5.1 Comprehensive surge protection concept

The first step in planning a protection concept is to detect all devices and areas of the system that must be protected. The required protection level is then determined for the devices. A comprehensive surge protection concept can only be achieved when all electrical circuits occurring in a surge protection area are included in the equipotential bonding by connecting suitable surge arresters. Such electrical circuits are, for example:

- Power supply lines
- Lines of measurement and control systems
- Network/data lines
- Telecommunications transmission lines
- Antenna lines from transceiver systems
- As in figure 5.1-1, an imaginary protective circuit must therefore be laid around the entire area to be protected.

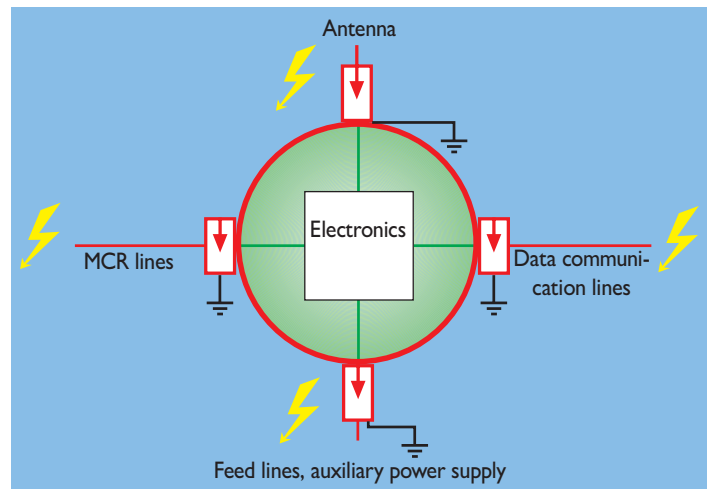


Fig. 5.1-1:
Effective protective circuit

The area within the protective circuit is planned so that it is not possible for surge voltages to couple from outside, and different electrical circuits such as power supply and data lines are also not able to influence each other within this area. It would be thus be possible to use floor ducts with grounded metal frames instead of plastic window ducts. Power supply and data lines must be laid shielded from each other in separate ducts.

After all electrical circuits that enter or leave this surge protection zone have been led through suitable surge arresters, all conductive parts such as pipework, for example, are also connected to the equipotential bonding.

Depending on how early on the surge protection concept can be integrated in the building and electrical planning phase, such a surge protection zone can affect an entire building, a room, part of a room or only a single computer. If only a single computer, perhaps even one working in isolated operation, is to be protected, it is not economical to extend the surge protection zone to an entire room or a building. However, later expansion of electronic systems should be considered from the outset.

In practice, two steps have proven useful in the planning and installation of surge protection:

1. Selecting the surge arresters according to the dielectric strength of the electrical and electronic systems.
2. Defining the correct installation location by dividing the entire volume requiring protection into surge protection areas.

5.2 Selection of the surge arresters

For power supply systems, the values for the impulse withstand voltage of the insulation are given in DIN VDE 0110 (Table, Fig. 5.2-1). Rated voltages in stages up to 1000 V are classified into surge voltage categories I to IV. Each surge voltage category is assigned a dielectric strength according to the nominal voltage. The nominal voltage here is based on the voltage between the phase conductor and PE. For 230/400 V three-phase systems, this means that the conductor-PE voltage of 300 V should be used to assign the rated surge voltage. It is then interesting to note that terminal equipment in the power supply still has to have a dielectric strength of 1500 V. When creating a surge protection concept, it is therefore fully sufficient to orient oneself according to a residual voltage of approx. 1000 V at the input of the equipment, while taking into account a respectful distance to these 1500 V. This is also the reason why a so-called fine protection, which limits the surge voltages to values of around $2 \times U_N$, is not necessary in the 230/400 V power supply.

According to DIN VDE 0110, a dielectric strength of 2500 V is required between the termination device and the sub-distribution. This requirement is fulfilled if a surge protection device is installed in the subdivision as second protective stage. Fig. 5.2-2 shows a surge arrester that fits the given space and installation conditions in the distribution in every respect.

To discharge the high currents, which could result from a lightning strike for example, lightning current arresters are installed in the main distribution or in the incoming supply system in the building. The lightning current equipotential bonding is also carried out in this area.



Fig. 5.2-2:
VALVETRAB VAL-CP

In accordance with DIN VDE 0110, only a residual voltage of 4000 V may exist between the main distribution and the subdistribution. The surge arrester must be selected accordingly and in respect to the expected discharge currents.

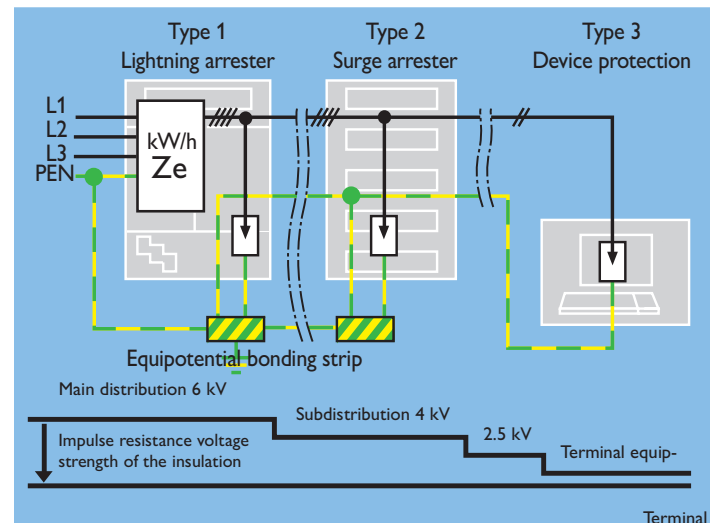


Fig. 5.2-3:
Insulation coordination in acc. with DIN VDE 0110/part 1

Fig. 5.2-3 shows the dielectric strengths according to DIN VDE 0110 from the incoming building supply to the terminal equipment and the site of the surge arresters to be installed.

A similar table for data processing and data transmission equipment as well as for MCR systems does not exist in the regulations. When selecting the surge arresters for the surge protection of MCR systems, one should therefore observe the manufacturer's information regarding dielectric strengths. Since the European EMC law went into effect in 1996 (and subsequent supplements and modifications), these values can be determined relatively easily, since the manufacturers of electronic equipment are required to adhere to minimum dielectric strengths according to IEC 61000-4-5.

However, not only the dielectric strengths are interesting for selecting surge arresters for MCR systems. Very decisive factors for the subsequent installation are the physical connection conditions (plug connections, terminal blocks), the possibilities for mounting (mountable on

Conductor PE voltage in V	Rated surge voltage in V (1.2/50) Surge voltage classes / DIN VDE 0110/1			
	I	II	III	IV
50	330	500	800	1500
100	500	800	1500	2500
150	800	1500	2500	4000
300	1500	2500	4000	6000
600	2500	4000	6000	8000
1000	4000	6000	8000	12000

Fig. 5.2-1:
Impulse withstand voltage according to DIN VDE 0110

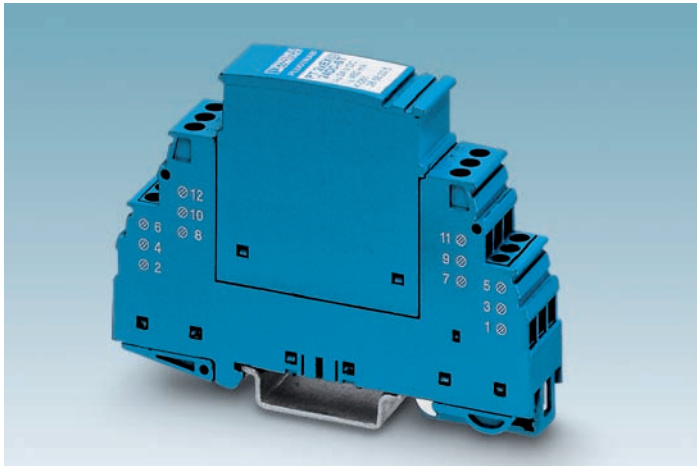


Fig. 5.2-4:
PLUGTRAB PT
Double conductor protection for 2 EEx ia circuits

DIN rails, adapters) and also the current carrying capacity of the surge arrester as well as the transmission frequencies.

In regard to the necessary operational safety, the circuits of EEx ia systems are considered to be especially sensitive. Above all the total inductance and the total capacitance of such circuits, incl. all associated electrical equipment, must not exceed set limit values. For this reason, the values of the inner capacitance C and the inductance L of surge arresters that are to be used to protect EEx circuits must be taken into account. The installation then takes place in accordance with DIN VDE 0165 and DIN VDE 0170/0171 or the national regulations of other countries or international regulations (EN 50020). The electrical planning is simplified considerably when a surge arrester is used that already fulfills these requirements, as shown in Fig. 5.2-4.

The surge arrester contains a protective circuit according to Fig. 5.2-5, which fulfills all the requirements of the standard.

It is considerably easier to select surge arresters for the data processing area than planners and installation technicians of these systems think. The Phoenix TRABTECH range offers a wide selection of surge arresters that are already adapted to the electrical and physical conditions of all common data transmission interfaces. It is therefore only necessary to determine the interface that is used and to select the corresponding surge arrester from the interface matrix in the catalog. The user does not need to take into account the pin assignments, mechanical connection conditions, transmission frequencies, voltages and currents. These values were all taken into account during development of the surge arrester. Examples of surge arresters for standardized interfaces that already contain currents, frequencies, and dielectric strengths are shown in Fig. 3.3-2.

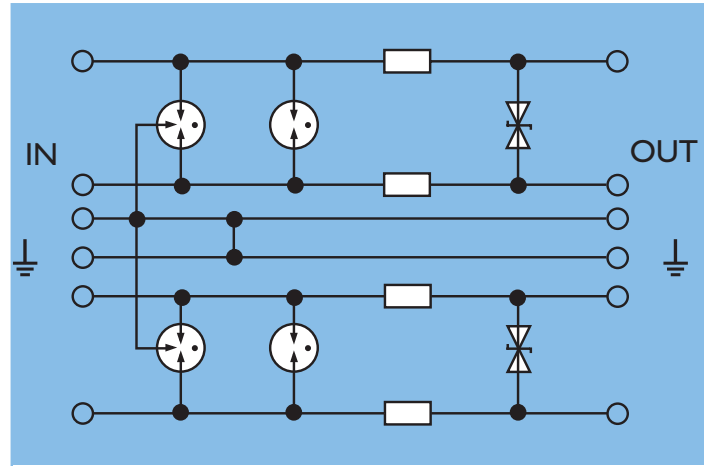


Fig. 5.2-5:
Circuit PT 2xEX(I)-24DC

6.0 The installation of surge arresters

6.1 Division of installation locations into EMI protection zones

After the correct surge arresters have been selected, it is necessary to determine the most favorable installation site for the protective effect and the volume to be protected. It has been shown that the best way to do this is to divide the volume to be protected into four EMI protection zones 0-3:

Zone 0:

Outside of the building; direct lightning strikes; no shielding against LEMP; (lightning protection zone)

Zone 1:

Inside the building; powerful transients from switching operations (SEMP), and partial lightning currents (surge protection zone 1)

Zone 2:

Inside the building; less powerful transients from switching operations (SEMP) and electrostatic discharges (ESD); (surge protection zone 2)

Zone 3:

Inside the building; no generation of transient currents and voltages over the interference limit; shielding and separate laying of circuits that could influence each other; (surge protection zone 3)

0 refers to the area of the strongest electromagnetic interference – a direct lightning strike is possible here – and 3 refers to a room in which no more interference over the destruction limit of even sensitive equipment and systems can occur. The areas 1 and 2 are located inbetween, according to the dielectric strengths of the electrical equipment and systems installed there and their resulting resistance to electromagnetic interferences.

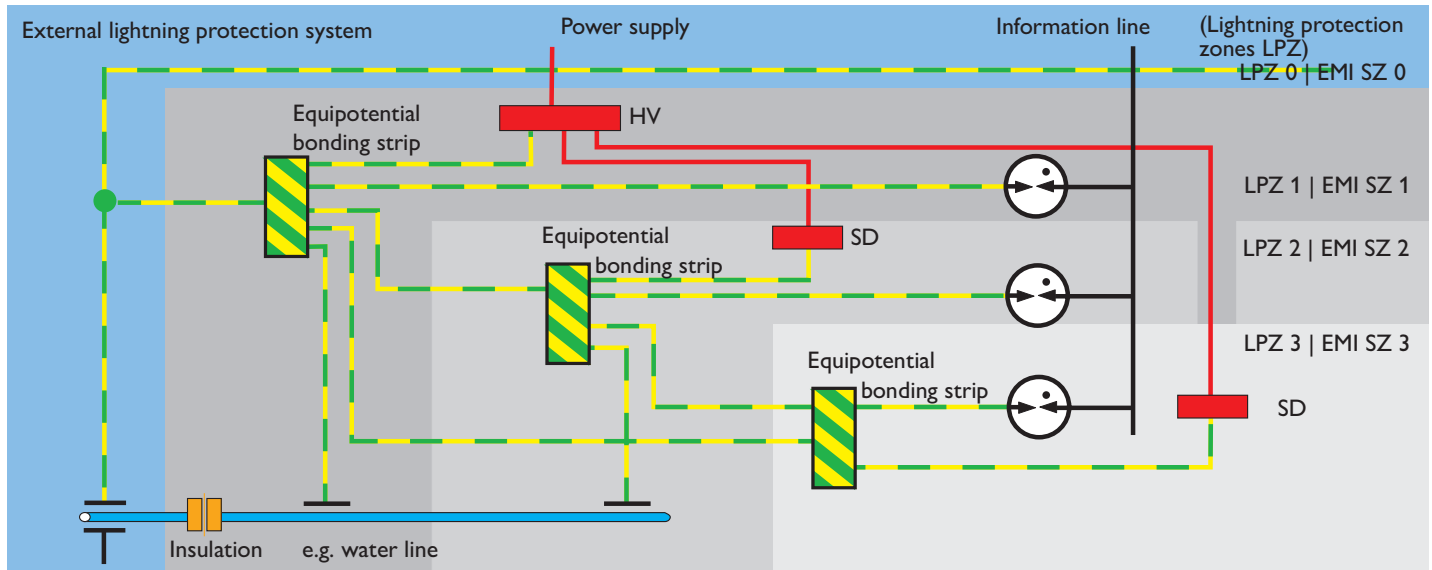


Fig. 6.1-1: Division and realization of surge protection zones

The system to be protected can be divided into EMC protection zones by developing a concept according to Fig. 6.1-1. The main equipotential bonding is created at the transition from the surge protection stage 0 to 1. All electrical connections and conductive connections that enter this surge protection zone are brought to the same potential by connecting them to the equipotential bonding bar. Active conductors of power supplies, data transmission systems and MCR equipment are placed directly on the grounding busbar (GB) through spark gaps or gas-filled surge arresters and passive conductive connections (PE, water line etc.). According to DIN VDE 0100 Part 540, the water line may only be used as a "natural" grounder under special circumstances, but it must be included in the equipotential bonding. Outside of Germany, the applicable national regulations must be observed.

In the EMC protection zone 2, you should proceed in the same way and contact all the above-mentioned connections on the local sub-grounding busbar. Passive, conductive parts are connected directly. The active conductors must be included in the equipotential bonding with surge protection devices. The sub-GB must be connected to the main-GB in the EMC protection zone 1 in the shortest and most direct way.

A sub-GB must also be installed at the transition to the EMC protection zone 3. The equipotential bonding is created in the same way as described previously.

In Fig. 6.1-1, the water line does not extend into the EMC protection zone 3. It is therefore not included in the equipotential bonding of this protection zone.

The active conductors of the power supply are also connected to the equipotential bonding with varistor-based surge voltage protective equipment in the EMC protection zone 3; data lines and MCR lines, however, require a narrowly limiting protection using suppressor diodes in most cases.

An equipotential bonding line is used to create the shortest possible connection to the grounding busbar in the surge protection zone 1 as well as to other sub-grounding busbars. In this way, a mesh-shaped equipotential bonding is created.

In practice, a two or three-stage surge protection for MCR and data interfaces is almost always realized with a combined protective circuit in a surge arrester directly at the entrance to the surge protection zone for technical installation reasons. This eliminates the gradual reduction of the surge voltage in the EMC protection zones 1 and 2. Within the

EMC protection zone 3, power supply lines and information lines are then laid separately from each other or shielded.

If electronic systems connected through data lines do not need as much protection, these feed lines must be laid separately from the other data lines or shielded.

This concept automatically leads to the correct place to install the surge arresters. All electrical equipment and systems must then be placed in the relevant EMC protection zone. In this case, it does not matter whether a protection zone is created around an entire room or only around a single device.

All EMC protection zones 1-3 can occur several times. From an economical point of view, it is wise to design the concept so that as many devices and systems as possible with the same protection requirement can be arranged in a protection zone. Such a successful surge voltage concept can only be achieved if it is already taken into account in the planning phase (see chapter "Ensuring surge protection when planning").

6.2 Installation instructions for surge protection devices in the power supply

6.2.1 Lightning arrester, type 1 FLASHTRAB

The connection of a lightning current arrester is shown in Fig. 6.2-1 using the FLASHTRAB FLT-CP-3S 350 as an example. This arrester is a protective device that implements protection of type 1 as well as also type 2. For the installation, please note the following:

- FLASHTRAB is arranged parallel, i.e. between the phase conductor (or neutral conductor) and the equipotential bonding, in the power supply. This means that operating current does not flow through the FLASHTRAB. Fig. 6.2.1-1 shows general installation requirements. The installation instructions for lightning current arresters and surge protection equipment in various power supply systems depending on the type of grounding (Fig. 6.2.1-2 to 6.2.1-5) must also be observed.
- For subsequent maintenance work and greater availability of the power supply, the lightning current arrester FLASHTRAB should be installed with an additional back-up fuse F2 that guarantees an over-current discrimination to F1. This is regarded as fulfilled for fuses according to DIN VDE 0636, if the rated current values for F2 to F1 are in the ratio 1:1.6; in other words, F1 must be two fusing stages higher.

her than F2. If F2 blows due to disproportionately high line follow currents, the equipment will still be operational through F1. Due to the surge strength of fuses, it is usually not sensible to select an F2 that is less than 63 A. If F2 has responded, FLASHTRAB will be switched off, cancelling the protection for the cable in question. Consequently, we recommend that this be monitored in conjunction with a signaling device in case F2 blows.

- The values of the maximum permissible back-up fuse (F2) and the connection cross-sections are documented in the Phoenix Contact catalog "TRABTECH Surge Protection".

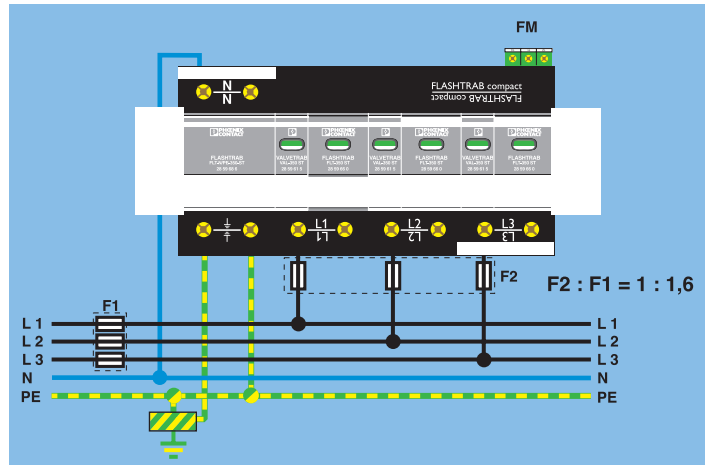


Fig. 6.2.1-1: FLASHTRAB compact FLT-CP-3S 350

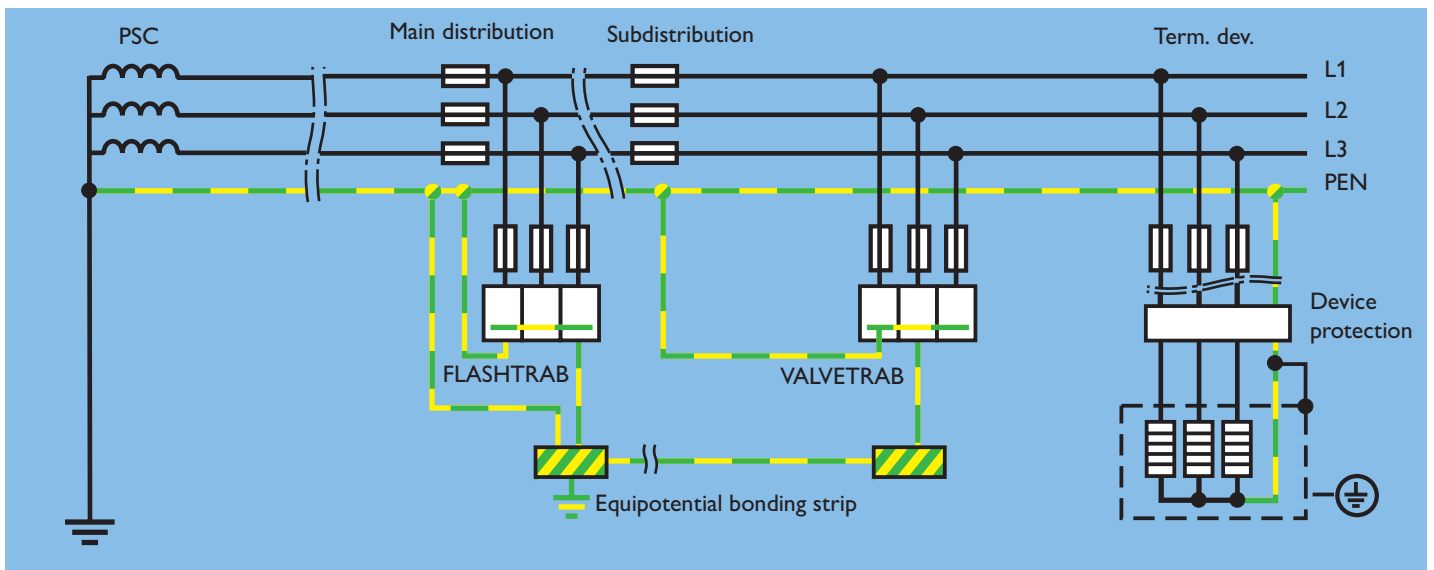


Fig. 6.2.1-2: TN-C system with PEN conductor, > 6 mm² (classic multiple protective earthing)

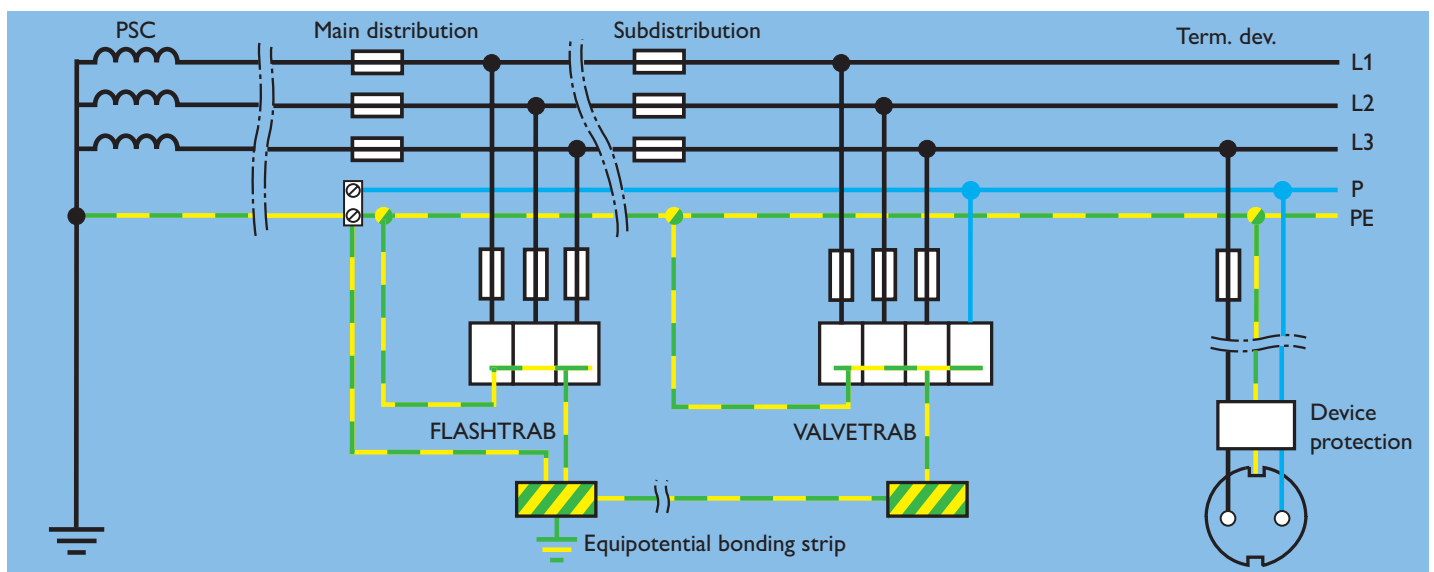


Fig. 6.2.1-3: TN-C-S system with PEN conductor and separate N/PE conductor (modern TN system)

- FLASHTRAB should be arranged directly at the incoming supply system of the building. It is recommended to install the lightning current arrester before the meter. However, only a FLASHTRAB that contains type 1 arresing paths based on spark gaps may be selected. Installation in the sealed area requires the permission of the responsible local public utility company. The VDEW has issued a guideline for using the surge protection devices in the area of the intermediate meter. Surge protection devices in the area of the intermediate meter.
- Most FLASHTRABs can be used in 50 Hz and 60 Hz AC and three-phase networks that have a maximum operating voltage of 440 V between the phase conductor and ground. Observe the maximum approved rated voltage.

When installed in TT systems, lightning current arresters and surge arresters (before residual-current-operated circuit breakers, of course) must be arranged in a "3+1" circuit. This means that either a FLASHTRAB or a VALVETRAB is connected from each phase to N.

This group of three is also connected from N to PE via a total surge cur-

rent spark gap (Fig. 6.2.1-5).

The total surge current spark gaps are characterized by a high surge current arresting capacity. However, they are not able to quench high line follow currents by themselves – which is not necessary in this application.

6.2.2 Surge arrester type 2 VALVETRAB VAL-MS and VAL-CP

- VAL... is connected in parallel, i.e. between the phase conductor or neutral conductor and PE, to the power supply system (Fig. 6.2.2-1).
- If F1 fuses exceeding 125 A gL are used on the supply side, VALVETRAB requires an additional back-up fuse.
F2 ≤ 125 A gL upstream. The blowing of this fuse leads to the disconnection of VALVETRAB. In this case the protective effect is eliminated. Consequently, we recommend that this is monitored in conjunction with a signaling device in case F2 blows.
- The connecting terminal blocks of VAL-MS are designed for a max. of

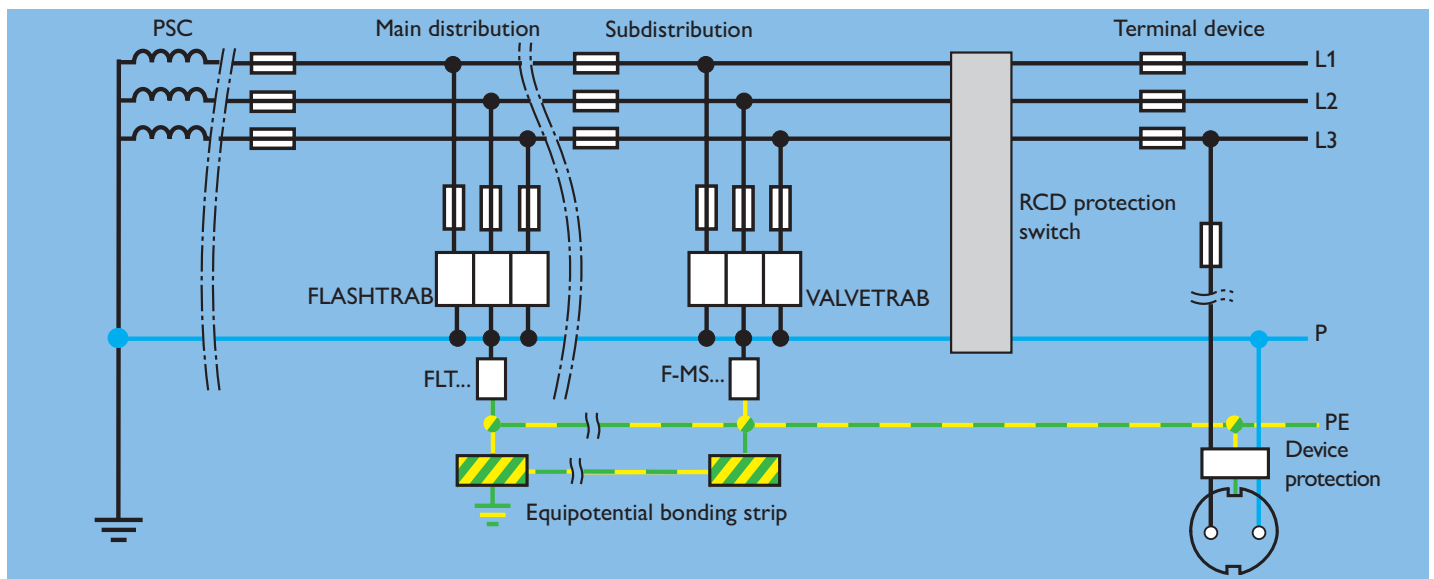


Fig. 6.2.1-4: TT system with fault current circuit breaker as safety equipment

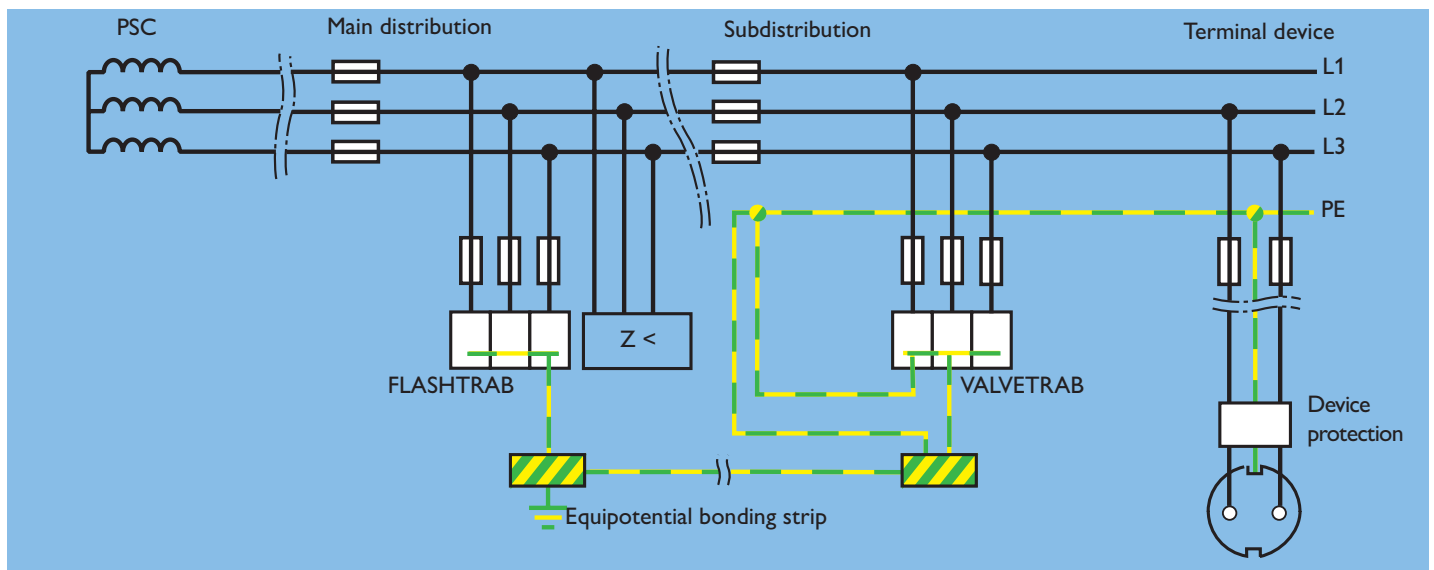


Fig. 6.2.1-5: IT system with insulation monitoring equipment (protective conductor system)

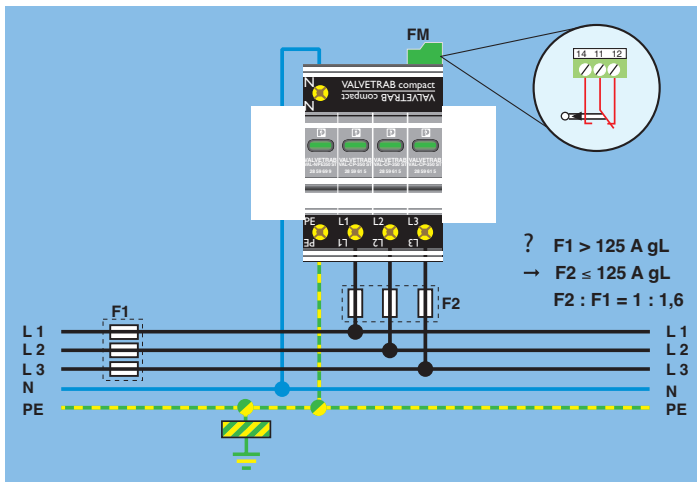


Fig. 6.2.2-1: Installation of VALVETRAB



Fig. 6.2.2-2: Arrester block VAL-CP-3S...

35 mm² and for max. of 25 mm² for VAL-CP. The connection cross-sections result from the switch-off conditions according to VDE 0100, depending on the back-up fuse used. They are at least 6 mm².

- In the TN-C system (PEN conductor), VAL... must only be installed for L1, L2 and L3.
- It is possible to install VAL... in the main distribution as well as in the subdistribution. The VAL... is installed in the main distribution when no lightning current arrester is planned for the system to be protected or when a lightning current arrester has already been placed before the meter. When it is installed in the subdistribution, VAL... forms the second protection stage.
- When the optionally available VAL... with remote indicator contacts (PDT) is used, the disconnection of the protection element can be signaled externally.
- VAL... is used in DC and AC networks with maximum operating voltages up to the rated surge arrester voltage (see catalog).
- For the "3+1 circuit" that is required in TT power supply systems, the Phoenix Contact range of TRABTECH surge arrester products offers a prewired, easy to install solution. There are two versions to choose between: VAL-CP-3S... with only 12 mm design width per channel (Fig. 6.2.2-2) and VAL-MS-3+1... with 17.5 mm per channel in accordance with 1TE (Fig. 6.2.2-3). The "3+1" circuit and thus these surge arrester blocks as well can also be advantageously used in TN-S power supply systems.

6.2.3 Device protection, type 3

The equipment protection, which reduces the remaining residual voltage further and additionally limits the normal mode voltage, can be created using surge arresters with various designs and connection conditions from the Phoenix TRABTECH range.

The equipment protection is generally connected in series to the power supply. The surge arresters are designed so that the surge arresting components are arranged between the phase conductor or neutral conductor and ground (PE) as well as between the active cores L and N.

- When surge arresters are connected in series for the equipment protection, the maximum operating currents must be observed.



Fig. 6.2.2-3: Arrester block VAL-MS...3+1

6.2.4 Interaction of various arrester types in the power supply

The conductor lengths given in Fig. 4.1-3 are valid for the distances of the surge arresters in the conductor path between the type 1 lightning current arrester, the type 2 surge arrester and the type 3 equipment protection. A lightning current arrester alone cannot provide sufficient protection in any case. It is necessary to install at least a second protection stage that is realized with surge arresters in the same or the following distribution. If a line path distance of 10 m is not available between the lightning arrester and the surge arrester, the FLASHTRAB compact FLT-CP... arresters (Fig. 6.2.4-1) offer an ideal solution under technical and economical aspects. Using this arrester combination makes it possible to connect the lightning current arrester and the surge arrester in parallel directly without any conductor spacing. This is possible, since lightning arresters triggered in the arrester combination are used at a low ignition voltage. The technology of this controller board is called AEC (Active Energy Control). This considerably improves the interaction of the surge arresters in comparison to coordinating the surge arresters using the required conductor lengths. The switching diagram is shown in Fig. 6.2.4-2.

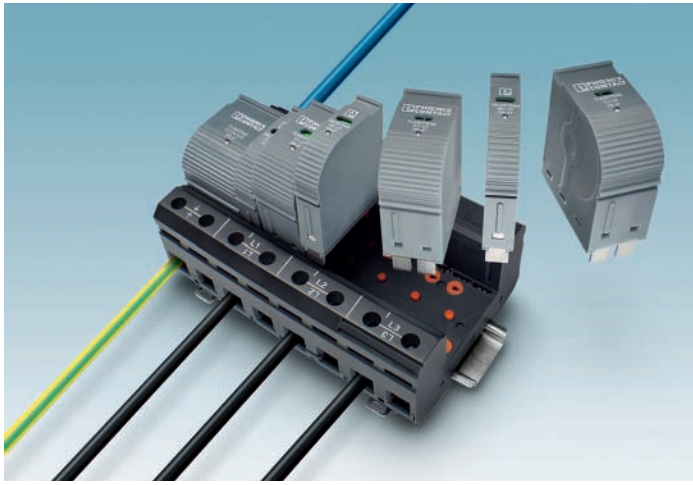


Fig. 6.2.4-1:
Puggable type 1+2 FLASHTRAB compact arrester combination

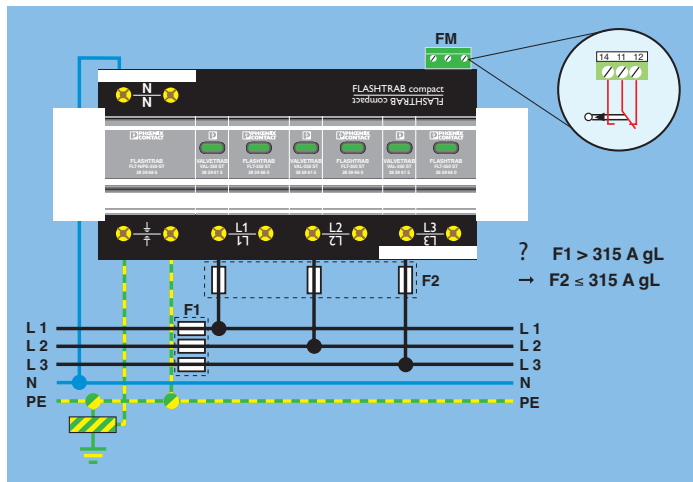


Fig. 6.2.4-2:
Coordinated installation of type 1 and type 2 arresters in the AEC technology with FLASHTRAB compact

If the equipment to be protected (volume to be protected) is more than 5m away from the feed distribution or if smaller residual voltages require more protection, additional equipment protection must be provided. The decoupling between the surge arrester in the distribution and the equipment protection must then be provided by a conductor path of at least 5 m.

In addition to the conductor entry of the PE conductor in the power supply, which is present to begin with, it is necessary to create an equipotential bonding between the subdistributions – in the case of industrial plants up to the volume to be protected. For this reason, each sub-distribution should have a grounding busbar that is connected with all other grounding busbars via a separate equipotential bonding conductor system and via the PE to connect the surge arresters. The equipotential bonding system should be meshed, in other words have a low impedance. The equipotential bonding cables must be laid with at least 6 mm² Cu.

6.2.5 1.5 Interaction of the surge arresters with residual-current-operated circuit breakers

Using surge current-resistant RCE circuit breakers is a basic requirement when installing surge arresters. Surge arresters must be arranged before RCD circuit breakers viewed from the direction of the power supply. In this way, the surge current is discharged to ground before the residual-current-operated circuit breaker. This minimizes the triggering of the circuit breaker and damage.

If residual-current-operated circuit breakers have biconnect terminal blocks, such as the surge arrester VAL-CP / VAL-MS... does, an easy-to-wire and cost-saving installation can be realized with suitable bridge systems.

6.3 Installation instructions for protective devices in MCR systems

All surge arresters that contain multi-stage protective circuits and are added to the electric circuit in series are marked with the words "IN" and "OUT" (Fig. 5.2-5). "IN" is always the unprotected side and points in the direction from which the surge voltage is expected. The protected side "OUT" points to the volume to be protected (see also the chapter "Combined protective circuits", chapter 4.2.4).

The surge arresters for MCR circuits must be selected from 5 V DC on up for different nominal voltages in the TRABTECH catalog. When voltage signals are transmitted, the nominal voltage of the surge arrester depends on the amount of the voltage signal.

In current loops (e.g. 4-20 mA), the actual voltage that occurs depends on the total resistance of the circuit. This resistance is often referred to as load "R_B". The voltage according to which the surge arrester should be selected then results from:

$$U = R_B \cdot 20 \text{ mA}$$

If this formula yields a value that is not a nominal voltage value of the surge arrester proposed, the surge arrester with the next highest nominal voltage should be selected. The surge arresters of the TRABTECH range are designed equally for AC (alternating current) and DC (direct current). The type of the module determines the circuit for the surge arrester. Modules of the same type only differ in the operating voltages and protection levels. The values for the AC and DC nominal voltage only differ in the peak factor.

$$U_{nenn} = \sqrt{2} \cdot U_{effek-}$$

A 24 V PLUGTRAB PT can also be used in systems up to 34 V DC by this method.

The required protective effect can only be obtained when the PE/GB connection of the volume to be protected is directly connected with the base point or earthing point of the surge arrester.

Fig. 6.3-1 shows the correct connection. Attention: If the protective equipment and the volume to be protected are connected as shown in Fig. 6.3-2, the path of the discharge current to GB in accordance to the formula,

$$u = L \cdot di/dt$$

will yield another surge voltage as a common mode voltage. This voltage would then be supplied to the electronic system by a separate ground connection.

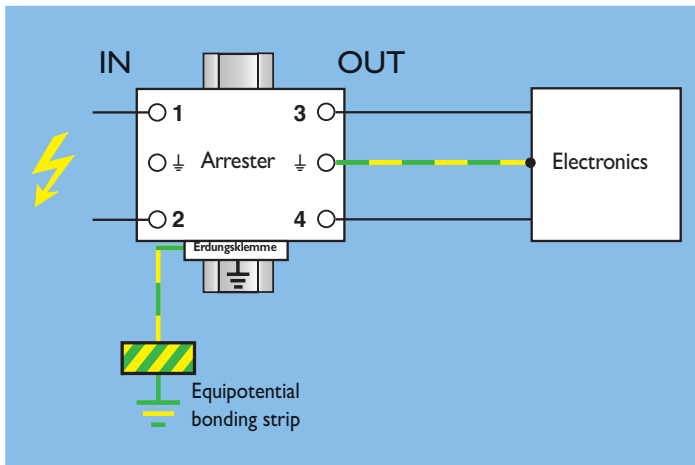


Fig. 6.3-1:
Correct PE/GB connection

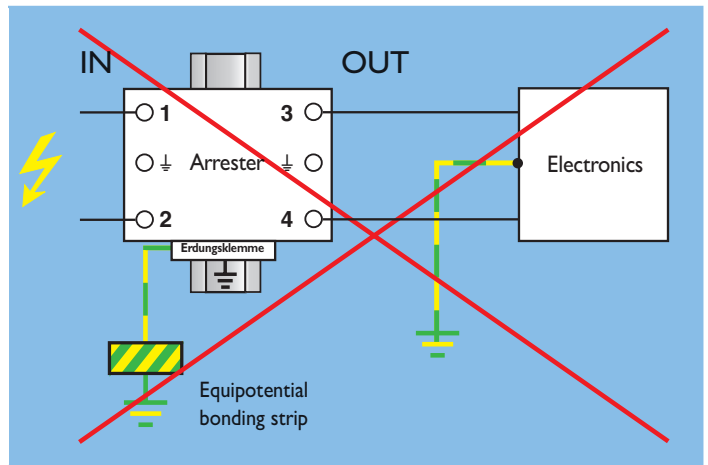


Fig. 6.3-2:
PE/GB connection incorrect

Gas-filled surge arresters can only interrupt current to a limited extent by themselves. If the surge arrester is triggered with a nominal voltage of 12 V DC and nominal currents of 100 mA, excessive follow currents can be expected. In such circuits, a safety fuse must be connected upstream from the surge arrester as a quenching aid. The nominal current for this fuse depends on the maximum operating current carrying capacity of the surge arrester.

6.4 Installation instructions for surge protection devices in information technology systems

The selection and installation of surge protection equipment for data systems is relatively simple. The protective equipment already takes into account all the requirements for the data transmission system. It must be selected from the TRABTECH catalog in accordance with the interface specifications and added to the cable in series.

- All surge arresters that contain multi-stage protective circuits and are switched to the electric circuit in series are marked with the words "IN" and "OUT" (Fig. 20). "IN" is always the unprotected side and points in the direction from which the surge voltage is expected. The protected side "OUT" points towards the volume to be protected. (see also the chapter "Combined protective circuits", chapter 4.2.4).
- Surge arresters in adapter designs, which are used to protect floating interfaces, have a single-stranded ground conductor that is directly connected to the protective circuit in many cases. This line, as shown in Fig. 6.4-1 by an arrester for Ethernet networks, has a length of 1.5 m in its delivery state. The grounding line must be shortened so far when installing the arrester that it can be connected directly to the ground without any detours. A practical feature is the connection to the grounded chassis of the volume to be protected.
- When protection for the power supply is combined with data interface protection, the mesh of the equipotential bonding should be closed by connecting all grounding connections immediately before the volume to be protected.

The common connection of DATATRAB and MAINS-PRINTRAB is shown in Fig. 6.4-2 as an example.



Fig. 6.4-1:
Surge voltage arrester for Ethernet interfaces

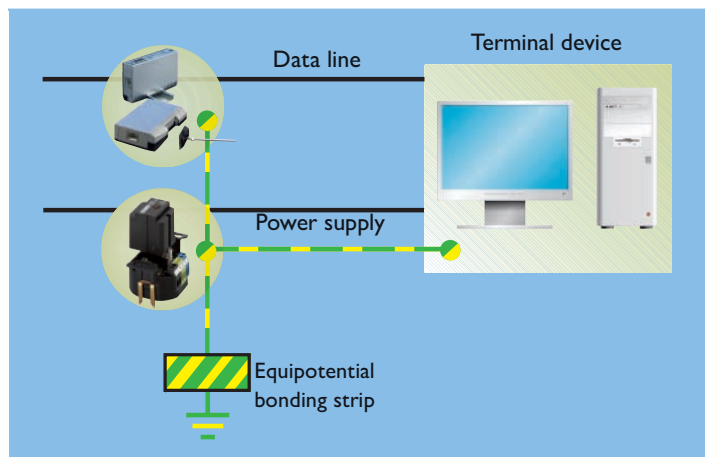


Fig. 6.4-2:
Equipment protection for the data interface and power supply with DATATRAB and PRINTRAB

Examples of the installation of surge arresters

Fig. 6.4-3-a to 6.4.9 show connections of MCR and data systems together with surge arresters, as they frequently occur in practice and can be used repeatedly in this configuration.

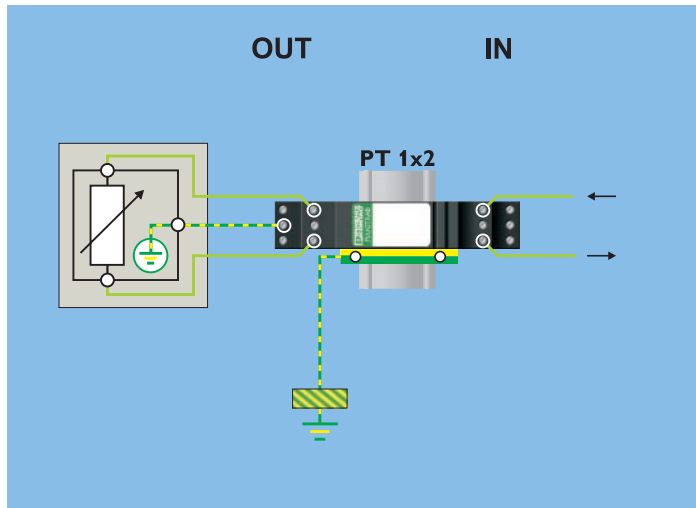


Fig. 6.4-3a: 2-conductor system - protection of the sensor

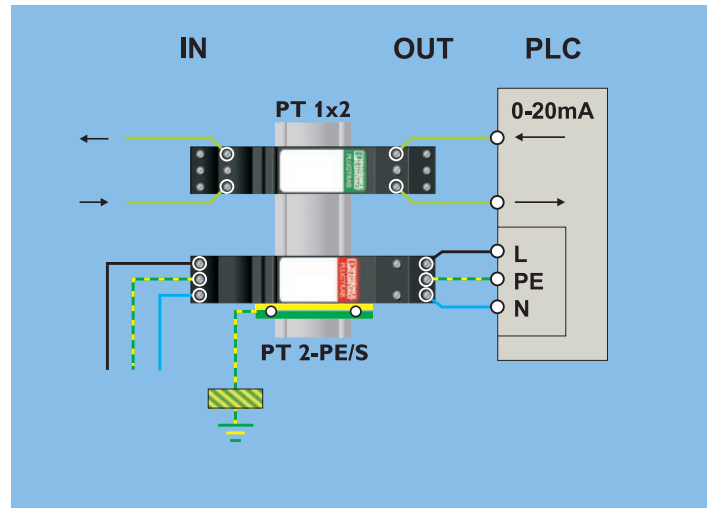


Fig. 6.4-3b: 2-conductor system - protection of the control unit

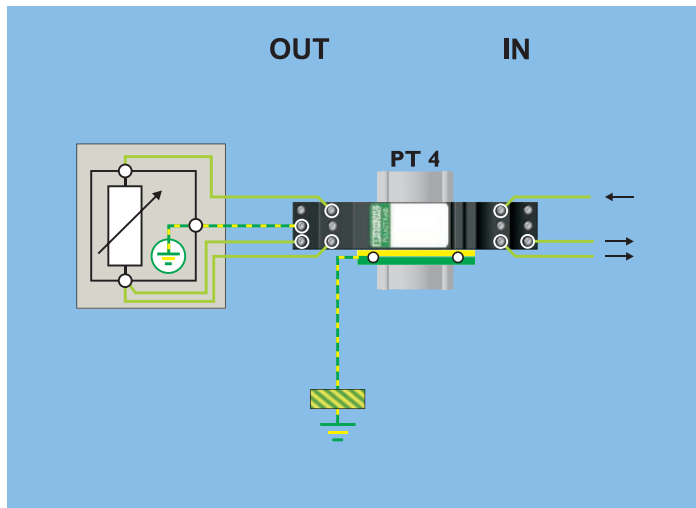


Fig. 6.4-4a: 3-conductor system - protection of the sensor

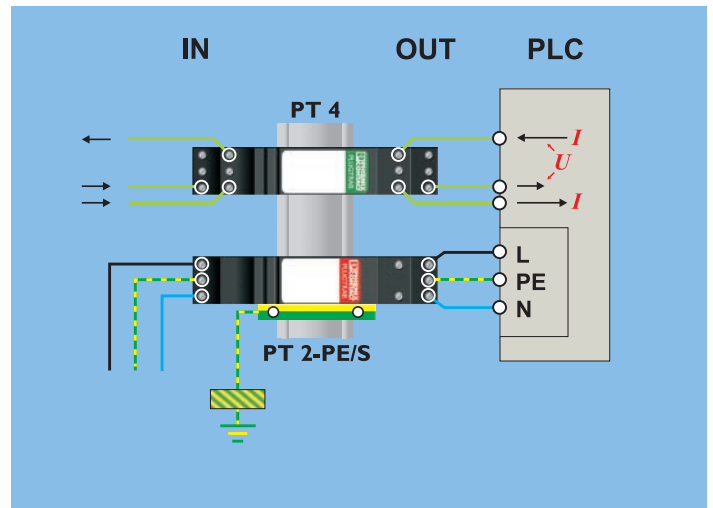


Fig. 6.4-4b: 3-conductor system - protection of the control unit

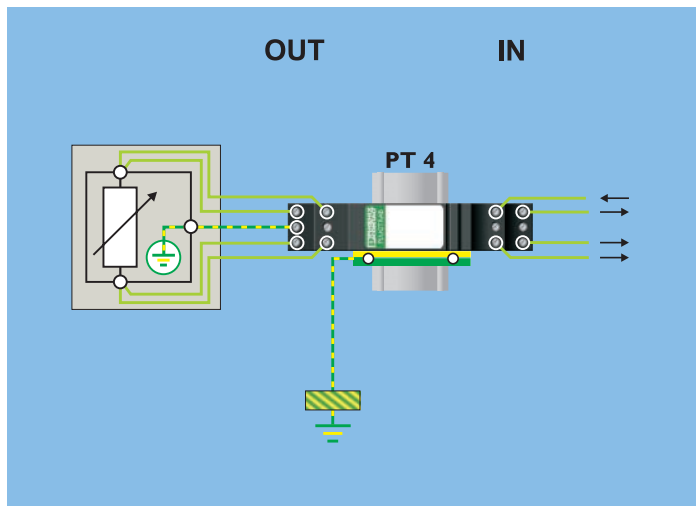


Fig. 6.4-5a: 4-conductor system - protection of the sensor

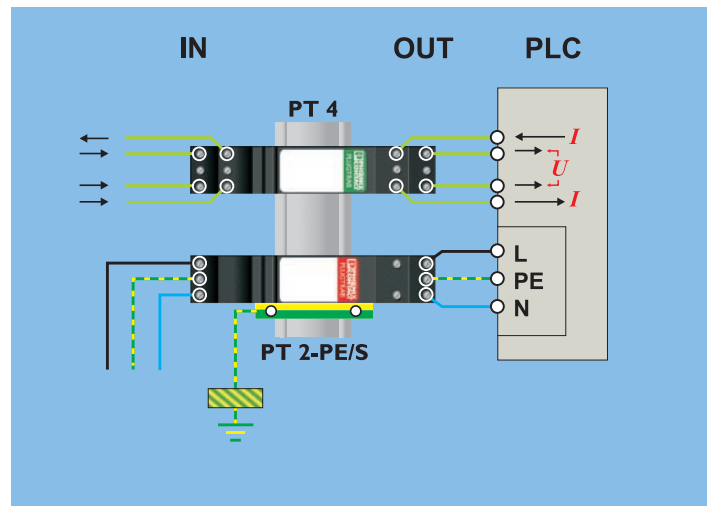


Fig. 6.4-5b: 4-conductor system - protection of the control unit

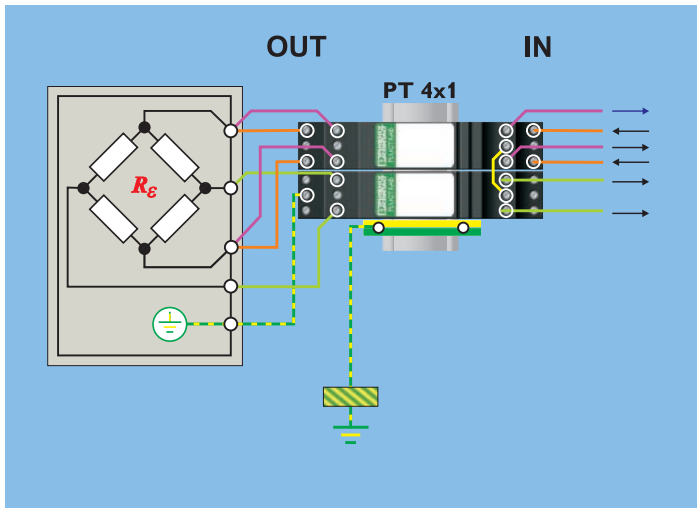


Fig. 6.4-6a: 6-conductor system - protection of the sensor

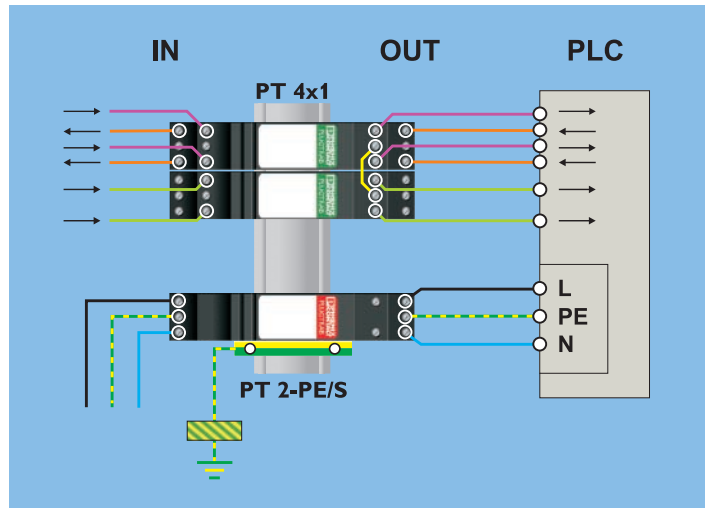


Fig. 6.4-6b: 6-conductor system - protection of the control unit

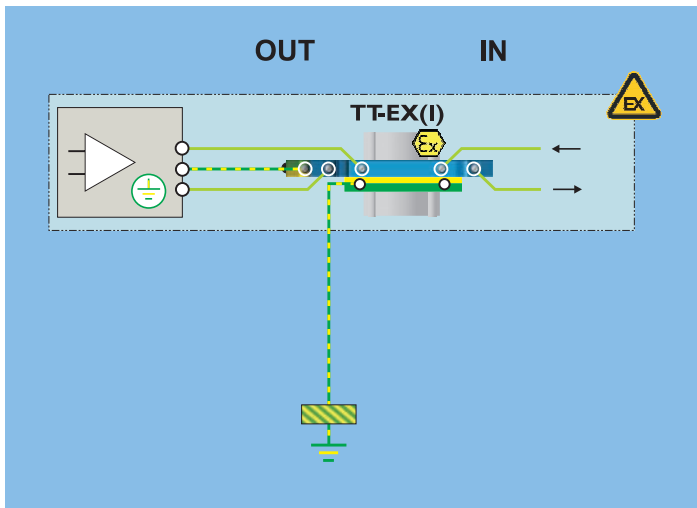


Fig. 6.4-7a: 2-conductor EX(i) - protection of the sensor

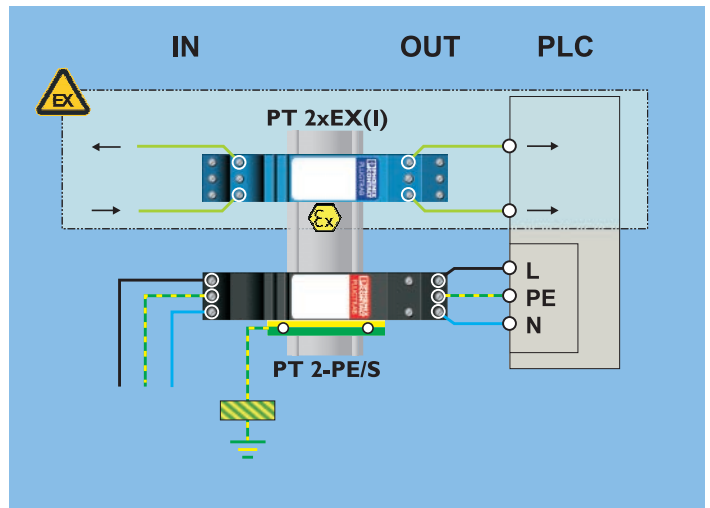


Fig. 6.4-7b: 2-conductor EX(i) - protection of the control unit

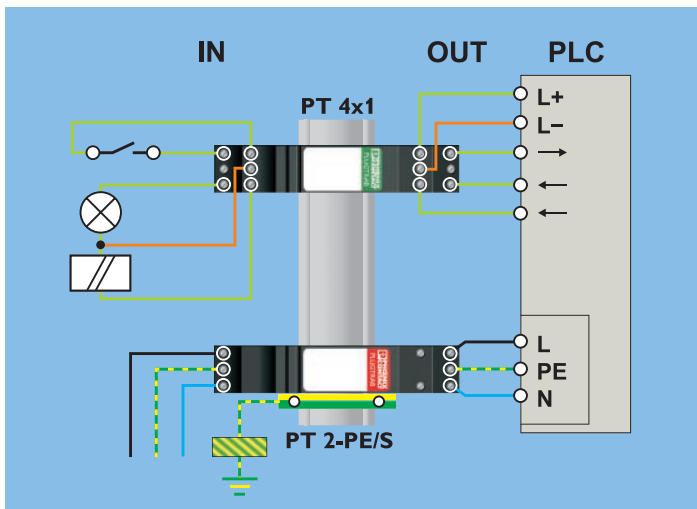


Fig. 6.4-8: Binary signal - protection solution PLUGTRAB

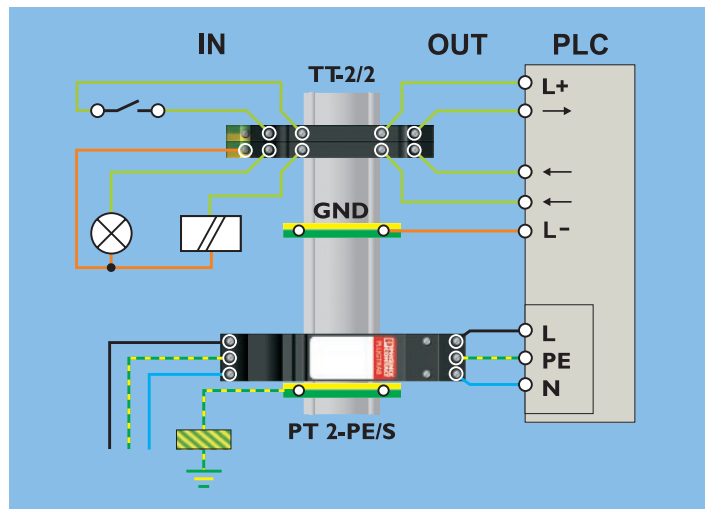


Fig. 6.4-9: Binary signal - protection solution TERMITRAB

7.0 Arrester test

Surge protection devices are exposed to very high voltage loads. Depending on the amount and frequency of such loads, individual components of the protective circuit may be damaged. Based on this reason, the function of the protective devices within a system must be inspected routinely. Some protective devices have an integrated display by which the defect is signaled. This allows an easy visual inspection. A high-grade arrester inspection in the system can only be performed in practice with a portable test device.

7.1 Test according to standard

The CHECKMASTER is a portable testing device, with which a professional test can be performed on arresters. The performance parameters of all components of a protective circuit are checked for their adherence of nominal data with consideration of the approved tolerance range. The extent of the deviation within the tolerance range is also evaluated. The possibility of the three test results as follows:

- Test object OK!
- Tolerance limit is reached! Replacement is recommended
- Test object is FAULTY! Replacement is required.

These results can be transferred to a computer for rework and for archiving or can be directly printed. The arrester test with the CHECKMASTER conforms with the DIN EN 62305-3 standard.

7.2 Test of variable arresters

Arresters of the most diverse designs can be tested with the CHECKMASTER, such as:

- FLASHTRAB compact
- VALVETRAB compact
- VALVETRAB
- PLUGTRAB
- COMTRAB

Test adapters with various test recordings are available for the different arrester versions, which are inserted into the testing device. The type of the arrester is entered on the keyboard or simply by scanning the printed bar code. The required arrester-specific test process is thereby defined.



Fig. 7.2-1:
Arrester testing device CHECKMASTER



Fig. 7.2-2:
Test records for various arrester designs

8.0 Appendix

8.1 Conclusion

This document gives practical information for planning surge protection concepts and selecting and installing surge arresters. It conveys basic theoretical and practical knowledge on the topic of surge protection. It is important to note that even a very good surge protection concept that has been adapted to the applications can only be used successfully if it is installed correctly and in accordance with the standards.

8.2 Literature:

Standards:

IEC 62305 - 1, 2, 3, 4
IEC 61643-1
DIN VDE 0100-443
DIN V VDE V 0100 - 534
DIN VDE 0100-540
DIN VDE 0110
DIN EN 62305 - 1, 2, 3, 4
DIN VDE 0675 Part 6
DIN VDE 0800 Part 2
DIN VDE 0843 Part 1, 2
DIN VDE 0845 Part 1

8.3 Publications:

Schimanski, J. "Surge Protection, Theory and Practice"
2. completely revised edition, **Hüthig GmbH** 2003

Wetter, M.; Schimanski, J.; Scheibe, K.
"Application of EN 61643-11 on a lightning arrester sample",
Presentations of the 5th **VDE/ABB Lightning protection conference** 11/2003

Hausmann, R. "IT Safety through surge protection",
Safety & Management 04/2004

Sieker, T. "Surge protection in safety-relevant systems - Is an inspection of surge protection devices necessary?",
MSR Magazin 04/2004

Wetter, M. "Easy protection from surge voltages with multi-phase protective systems", **etz** 10/2004

Wetter, M.; Schimanski, J.; Scheibe, K.
"Testing the Performance of Surge Protection Devices",
Proceedings Volume II, **ICLP Avignon** 09/2004
Heckler, H. "Evolution or revolution – solutions for the surge protection of power supply systems",
eA elektro AUTOMATION 03/2005

Schimanski, J.; Heckler, H.; Wetter, M. "Deflection capacity and response of lightning arresters", **etz** 08/2005

Heckler, H. "Modular lightning and surge protection",
ep Elektropaktiker 09/2005

Wetter, M.; Schimanski, J.; Scheibe, K. "Arrester test within the scope of the test and maintenance of lightning protection systems",
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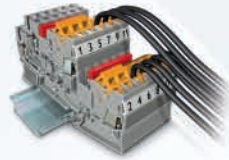
Fritzemeier, B. "Surge protection for fire alarm systems",
de Der Elektro- und Gebäudetechniker 13-14/2005

Hausmann, R. "Surge protection for EDP systems",
de Der Elektro- und Gebäudetechniker 03/2006

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