8. Selection, installation and assembly of surge protective devices (SPDs)

8.1 Power supply systems (within the scope of the lightning protection zones concept according to IEC 62305-4 (EN 62305-4))

The installation of a lightning and surge protection system for electrical installations represents the latest state of the art and is an indispensable infrastructural condition for the trouble-free operation of complex electrical and electronic systems without consequential damage. The requirements on SPDs needed for the installation of this type of lightning and surge protection system as part of the lightning protection zones concept according to IEC 62305-4 (EN 62305-4) for power supply systems are stipulated in IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001).

SPDs employed as part of the structure's fixed installation are classified according to the requirements and loads on the installation sites as surge protective devices Type 1, 2 and 3 and tested according to IEC 61643-1 (EN 61643-11).
The highest requirements with respect to the discharge capacity are made on SPDs Type 1. These are employed within the scope of the lightning and surge protection system at the boundary of lightning protection zone LPZ 0_A to LPZ 1 and higher, as shown in **Figure 8.1.1**. These protective devices must be capable of carrying partial lightning currents, waveform 10/350 µs, many times without consequential damage to the equipment. These SPDs Type 1 are called lightning current arresters. The function of these protective devices is to prevent destructive partial lightning currents from penetrating the electrical installation of a structure.

At the boundary of lightning protection zone LPZ 0_B to LPZ 1 and higher, or lightning protection zone LPZ 1 to LPZ 2 and higher, SPDs Type 2 are employed to protect against surges. Their discharge capacity is around some 10 kA (8/20 µs).

The last link in the lightning and surge protection system for power supply installations is the protection of terminal devices (boundary from lightning protection zone LPZ 2 to LPZ 3 and higher). The main function of a protective device Type 3 used at this point is to protect against surges arising between L and N in the electrical system. These are particularly switching surges.The different functions, arrangements and requirements of arresters is given in **Table 8.1.1**.

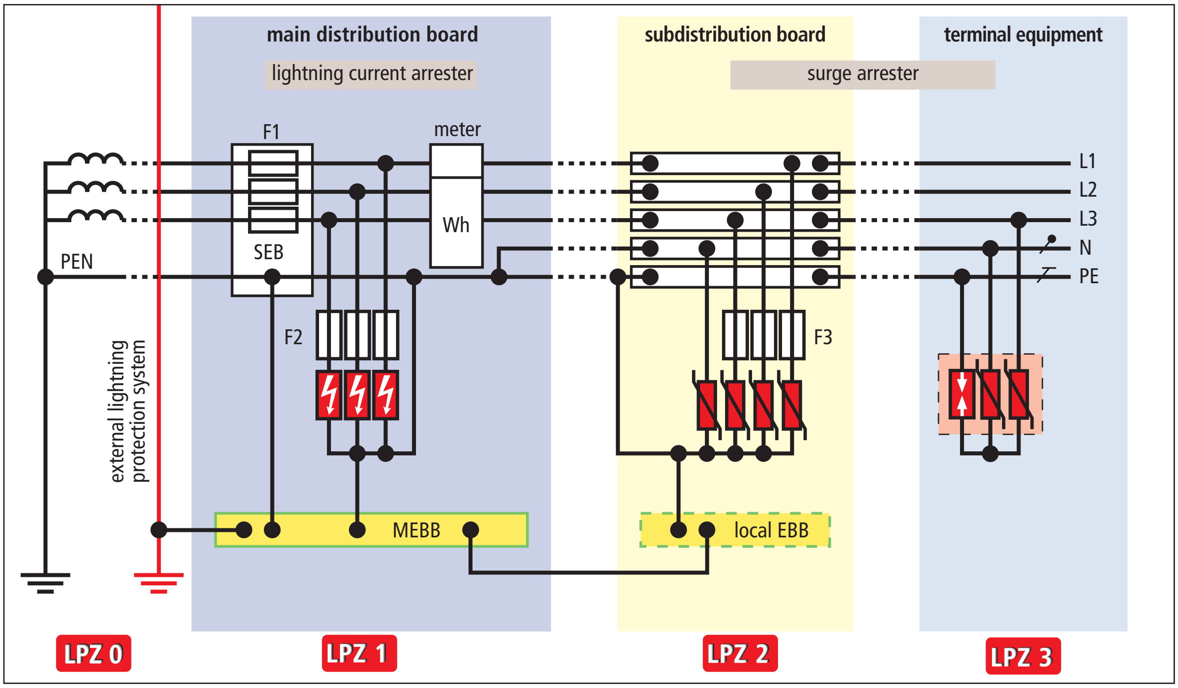


Fig. 8.1.1 Use of SPDs in power supply systems (schematic diagram)

Standard / Type/Description	E DIN VDE 0675-6 with A1, A2 (already withdrawn)	IEC 61643-1: 2005	EN 61643-11: 2002
Lightning current arrester; Combined lightning current and surge arrester	Class B	SPD class I	SPD Type 1
Surge arrester for distribution boards, subdistribution boards, fixed installations	Class C	SPD class II	SPD Type 2
Surge arrester for socket outlets/ terminal units	Class D	SPD class III	SPD Type 3

Table 8.1.1 Classification of SPDs according to VDE, IEC and EN

8.1.1 Technical characteristics of SPDs

Maximum continuous voltage U_c

The maximum continuous voltage (equal to: rated voltage) is the root mean square (rms) value of the max. voltage which may be applied to the correspondingly marked terminals of the surge protective device during operation. It is the maximum voltage on the arrester in the defined non-conductive state which ensures that this state is regained after it has responded and discharged.
The value of U_c shall be selected in accordance with the nominal voltage of the system to be protected and the requirements of the installation provisions (IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001)). Taking into account a 10 % voltage tolerance for TN and TT systems, the maximum continuous voltage U_c is 253 V for 230/400 V systems.

Lightning impulse current I_{imp}

This is a standardised impulse current curve with a 10/350 μs waveform. Its parameters (peak value, charge, specific energy) simulate the load caused by natural lightning currents.
Lightning impulse currents (10/350 μs) apply to SPDs Type 1. They must be able to discharge such lightning impulse currents several times without consequential damage to the equipment.

Nominal discharge current I_n

The nominal discharge current I_n is the peak value of the current flowing through the surge protective device (SPD). It has an 8/20 μs impulse current waveform and is rated for classifying the test of SPDs Type 2 and also for conditioning the SPDs for Type 1 and 2 tests.

Voltage protection level U_p

The voltage protection level of an SPD denotes the maximum instantaneous value of the voltage on the terminals of an SPD while at the same time characterising their capacity to limit surges to a residual level.

Depending on the type of SPD, the voltage protection level is determined by means of the following individual tests:

⇒ Lightning impulse sparkover voltage 1.2/50 μs (100 %)

⇒ Residual voltage for nominal discharge current (in accordance with EN 61643-11: U_{res})

The surge protective device appropriate to the installation site is chosen in accordance with the overvoltage categories described in IEC 60664-1 (EN 60664-1). It must be noted that the required minimum value of 2.5 kV for a 230/400 V three-phase system only applies to equipment belonging to the fixed electrical installation. Equipment in the terminal circuits supplied by the installation require a voltage protection level which is much lower than 2.5 kV.
IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) also requires a minimum voltage protection level of 2.5 kV for a 230/400 V low-voltage consumers' installation. This minimum voltage protection level can be realised by means of a coordinated system of SPDs Type 1 and SPDs Type 2, or by employing a Type 1 combined lightning current and surge arrester.

Short-circuit withstand capability

This is the value of the prospective power-frequency short circuit current controlled by the surge protective device in case it is furnished with an upstream backup fuse (backup protection).

Follow current extinguishing capability U_c (I_{fi})

The follow current extinguishing capability, also termed breaking capacity, is the unaffected

(prospective) rms value of the mains follow current which can automatically be extinguished by the surge protective device when U_c is applied.
According to IEC 62305-3 (EN 62305-3) and IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) the follow current extinguishing capability of the SPDs should correspond to the maximum prospective short circuit current at the SPD's installation site. For distributions in industrial plants with very high short circuit currents a corresponding backup fuse has to be chosen for the protective device which interrupts the mains follow current through the protective device.
According to both IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) and EN 61643-11, SPDs connected between neutral conductors and PE conductors, where a follow current with mains frequency can arise after the SPD has responded (e.g. spark gaps), must have a follow current extinguishing capability of $I_{fi} \geq 100\ A_{rms}$.

Follow current limiting (for spark-gap based SPDs Type 1)
Follow current limiting is the capability of a spark-gap based SPD to limit any mains follow currents arising to such a degree that the current actually flowing is noticeably smaller than the possible short circuit current at the installation site.
A high degree of follow current limiting prevents upstream protective elements (e.g. fuses) from tripping because of a too high mains follow current.
The follow current limiting is an important parameter for the availability of the electrical installation, particularly for spark-gap based SPDs with a low voltage protection level.

Coordination
In order to ensure a selective functioning of the various SPDs, an energy coordination among the individual SPDs is absolutely essential. The basic principle of energy coordination is characterised by the fact that each protective stage must only discharge the amount of interference energy the SPD is designed for. If higher interference energies occur, the protective stage upstream of the SPD, e.g. SPD Type 1, must take over the discharge of the impulse current and relieve the downstream protective devices. This type of coordination must take into account all possible incidences of interference such as switching surges, partial lightning currents, etc.. According to IEC 62305-4 (EN 62305-4) the manufacturer must prove the energy coordination of its SPDs.
The devices in the Red/Line family are coordinated with each other and tested with reference to their energy coordination.

TOV
TOV (**T**emporary **O**ver**V**oltage) is the term used to describe temporary surges which can arise as a result of faults within the medium and low-voltage networks.
To TN systems as well as the L-N path in TT systems and for a measuring time of 5 seconds applies: $U_{TOV} = 1.45 \times U_0$, where U_0 represents the nominal a.c. voltage of the line to earth.
At 230/400 V systems the TOV to be taken into consideration for the SPDs between L and N is $U_{tov} = 333.5$ V. For TOVs arising in low-voltage systems as a result of earth faults in the high-voltage system, $U_{TOV} = 1200$ V for the N-PE path in TT systems has to be taken into consideration for 200 ms. IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) requires a TOV withstand capability for SPDs installed in low voltage consumer's installations.
The devices of the Red/Line family of products must be rated for TOVs according to EN 61643-11 and meet th requirements of IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001).

8.1.2 Use of SPDs in various systems

Measures to ensure protection against life hazards always take priority over surge protective measures. Since both measures are directly linked to the type of power supply systems and hence also with the use of surge protective devices (SPDs), the following describes TN, TT and IT systems and the variety of ways in which SPDs can be used. Electric currents flowing through the human body can have hazardous consequences. Every electrical installation is therefore required to incorporate protective measures to prevent hazardous currents flowing through the human body. Components being energised during normal operation must be insulated, covered, sheathed or arranged to prevent from being touched if this could result in hazardous currents flowing through the body. This protective measure is termed "protection against electric shock under normal conditions". Moreover, it goes without saying, of course, that a hazard must not be caused either by current flowing through the body if, as the result of a fault, e.g. a faulty insulation, the voltage is transferred to the metal enclosure (body of a piece of electrical equipment). This protection against hazards which, in the event of a fault, can result from touching bodies or extraneous conductive components, is termed "protection against electric shock under fault conditions".

Generally, the limit of the permanently permissible touch voltage U_L for a.c. voltages is 50 V and for d.c. 120 V.

In electrical circuits containing socket outlets and in electrical circuits containing Class I mobile equipment normally held permanently in the hand during operation, higher touch voltages, which can arise in the event of a fault, must be disconnected automatically within 0.4 s. In all other electrical circuits, higher touch voltages must be automatically disconnected within 5 s.

IEC 60364-4-41: 2005-12 describes protective measures against indirect shock hazard with protective conductors. These protective measures operate in the event of a fault by means of automatic disconnection or message. When setting up the measures for the "protection against electric shock under fault conditions", they must be assigned according to the system configuration and the protective device.

According to IEC 60364-4-41: 2005-12, a low voltage distribution system in its entirety, from the power source of the electrical installation to the last piece of equipment, is essentially characterised by:

⇒ earthing conditions at the power source of the electrical installation (e.g. low voltage side of the local network transformer)

and

⇒ earthing conditions of the body of the equipment in the electrical consumer´s installations.

Hence, essentially, three basic types are defined as distribution systems:
TN system, **TT** system and **IT** system.

The letters used have the following significance:

The **FIRST LETTER** describes the earthing conditions of the supplying power source of the electrical installation:

T direct earthing of one point of the power source (generally the neutral point of the transformer),

I Insulation of all active components from the earth or connection of one point of the power source to earth via an impedance.

The **SECOND LETTER** describes the earthing conditions of the bodies of the equipment of the electrical installation:

T Body of the equipment is earthed directly, regardless of any possible existing earthing of one point of the power supply,

N Body of the electrical equipment is directly connected to the power system earthing (earthing of the power source of the electrical installation).

SUBSEQUENT LETTERS describe the arrangement of the neutral conductor and the protective conductor:

S Neutral conductor and protective conductor are separate from each other,

C Neutral conductor and protective conductor are combined (in one conductor).

There are therefore three possible options for the TN system:
TN-S system, **TN-C** system and **TN-C-S** system.

The protective devices which can be installed in the various systems are:

⇒ overcurrent protective device,

⇒ residual current device,

⇒ insulation monitoring device,

⇒ fault-voltage-operated protection device (special cases).

As previously mentioned, the system configuration must be assigned to the protective device. This results in the following assignments:

TN system

⇒ Overcurrent protective device,

⇒ Residual current device.

TT system

⇒ Overcurrent protective device,

⇒ Residual current device,

⇒ Fault-voltage-operated protective device (special cases).

IT system

⇒ Overcurrent protective device,

⇒ Residual current device,

⇒ Insulation monitoring device,

These measures to protect against life hazards have top priority when installing power supply systems. All other protective measures such as lightning and surge protection of electrical systems and installations are secondary to the protective measures taken against indirect contact with protective conductors under consideration of the system configuration and the protective device. The latter must not be overridden by the use of protective devices for lightning and surge protection. The occurrence of a fault in an SPD, unlikely as it may be, shall also be taken into account. This has particular significance because the surge protective devices are always used to the protective conductor.
In the following sections we therefore describe the use of SPDs in various system configurations. These circuit proposals are taken from IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001).

The concepts shown illustrate the use of lightning current arresters mainly in the area of the service entrance box, i.e. upstream of the meter. IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) defines the installation site of lightning current arresters as "close to the origin of the installation".

In Germany the use of lightning current arresters upstream the meter is regulated by the VDN-Richtlinie 2004-08 [engl.: Directive of the Association of the German Network Operators]: "Überspannungs-Schutzeinrichtungen Typ 1. Richtlinie für den Einsatz von Überspannungs-Schutzeinrichtungen (ÜSE) Typ 1 (bisher Anforderungsklasse B) in Hauptstromversorgungssystemen." [engl: "Surge protective devices Type 1. Directive for the use of surge protective equipment Type 1 (up to now Class B) in main distribution systems"
This directive, compiled by the VDN defines basic requirements which, depending on the Distribution Network Operator (DNO) can lead to different technical designs.
The preferred kind of supply (network configuration) must be ascertained from the responsible operator of the distribution network

8.1.3 Use of SPDs in TN Systems

For "protection against electric shock under fault conditions" in TN systems, overcurrent and residual current devices have been approved. For the use of SPDs this means that these protective devices may only be arranged downstream of the devices for "protection against electric shock under fault conditions" in order to ensure that the measure to protect against life hazards also operates in the event of a failure of an SPD.
If an SPD Type 1 or 2 is installed downstream of a residual current device, it has to be expected that, because of the discharged impulse current to PE, this process will be interpreted as residual current by a residual current device (RCD), and it interrupts the circuit.
Moreover, if an SPD Type 1 is loaded with partial lightning currents it must be assumed that the high dynamics of the lightning current will cause mechanical damage on the residual current device (**Figure 8.1.3.1**). This would override the protective measure "protection against electric shock under fault conditions".

Of course, this must be avoided. Therefore both lightning current arresters Type 1 and SPDs Type 2 should be used upstream of the residual current device. Hence, for SPDs Type 1 and 2, the only possible measure for "protection against electric shock under fault conditions" is using overcurrent protective devices. The use of SPDs must therefore always be considered in conjunction with a fuse as the overcurrent protective device. Whether or not a supplementary separate backup fuse must be designated for the arrester branch, depends on the size of the next upstream supply fuse and the backup fuse approved for the SPD. The following maximum continuous voltages apply to SPDs Type 1, 2 and 3 when used in TN systems (**Figures.8.1.3.2** and **8.1.3.3a** to **b**):
Figure 8.1.3.4 illustrates an example of the connections for use of lightning current arresters and surge protective devices in TN-C-S systems. It can be seen that SPDs Type 3 are used downstream of the residual current device (RCD). In this context, please note the following:
As a result of the frequency of switching surges in the terminal circuits, SPDs Type 3 are primarily employed to protect against differential mode voltages. These surges generally arise between L and N. A surge limitation between L and N means

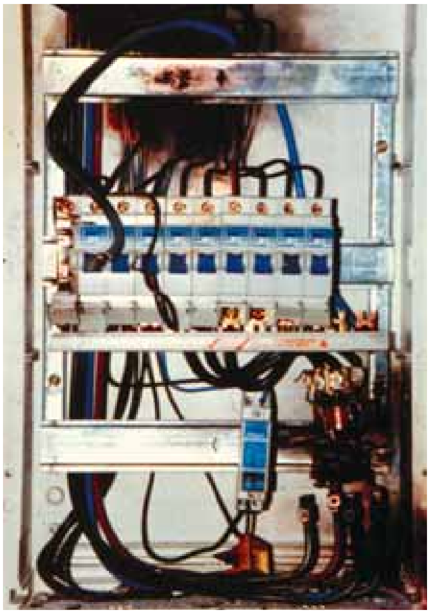


Fig. 8.1.3.1 RCD destroyed by lightning impulse current

that no impulse current is discharged to PE. Thus, this process can also not be interpreted as residual current by the RCD. In all other cases, SPDs Type 3 are designed for a nominal discharge capacity of 1.5 kA. These values are sufficient in the sense that upstream protective stages of SPDs Type 1 and 2 take over the discharge of high energy impulses. When using an RCD capable of withstanding impulse currents, these impulse currents are not able to trip the RCD or cause mechanical damage. The **Figures 8.1.3.5** to **8.1.3.9** illustrate the use of SPDs as part of the lightning protection zones concept, and the required lightning and surge protective measures for a TN-C-S system.

8.1.4 Use of SPDs in TT systems

For "protection against electric shock under fault conditions" in TT systems, the overcurrent protective devices, residual current devices (RCD) and, in special cases, fault-voltage-operated

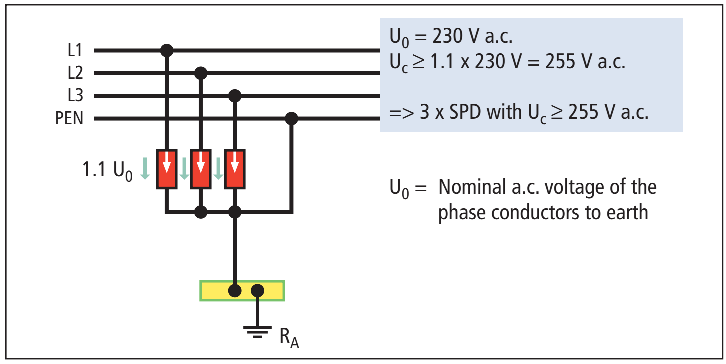


Fig. 8.1.3.2 "3-0" circuit in TN-C systems

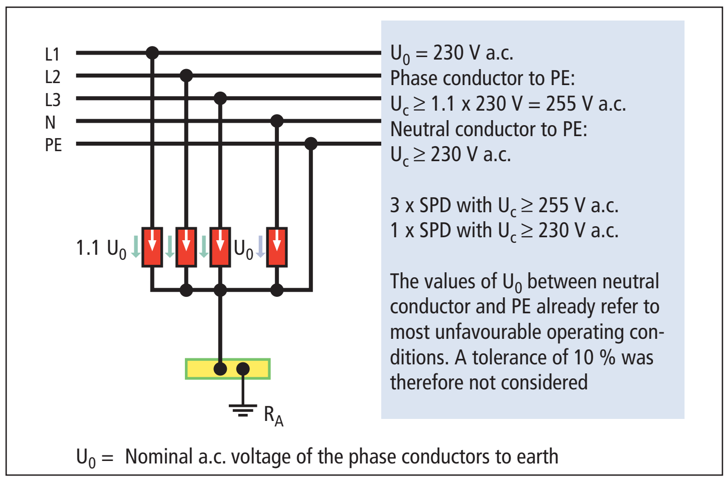


Fig. 8.1.3.3a "4-0" circuit in TN-S systems

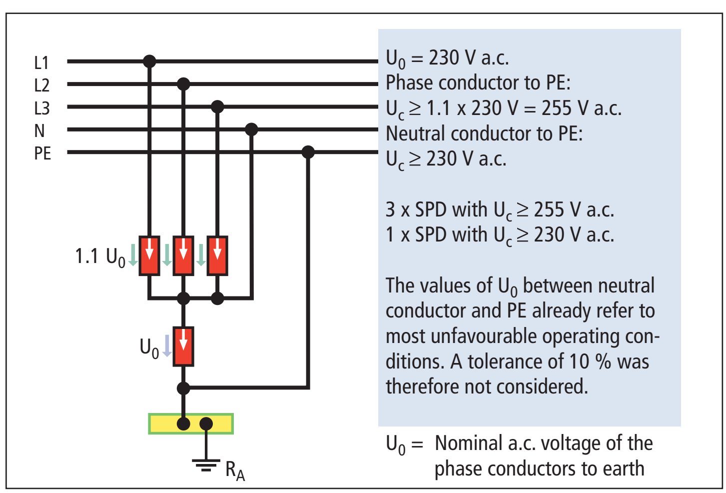


Fig. 8.1.3.3b "3+1" circuit in TN-S systems

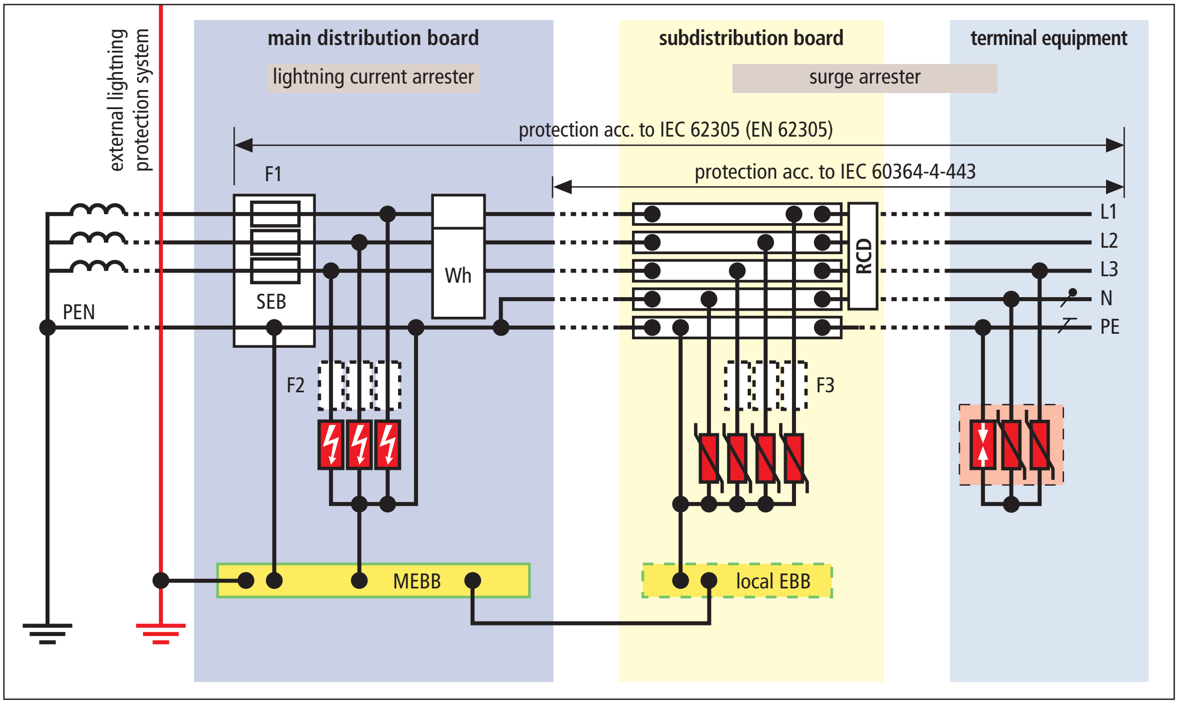


Fig. 8.1.3.4 Use of SPDs in TN-C-S systems

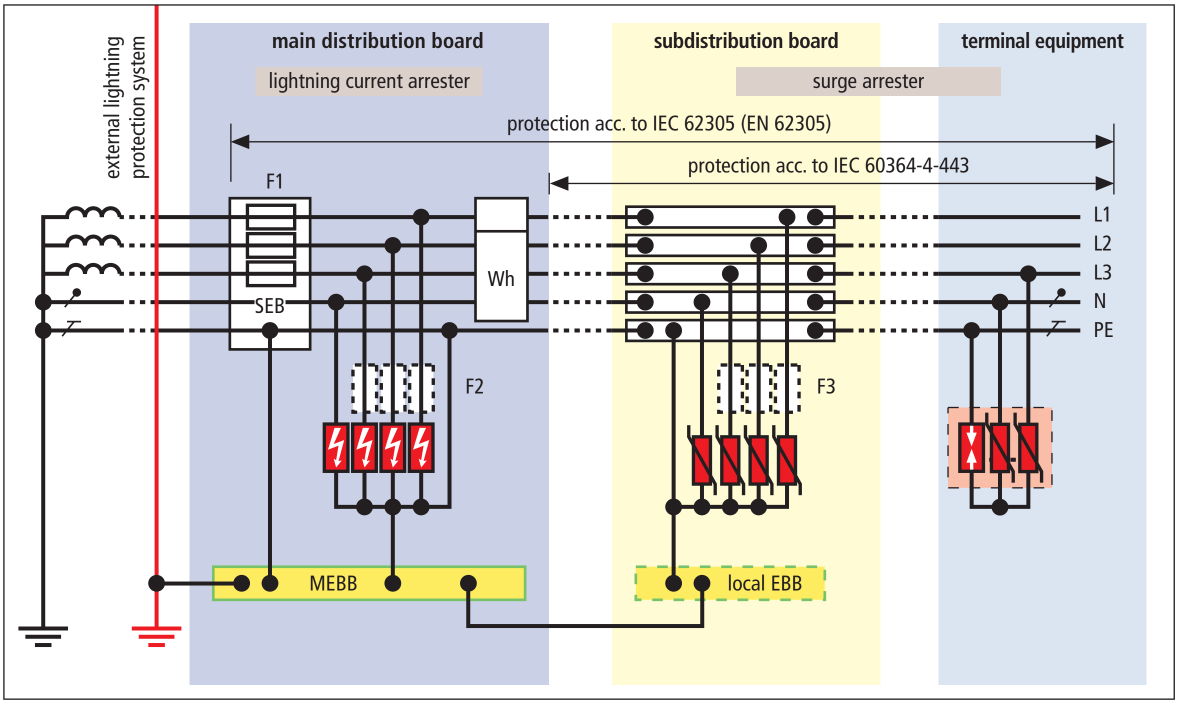


Fig. 8.1.3.5 Use of SPDs in TN-S systems

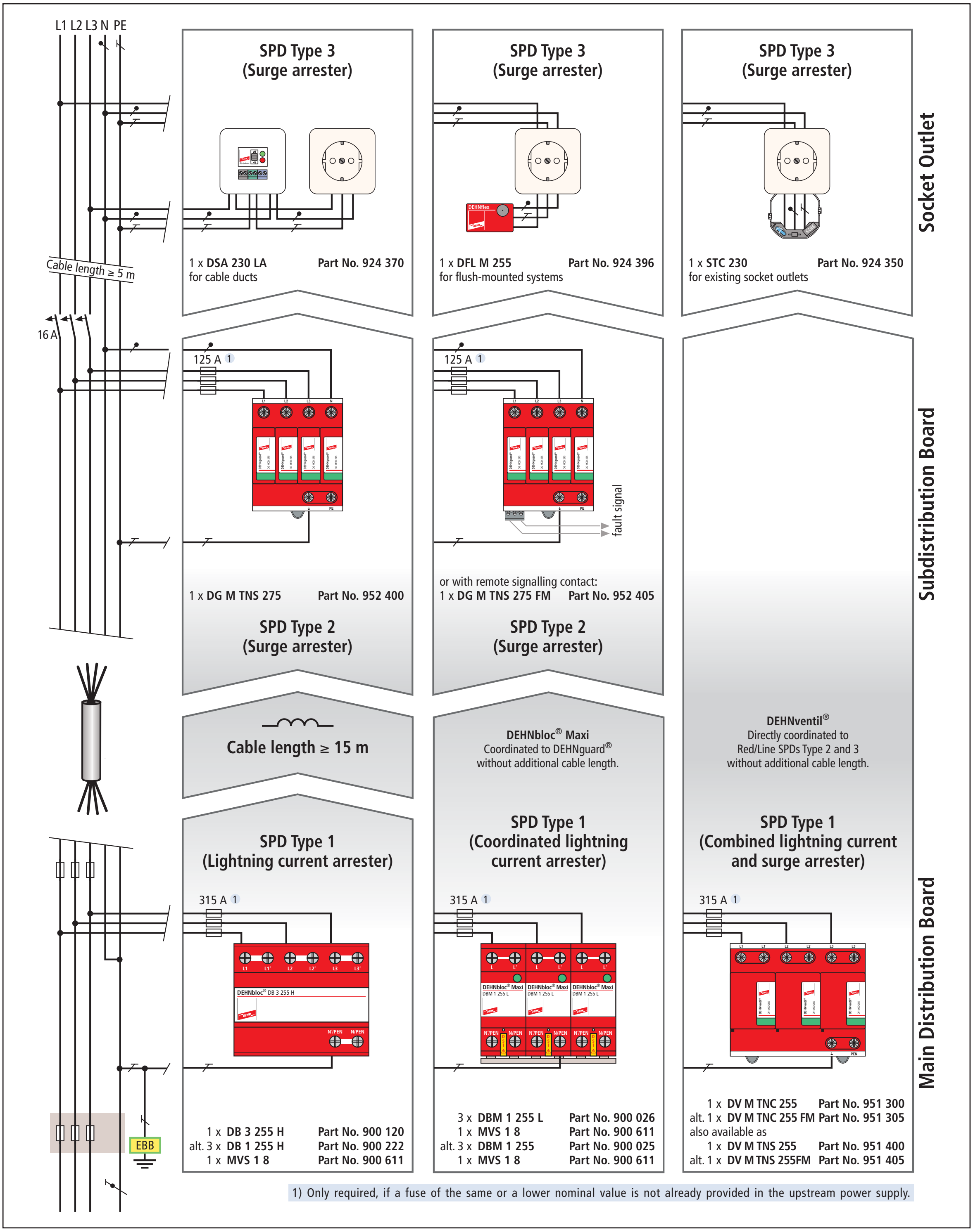


Fig. 8.1.3.6 SPDs used in TN systems – Example: Office Building – Separation of the PEN in the main distribution board

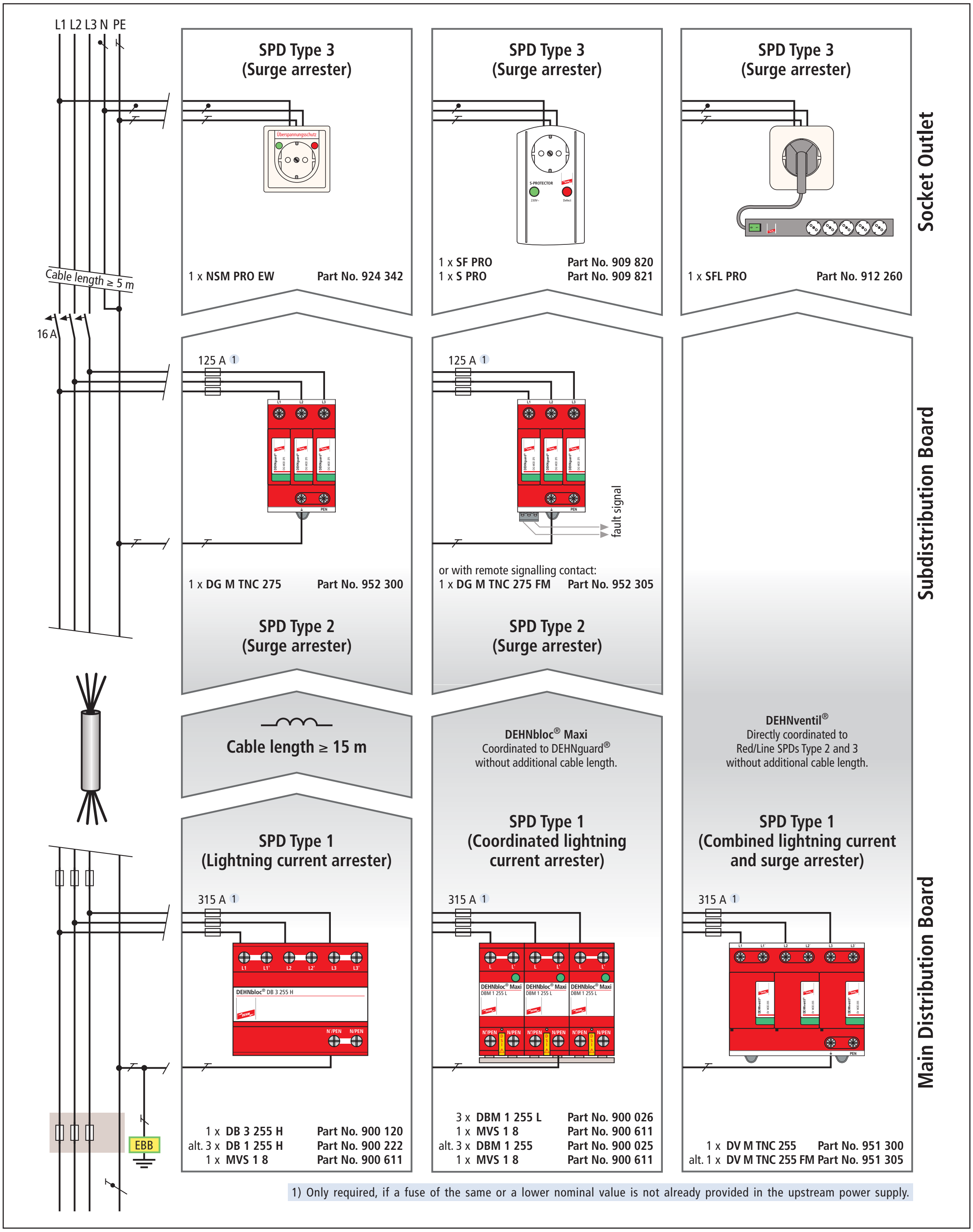


Fig. 8.1.3.7 SPDs used in TN systems – Example: Office Building – Separation of the PEN in the subdistribution board

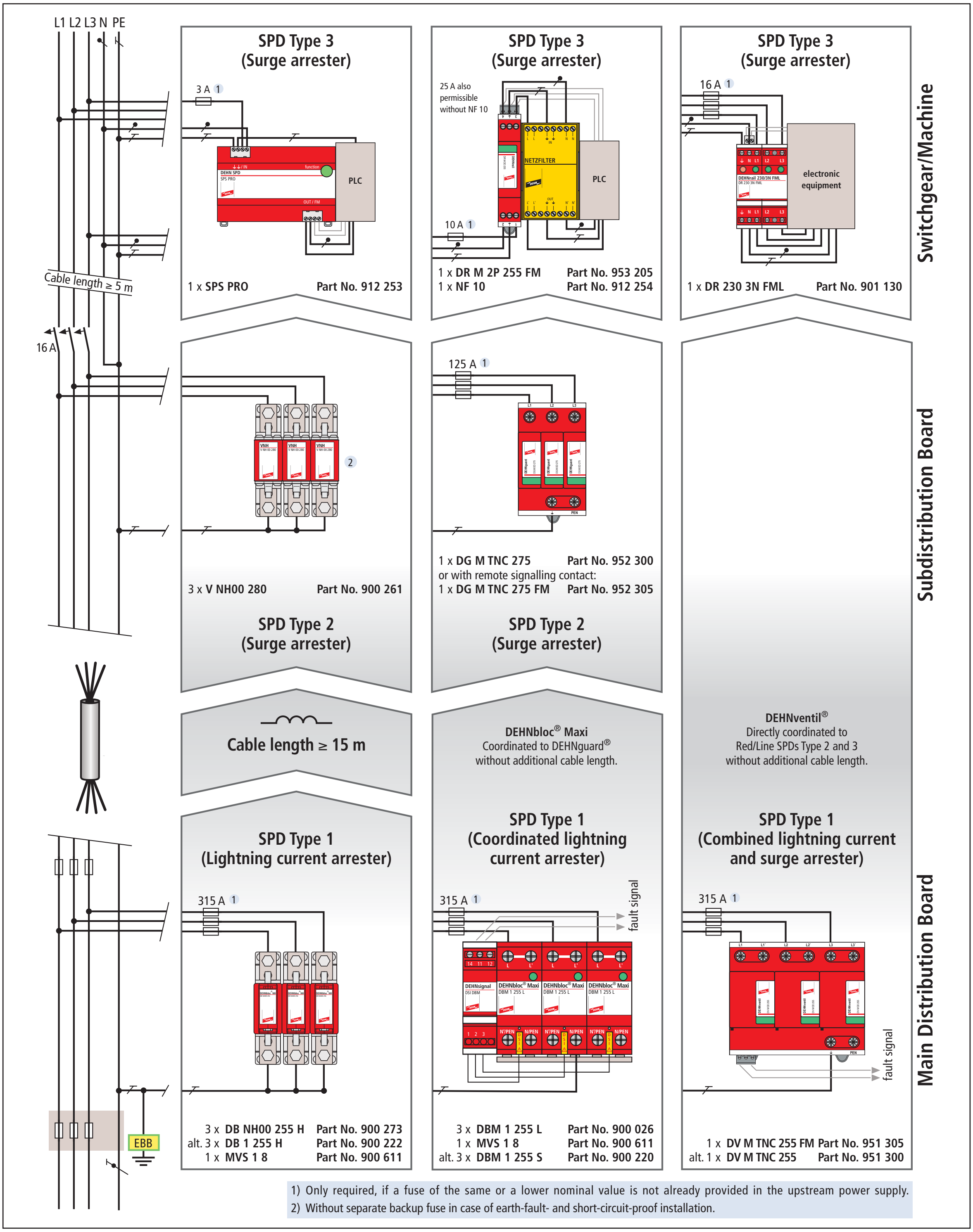


Fig. 8.1.3.8 SPDs used in TN systems – Example: Industry – Separation of the PEN in the subdistribution board

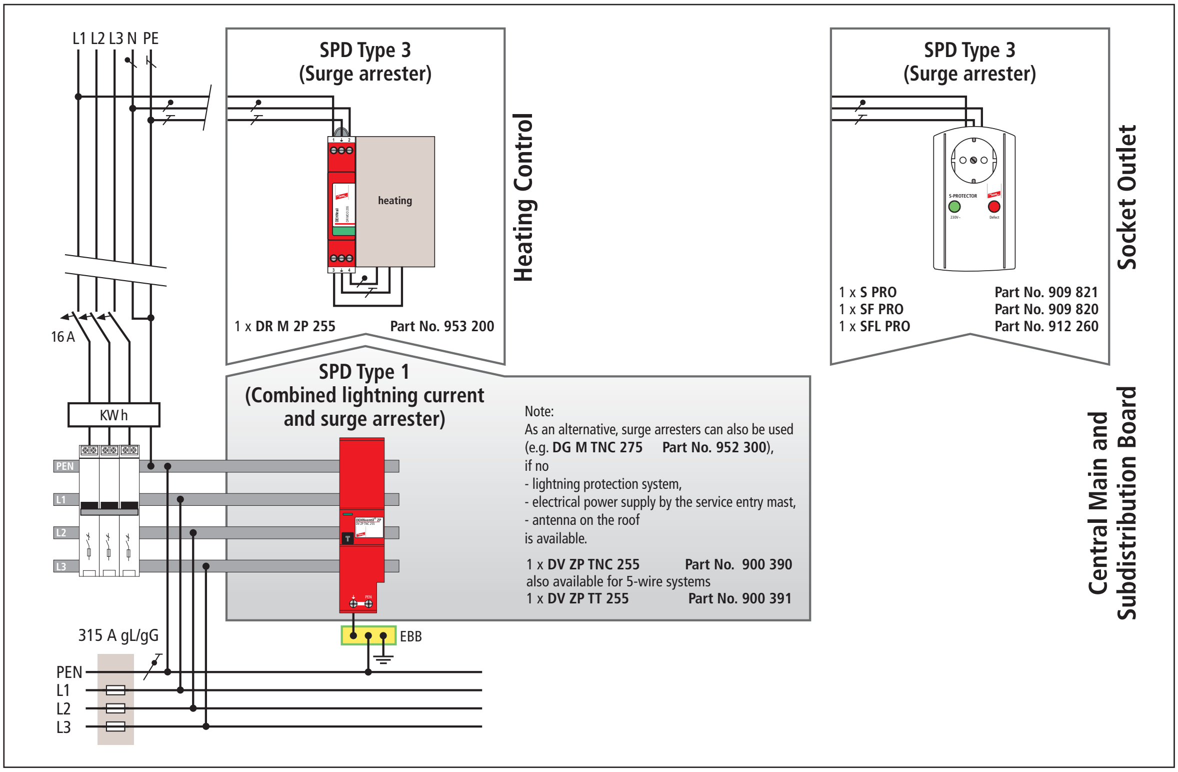


Fig. 8.1.3.9 SPDs used in TN systems – Example: Residential building

protective devices have been approved. This means that, in TT systems, lightning current and surge arresters may only be arranged downstream of the above described protective devices in order to ensure the "protection against electric shock under fault conditions" in the event of an SPD failure.

As previously described in Section 8.1.3, in case of an arrangement of an SPD Type 1 or 2 downstream of an RCD, it has to be expected that, because of the impulse current discharged to PE, this discharge process will be

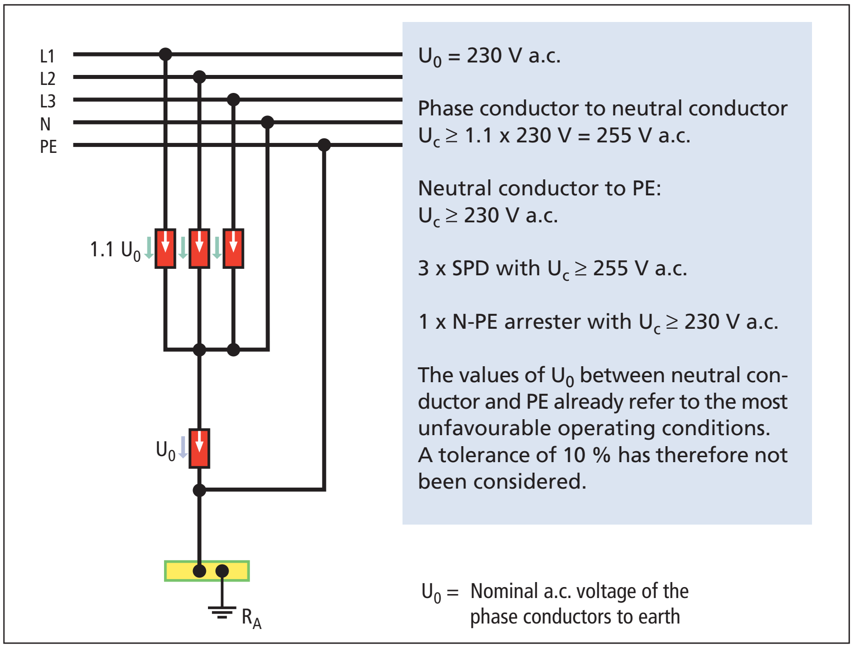


Fig. 8.1.4.1 TT system (230/400 V); "3+1" circuit

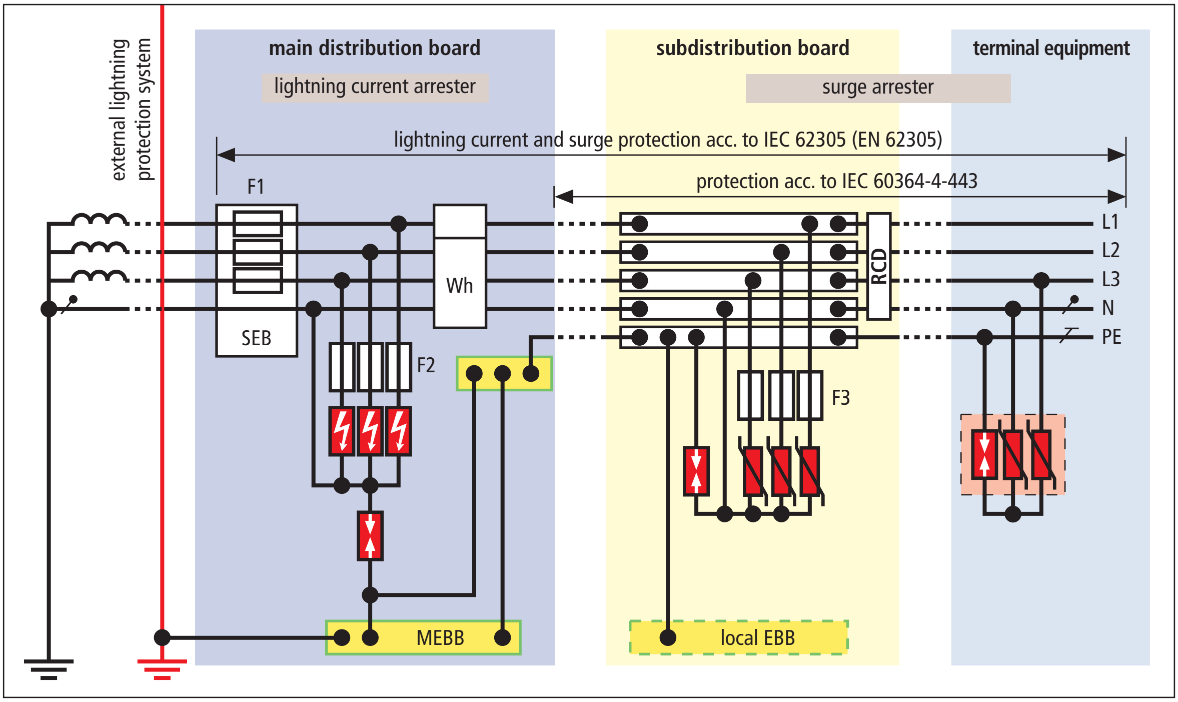


Fig. 8.1.4.2 Use of SPDs in TT systems

interpreted by the RCD as residual current, and then the circuit is interrupted by the same. If SPDs Type 1 are used, it must further be assumed that the dynamics of the discharged partial lightning current would cause mechanical damage to the RCD as the SPD Type 1 responds as is the case with TN systems. This would damage the protective device for "protection against electric shock under fault conditions" and override the protective measure. This type of state, which can result in life hazard, must of course be avoided. Hence, both SPDs Type 1 and SPDs Type 2 must always be installed upstream of the residual current device in TT systems. SPDs Type 1 and 2 must be arranged in TT systems to meet the conditions for the use of overcurrent protective devices for "protection against electric shock under fault conditions".

In the event of a failure, i.e. a faulty SPD, short circuit currents must flow to initiate an automatic disconnection of the overcurrent protective devices within 5 s. If the arresters in the TT system were arranged as shown in **Figures 8.1.3.4** and **8.1.3.5** for TN systems then, in the event of a fault, only earth fault currents would arise instead of short circuit currents. In certain circumstances, however, these earth fault currents do not trip an upstream overcurrent protective device within the time required.

SPDs Type 1 and 2 in TT systems are therefore arranged between L and N. This arrangement shall ensure that, in the event of a faulty protective device in the TT system, a short circuit current can develop and cause the next upstream overcurrent protective device to respond. However, since lightning currents always occur to earth, i.e. PE, a supplementary discharge path between N and PE must be provided.

These so-called "N-PE arresters" must meet special requirements since here, on the one hand, the sum of the partial discharge currents from L1, L2, L3 and N must be carried and, on the other, there must be a follow current extinguishing capability of 100 A_{rms} because of a possible shifting of the neutral point.

The following maximum continuous voltages apply to the use of SPDs in TT systems between L and N (**Figure 8.1.4.1**):

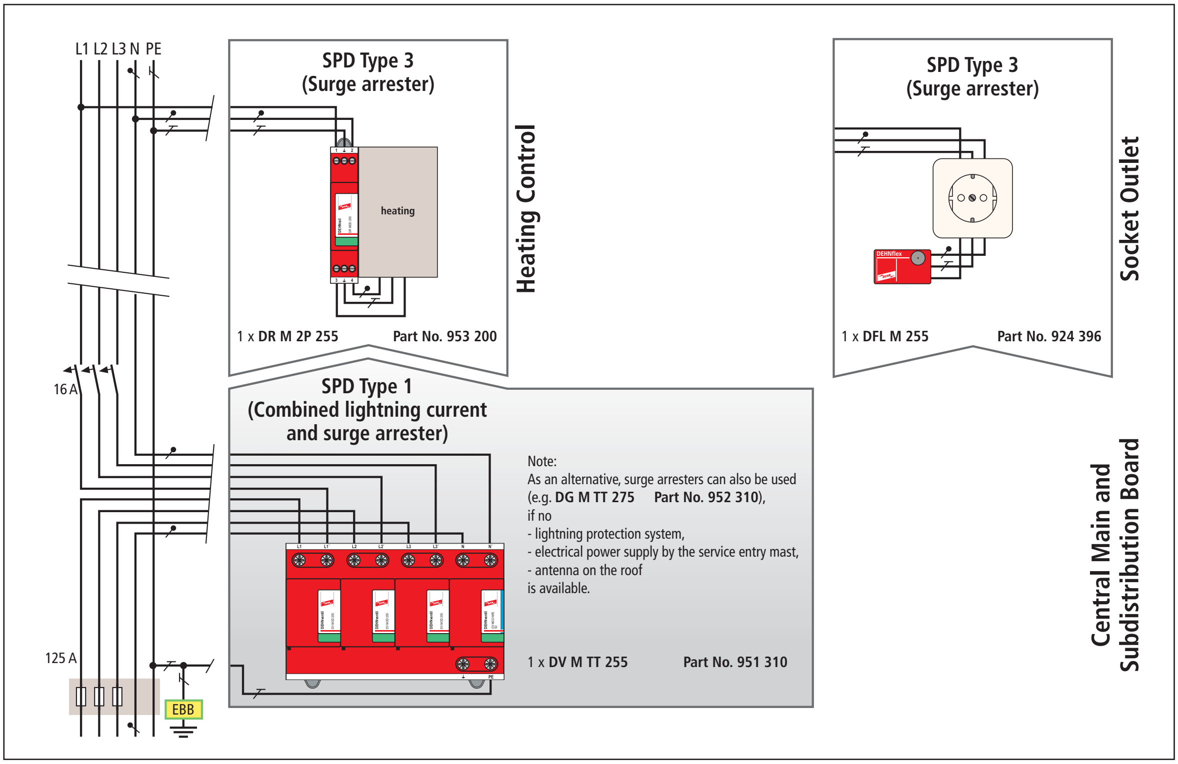


Fig. 8.1.4.3 SPDs used in TT systems – Example: Residential Building

The lightning current carrying capability of the SPDs Type 1 must be designed to conform to lightning protection levels I, II, III/IV, as per IEC 62305-1 (EN 62305-1).
For the lightning current carrying capability of the SPDs between N and PE, the following values must be maintained:

Lightning protection level:

I	$I_{imp} \geq$ 100 kA (10/350 µs)
II	$I_{imp} \geq$ 75 kA (10/350 µs)
III/IV	$I_{imp} \geq$ 50 kA (10/350 µs).

The SPDs Type 2 are also connected between L and N and between N and PE. For the SPD between N and PE, in combination with SPDs Type 2, the discharge capacity must be at least $I_n \geq$ 20 kA (8/20 µs) for three-phase systems and $I_n \geq$ 10 kA (8/20 µs) for single-phase systems.
Since coordination is always performed on the basis of the worst-case conditions (10/350 µs waveform), the N-PE Type 2 arrester from the Red/Line family is based on a value of 12 kA (10/350 µs).

Figure 8.1.4.2 to **8.1.4.6** shows examples of the connections for use of SPDs in TT systems. As is the case in TN systems, surge protective devices Type 3 are installed downstream of the RCD. Generally, the impulse current discharged by this SPD is so low that the RCD does not recognise this process as a residual current.

However, it is still important to use an RCD capable of withstanding impulse currents.

8.1.5 Use of SPDs in IT systems

For "protection against electric shock under fault conditions" in IT systems, overcurrent protective devices, residual current devices (RCD) and insulation monitoring devices have been approved.

Whereas in TN or TT systems, the "protection against electric shock under fault conditions" in the event of the first fault is ensured by the appropriate automatic disconnection from supply

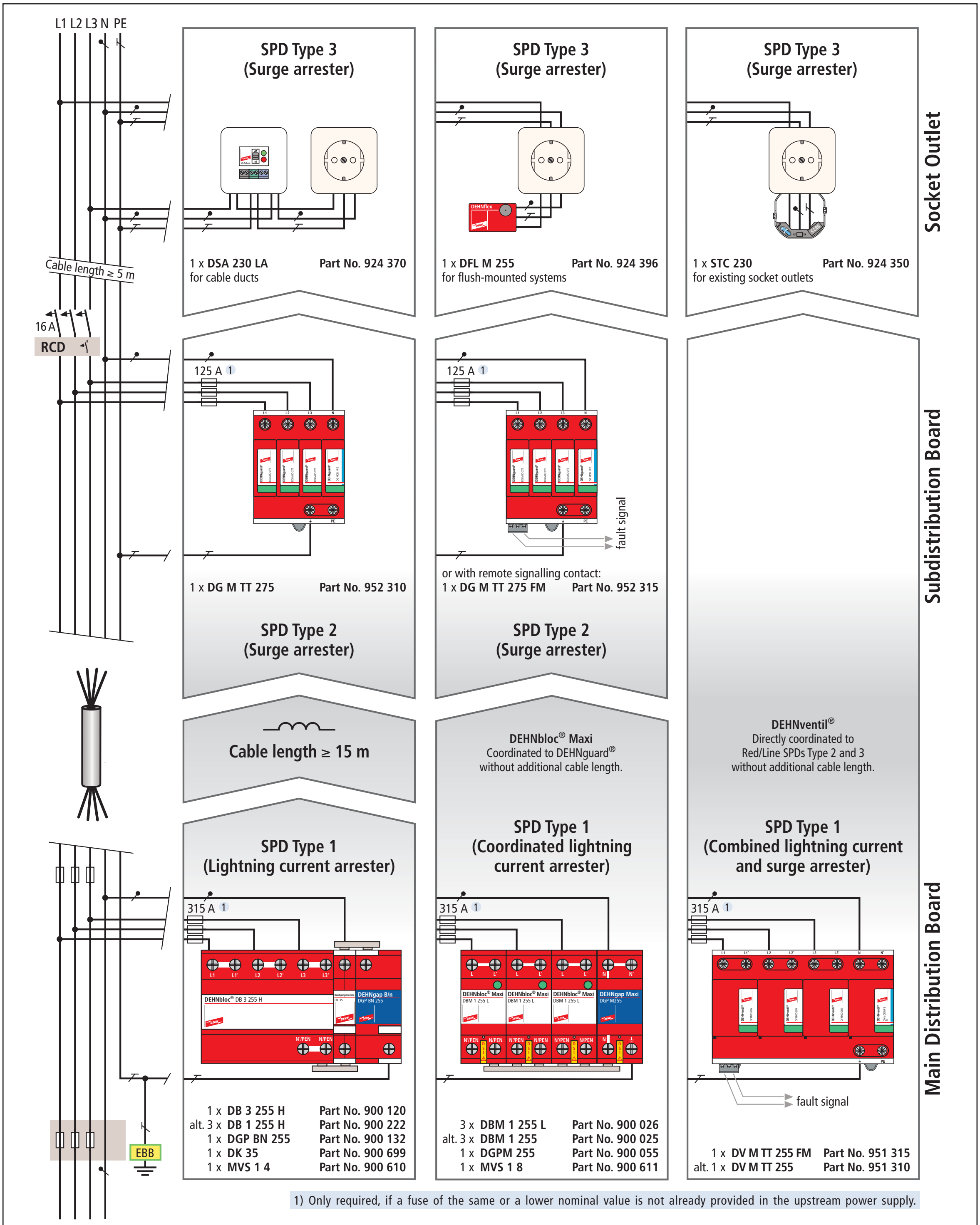


Fig. 8.1.4.4 SPDs used in TT systems – Example: Office building

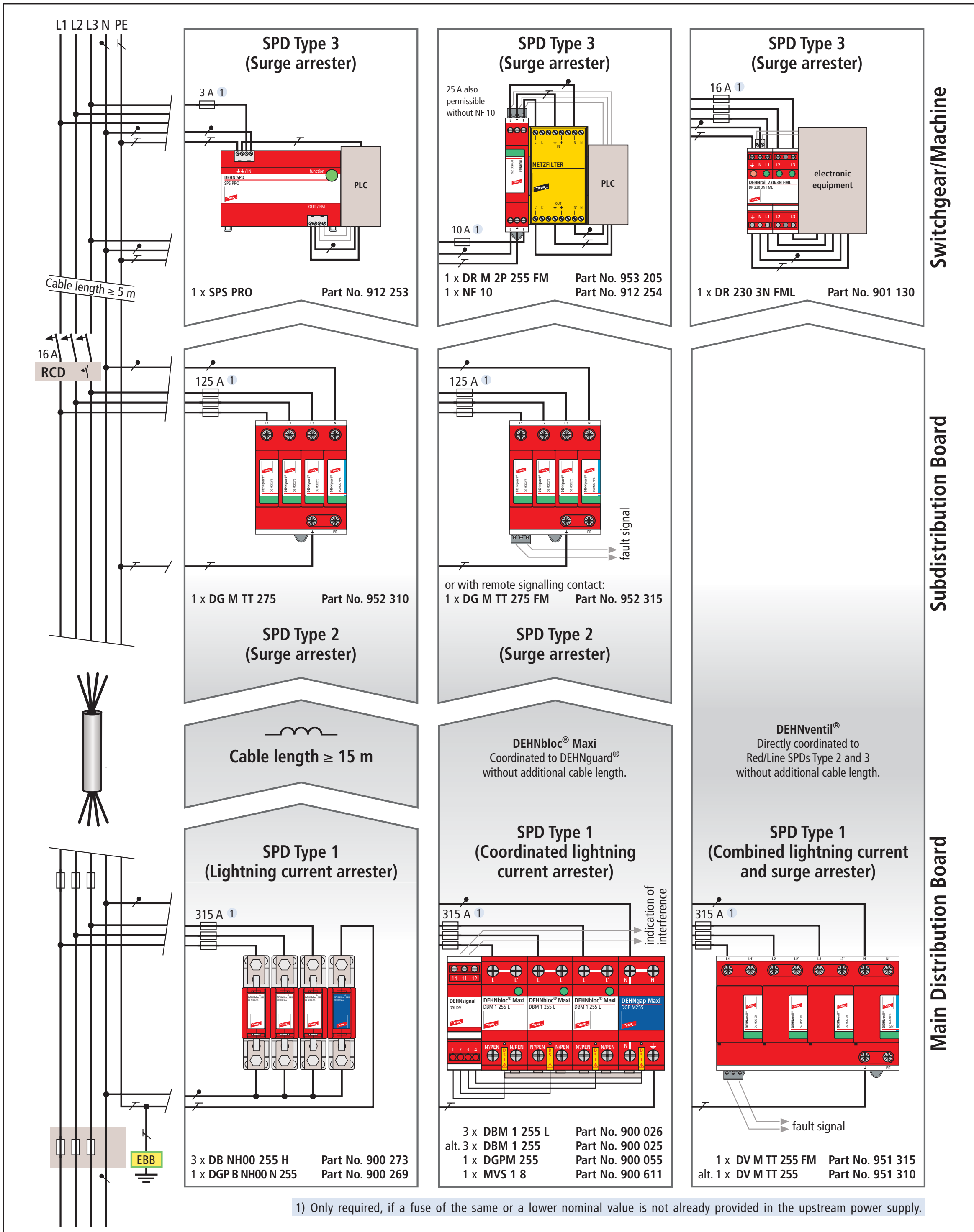


Fig. 8.1.4.5 SPDs used in TT systems – Example: Industry

through the overcurrent protective devices or RCDs, the first fault in an IT system only creates an alarm. An excessive shock hazard voltage cannot occur because the first fault in the IT system simply creates an earth connection of the system. The operating state of the IT system then becomes a TN or TT system. Hence, an IT system can be further operated at no risk after the first fault. Thus, work or production processes already begun (e.g. chemical industry) can still be completed. For the first fault, the protective conductor adopts the potential of the faulty external conductor, which, however, does not create a risk, because all bodies and metal components which persons can come into contact with, adopt this potential via the protective conductor. Hence, no hazardous potential differences can be bridged either. When the first fault occurs, however, it must be noted, that the voltage of the IT system of the intact conductors to earth corresponds to the voltage between the external conductors. Hence, in a 230/400 V IT system, in the event of a faulty SPD there is a voltage of 400 V across the non-faulty SPD. This possible operating state must be taken into account when choosing the SPDs with respect to their maximum continuous voltage.

When considering IT systems, a distinction is made between IT systems with neutral conductors entering the building with the others, and IT systems without such neutral conductors. For IT systems with the latter configuration, the SPDs in the so-called "3-0" circuit must be installed between each external conductor and the PE conductor. For IT systems with neutral conductors entering the building with the others, both the "4-0" and the "3+1" circuit can be used. When using the "3+1" circuit, it must be noted that, in the N-PE path, an SPD must be employed with a follow current extinguishing capability appropriate to the system conditions.

The following maximum continuous operating voltages apply to the use of SPDs Type 1, 2 and 3 in IT systems with and without neutral conductors entering the building with the others (**Figures 8.1.5.1a – c)**.

A second fault in an IT system must then cause a tripping of a protective device. The statements about TN and TT systems made in Sections 8.1 and 8.2 apply to the use of SPDs in IT systems in connec-

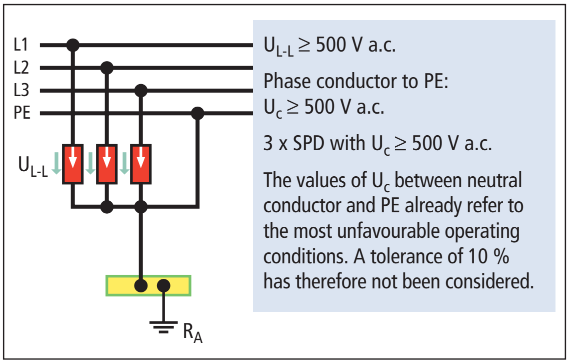


Fig. 8.1.5.1a IT system without neutral conductor; "3-0" circuit

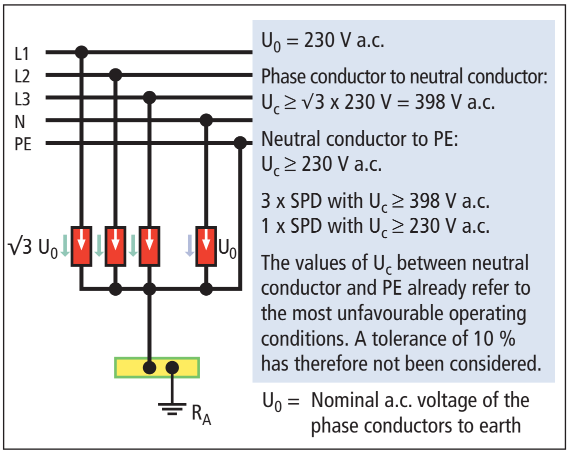


Fig. 8.1.5.1b IT system with neutral conductor; "4-0" conductor

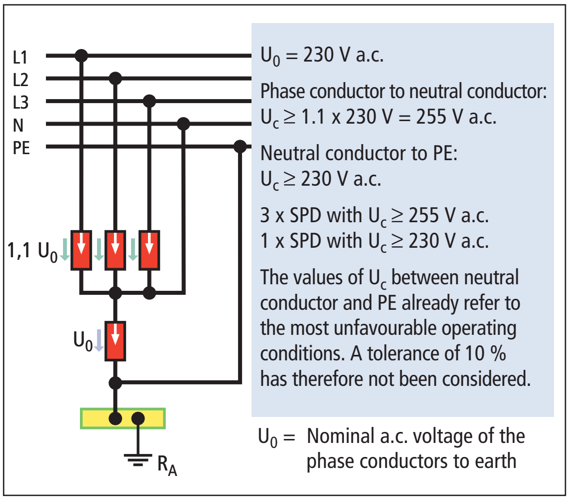


Fig. 8.1.5.1c IT system with neutral conductor; "3+1" circuit

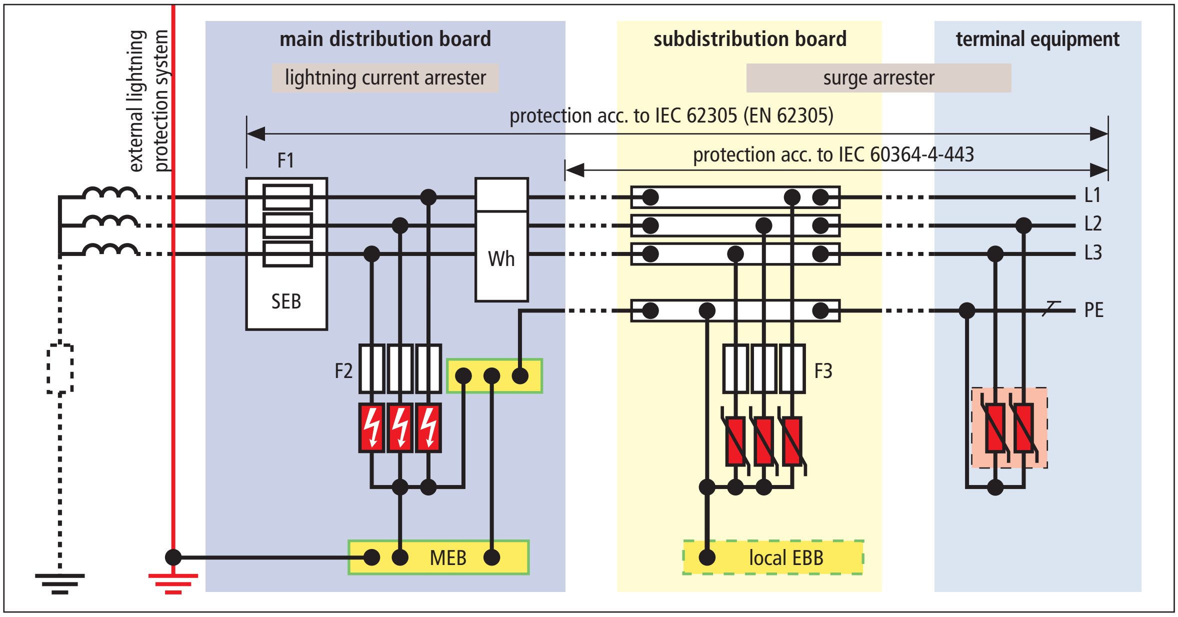


Fig. 8.1.5.2 Use of SPDs in IT systems without neutral conductor

tion with a protective device for "protection against electric shock under fault conditions".
The use of SPDs Type 1 and 2 upstream of the RCD is therefore also recommended for IT systems. A connection example for the use of SPDs in IT systems without neutral conductors entering the building with the others is shown in **Figure 8.1.5.2** and **8.1.5.3**.

Figure 8.1.5.4 shows the use of SPDs in IT systems with neutral conductor.

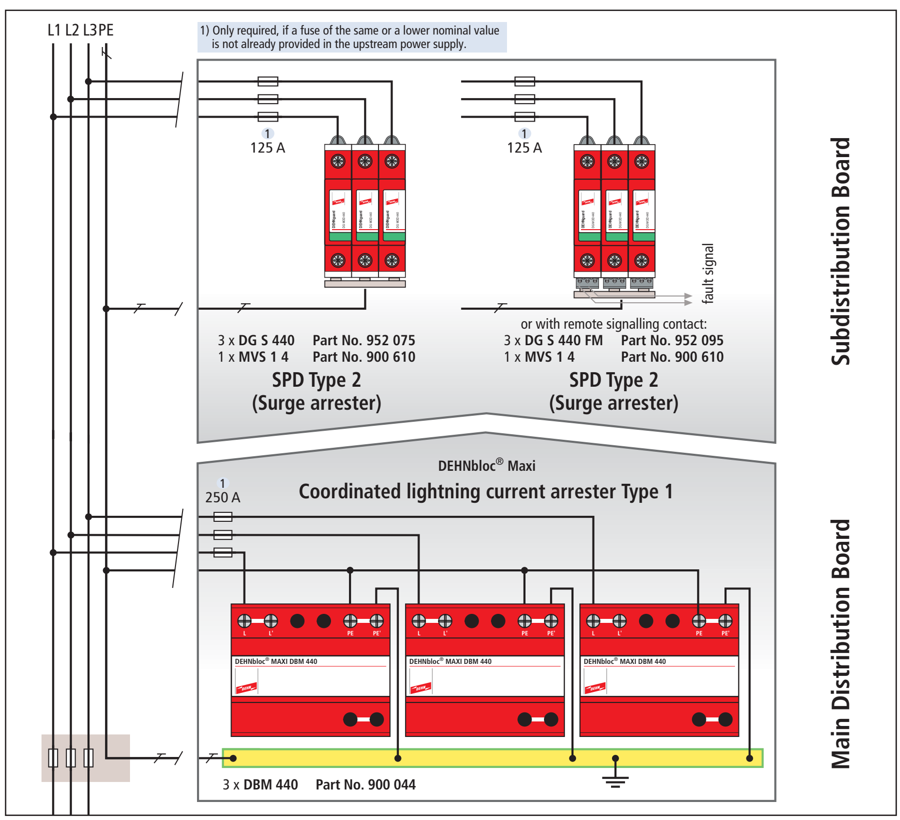


Fig. 8.1.5.3 Use of SPDs in 400 V IT systems – Example without neutral conductor

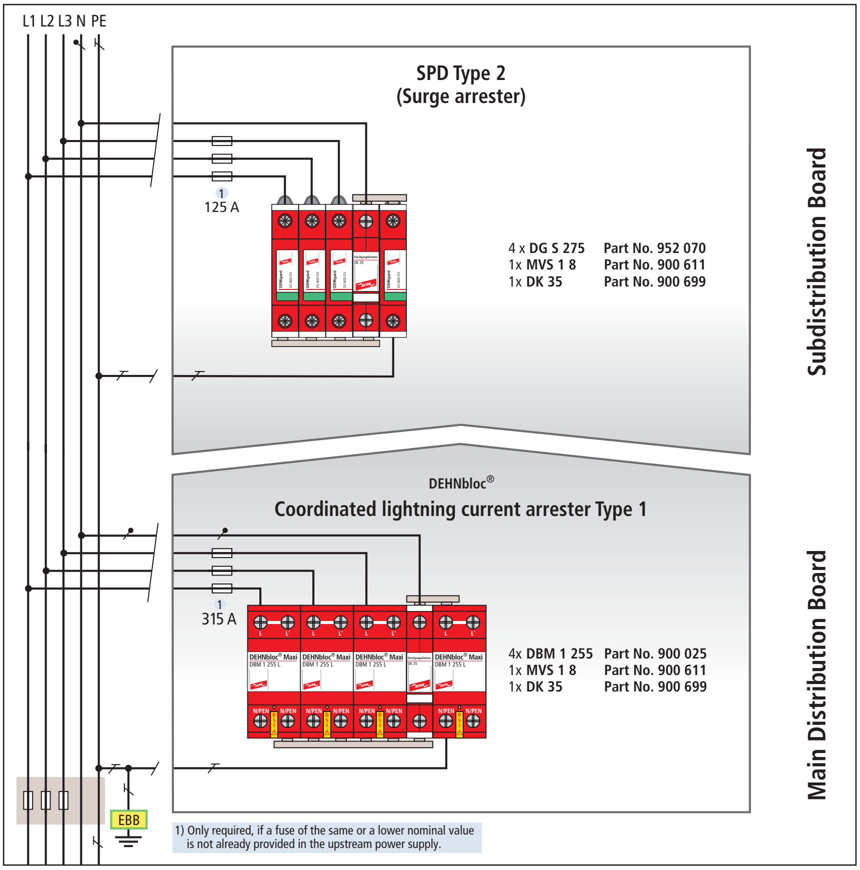


Fig. 8.1.5.4 Use of SPDs in 230/400 V IT systems – Example with neutral conductor

8.1.6 Rating the lengths of the connecting leads for SPDs

Rating the lengths of connecting leads of surge protective devices is a significant part of the IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) installation regulations.

The aspects stated below are also frequently the reason for complaints through experts, members of technical inspectorates, etc. inspecting the structure.

Series connection (V-shape) in accordance with IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001)

Crucial for the protection of systems, equipment and consumers is the actual level of impulse voltage across the installations to be protected. The optimum protective effect is then achieved when the impulse level across the installation to be protected matches the voltage protection level provided by the surge protective device. Therefore, IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) suggests a series connection system (V-shape) as shown in **Figure 8.1.6.1** to be used for connecting surge protective devices. This requires no separate conductor branches for connecting the surge protective devices.

Parallel connection system in accordance with IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001)

The optimum series connection system cannot be used under all system conditions.

Nominal currents carried via the double terminals on the surge protective device as part of the series wiring are limited by the thermal loadability of the double terminals. For this reason, the manufacturer of the surge protective device prescribes a certain max. permissible value of the backup fuse which, in turn, means that series wiring can sometimes not be used for systems with higher nominal operating currents.

Meanwhile, the industry provides so-called two-conductor terminals to solve this problem. Thus, the cable lengths can still be kept short, even if the nominal operating current is increased. When using the two-conductor terminals, however, it must be ensured that the value of the backup fuse stated by the manufacturer for this particular application is always observed (**Figures 8.1.6.2** and **8.1.6.3**).

If series connection is definitely no option, surge protective devices must be integrated into a separate branch circuit. If the nominal value of the next upstream installation fuse exceeds the nominal current of the max. permissible backup fuse of the surge protective device, the branch must be equipped with a backup fuse for the surge protec-

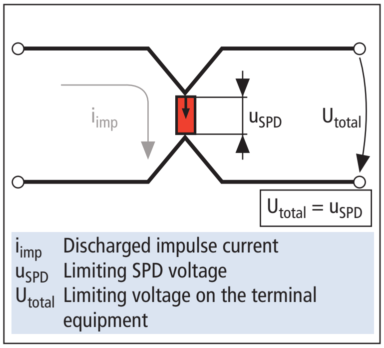


Fig. 8.1.6.1 Surge protective devices in V-shape series connection

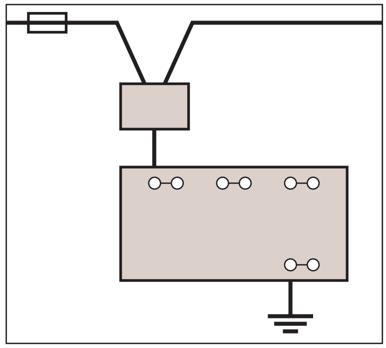


Fig. 8.1.6.2 Principle of "two-conductor terminals (TCT)" – Illustration of a single-pole unit

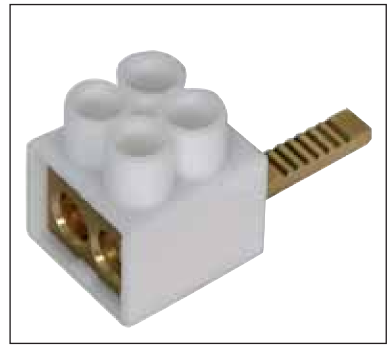


Fig. 8.1.6.3 Pin connection terminal (PCT) 2x16

tive device (**Figure 8.1.6.4**), or SPDs with integrated backup fuse are used (**Figures 8.1.6.5** and **8.1.6.6**).

When the surge protective device in the conductor branch responds, the discharge current flows through further elements (conductors, fuses) causing additional dynamic voltage drops across these impedances.

It can be stated here that the ohmic component is negligible compared to the inductive component.

Taking into account the relation

$$u_{dyn} = i \cdot R + \left(\frac{di}{dt}\right) L$$

and the rate of current change (di/dt) for transient processes of a few 10 kA/µs, the dynamic voltage drop U_{dyn} is considerably determined by the inductive component.

In order to keep this dynamic voltage drop low, the electrician carrying out the work must keep the inductance of the connecting cable and hence its length as low as possible. IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) therefore recommends to design the total cable length of surge protective devices in branch circuits to be not longer than 0.5 m (**Figure 8.1.6.7**).

Design of the connecting lead on the earth side

This requirement, which is seemingly difficult to realise, shall be explained with the help of the

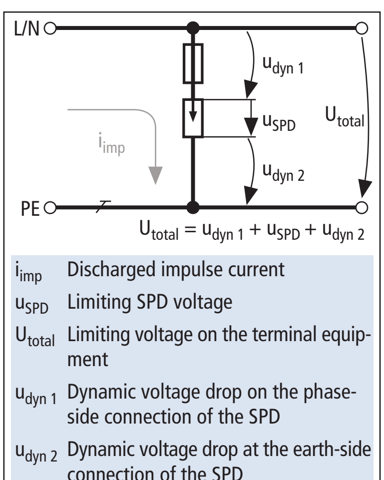


Fig. 8.1.6.4 Connection of surge protective devices in cable branches

Fig. 8.1.6.5 DEHNbloc Maxi S: coordinated lightning current arrester for the busbar with integrated backup fuse

Fig. 8.1.6.6 Surge protective device Type 2 V NH for use in NH fuse bases

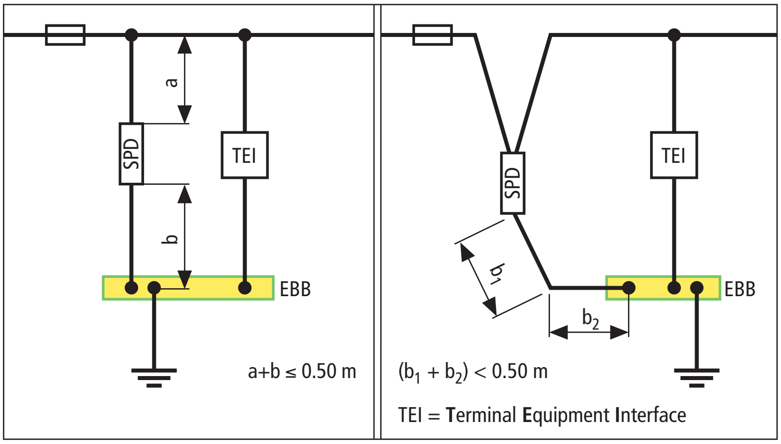


Fig. 8.1.6.7 Recommended max. cable lengths of surge protective devices in branch circuits

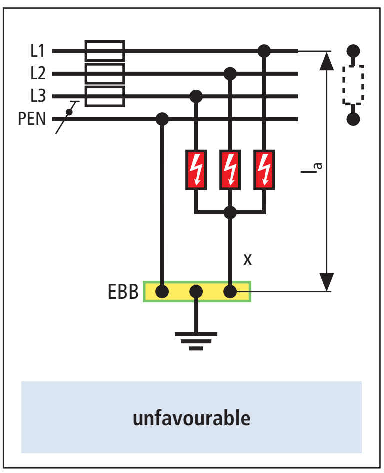


Fig. 8.1.6.8a Unfavourable conductor routing from the "consumer's point of view"

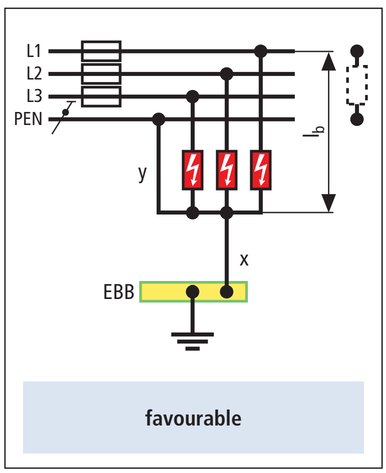


Fig. 8.1.6.8b Favourable conductor routing from the "consumer's point of view"

Thus, the effective cable length (l_a) for the surge protective devices corresponds to the distance between the installation site of the surge protective devices (e.g. service entrance box, main distribution board) to the equipotential bonding bar. A connection configuration of this type mostly achieves minimum effective protection of the installation. Without great expenses, however, it is possible to use a conductor leading as shown in **Figure 8.1.6.8b** to reduce the effective cable length of the surge protective devices (l_b < 0.5 m).
This is achieved by using a "bypass" conductor (y) from the terminal of the earth side of the arrester to the PEN. The connection from the terminal of the earth side of the arrester to the equipotential bonding bar (x) remains as it was.

According to the VDN-Richtlinie 2004-08 [engl.: Directive of the Association of the German Network Operators]: "Überspannungs-Schutzeinrichtungen Typ 1. Richtlinie für den Einsatz von Überspannungs-Schutzeinrichtungen (ÜSE) Typ 1 (bisher Anforderungsklasse B) in Hauptstromversorgungssystemen." [engl: "Surge protective devices Type 1. Directive for the use of surge protective equipment Type 1 (up to now Class B) in main distribution systems."], the bypass conductor (y) may only be omitted if the surge protective device is installed in the immediate vicinity (≤ 0.5 m) of the service entrance box and hence also in the immediate vicinity of the equipotential bonding.

example shown in **Figures 8.1.6.8a** and **b**. These show the main equipotential bonding (in future: protective equipotential bonding) of a low voltage consumer's installation in accordance with IEC 60364-4-41 and IEC 60364-5-54. Here, the use of surge protective devices Type 1 extends the equipotential bonding to become a lightning equipotential bonding.
In **Figure 8.1.6.8a**, both measures are installed separately. In this case, the PEN was connected to the equipotential bonding bar and the earthing connection of the surge protective devices was performed via a separate equipotential bonding conductor.

When installing the connection y, the distance between service entrance box or main distribution board and equipotential bonding bar is thus insignificant. The solution for this problem referred only to the design of the connecting cable on the earth side of the surge protective devices.

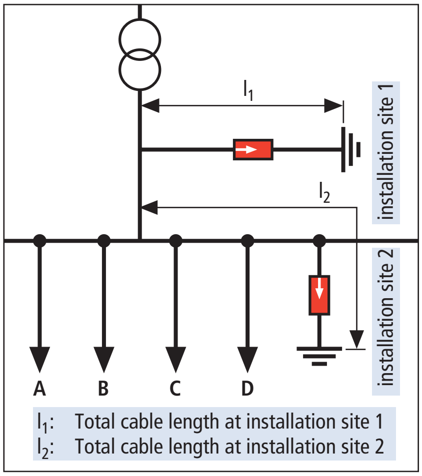


Fig. 8.1.6.9 Arrangement of surge protective devices in a system and the resulting effective cable length

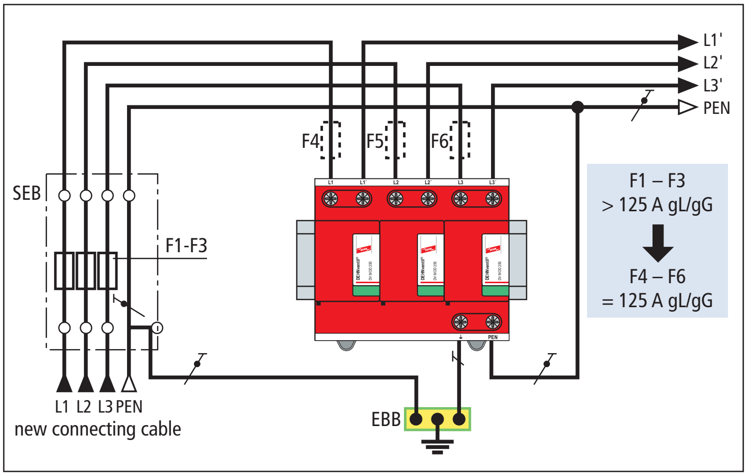


Fig. 8.1.6.10 Series connection V-shape

Design of the phase-side connecting cable

The cable length on the phase side must also be taken into consideration. The following case study shall illustrate this:

In expanded control systems, surge protection must be provided for the busbar system and the circuits attached thereto (A to D) with their consumers (**Figure 8.1.6.9**).

For the use of the surge protective devices in this case, installation sites 1 and 2 are taken as alternatives. Installation site 1 is located directly at the supply of the busbar system. This ensures the same level of protection against surges for all consumers. The effective cable length of the surge protective device at installation site 1 is l_1 for all consumers. If there is not enough space, the installation site of the surge protective devices is sometimes chosen at a position along the busbar system. In extreme cases, installation site 2 can be chosen for the arrangement shown in **Figure 8.1.6.9**. For circuit A results the effective cable length l_2. Busbar systems in fact have a lower inductance compared to cables and conductors (approx. 1/4) and hence a lower inductive voltage drop. However, the length of the busbars must not be disregarded.

The design of the connecting cables has considerable influence on the effectiveness of surge protective devices and must therefore be taken into consideration at the design stage of the installation!

The contents of IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) described above were important guidelines for the development of the new DEHNventil combined lightning current and surge arrester which was supposed to combine the requirements on lightning current and surge arresters in accordance with the IEC 62305 Part 1 – 4 (EN 62305 Part 1 – 4) standard series in a single device.

This allows to realise a series connection directly via the device. **Figure 8.1.6.10** shows such a series connection in form of an operating circuit diagram.

Fig. 8.1.6.11 V-shape series connection of the DEHNventil M TNC combined lightning current and surge protective device by means of a busbar

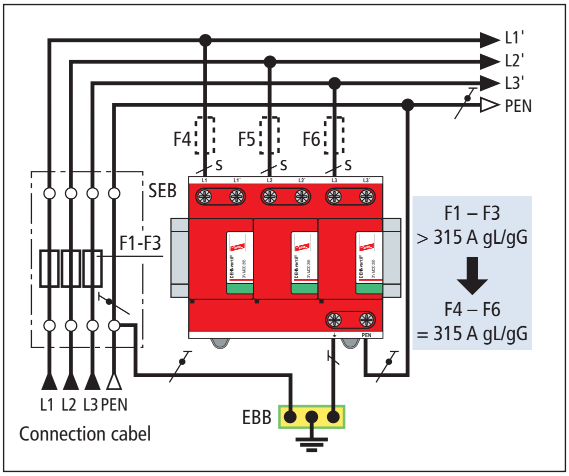


Fig. 8.1.6.12 Parallel wiring

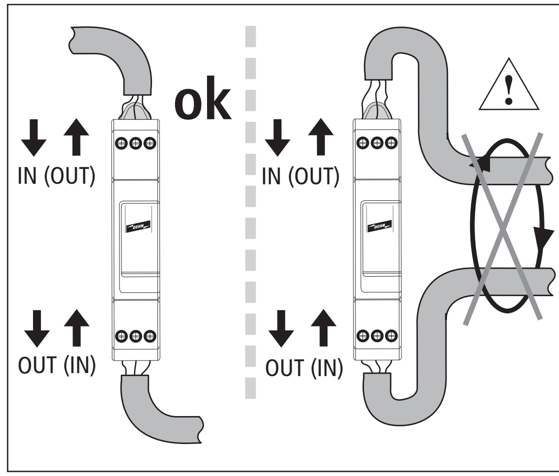


Fig. 8.1.6.13 Cable routing

From **Figure 8.1.6.11** it can be taken how advantageous it is to implement a series connection with the aid of a busbar.

Because of the thermal loading capacity of the double terminals employed, a v-shape series connection (also called through-wiring) can be used up to 125 A.

For load currents > 125 A, the surge protective devices are connected in the conductor branch (so-called parallel wiring). The maximum cable lengths according to IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001) must be observed. The parallel wiring can be implemented as shown in **Figure 8.1.6.12**.

In this context, it should be ensured that the connecting cable on the earth side still benefits from the double terminal for the earth connection. As shown in **Figure 8.1.6.12**, it is often possible, without great effort, to achieve an effective cable length of the order of magnitude l < 0.5 m with a conductor leading from terminal component "PE" of the earth-side double terminal to PEN.

At the installation of surge protective devices in distributions it must generally be considered that conductors loaded by impulse currents and those not loaded by impulse currents are routed as separately as possible. In any case, a parallel routing of both conductors has to be avoided (**Figure 8.1.6.13**).

8.1.7 Rating of the terminal cross-sections and the backup protection of surge protective devices

Connecting leads of arresters can be subjected to loads from impulse currents, operating currents and short circuit currents. The individual loads depend on various factors:

⇒ Type of protective circuit: one-port (**Figure 8.1.7.1**) / two-port (**Figure 8.1.7.2**)

⇒ Type of arrester: lightning current arrester, combined lightning current and surge arrester, surge protective devices

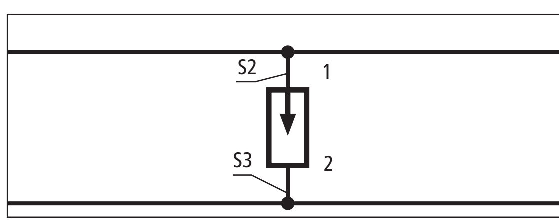


Fig. 8.1.7.1 One-port protective circuit

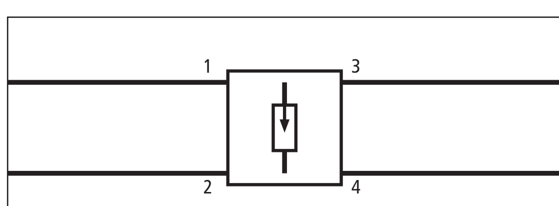


Fig. 8.1.7.2 Two-port protective circuit

Conductor material	Insulating material		
	PVC	EPR / XLPE	Rubber
Cu	115	143	141
Al	76	94	93

Table 8.1.7.1 Material coefficient k for copper and aluminium conductors with different insulating material

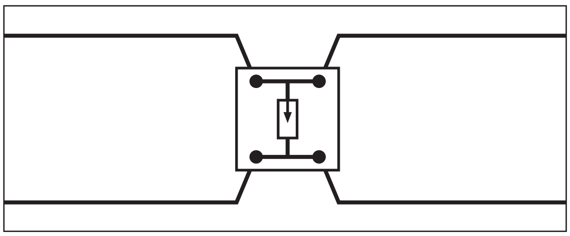
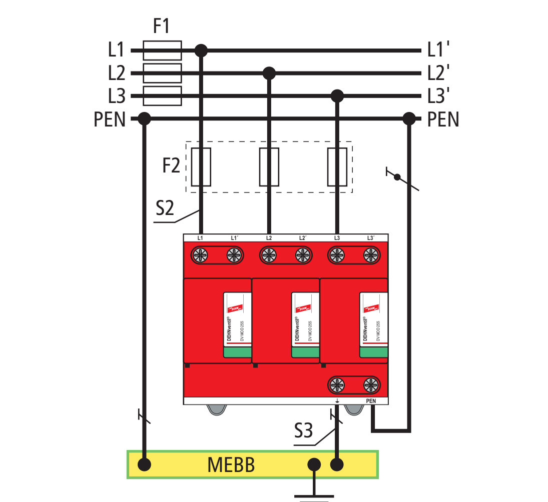


Fig. 8.1.7.3 SPD with through-wiring

⇒ Performance of the arrester on follow currents: follow current extinction/follow current limitation

If surge protective devices are installed as shown in **Figure 8.1.7.1**, the S2 and S3 connecting cables must only be rated upon the criteria of short circuit protection according to IEC 60364-4-43 and the impulse current carrying capability. The data sheet of the protective device provides the maximum permissible overcurrent protection which can be used in this application as backup protection for the arrester.

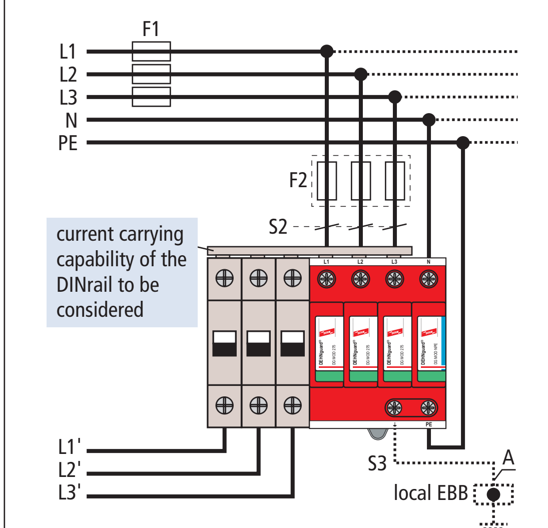
When installing the devices, it must be ensured that the short circuit current actually flowing is able to trip the backup protection. The rating of the cross-sectional area or of the conductor is then given by the following equation:



DEHNventil DV M TNC 255	
F1	F1 > 315 A gL / gG → F2 ≤ 315 A gL / gG
F2	F1 ≤ 315 A gL / gG → ~~F2~~

Fuse F1 A gL / gG	S2 / mm²	S3 / mm²	Fuse F2 A gL / gG
25	10	16	---
35	10	16	---
40	10	16	---
50	10	16	---
63	10	16	---
80	10	16	---
100	16	16	---
125	16	16	---
160	25	25	---
200	35	35	---
250	35	35	---
315	50	50	---
> 315	50	50	≤ 315

Fig. 8.1.7.4 Example: DEHNventil, DV TNC 255



DEHNguard M TNC 275 **DEHNguard** M TNS 275 **DEHNguard** M TT 275	
F1	F1 > 125 A gL / gG → F2 ≤ 125 A gL / gG
F2	F1 ≤ 125 A gL / gG → ~~F2~~

Fuse F1 A gL / gG	S2 / mm²	S3 / mm²	Fuse F2 A gL / gG
35	4	6	---
40	4	6	---
50	6	6	---
63	10	10	---
80	10	10	---
100	16	16	---
125	16	16	125
160	25	16	125
200	35	16	125
250	35	16	125
315	50	16	125
400	70	16	125

Fig. 8.1.7.5 Example: DEHNguard (M) TNC/TNS/TT

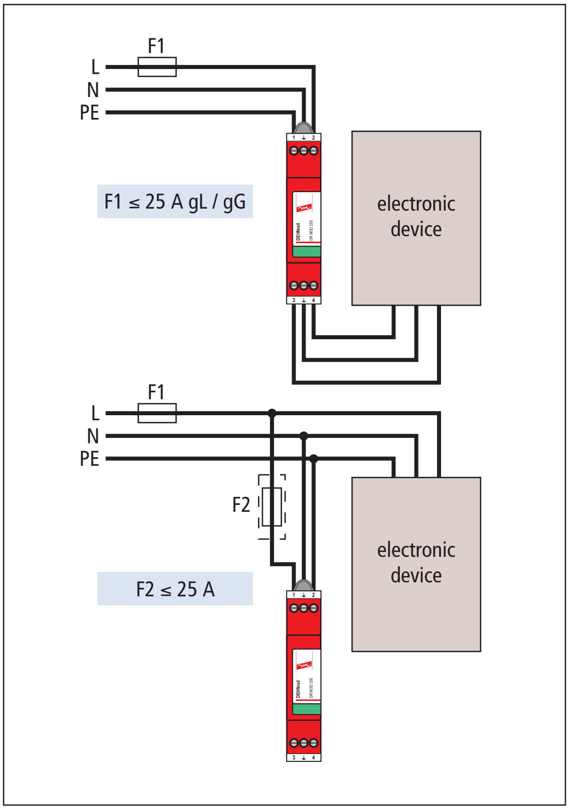


Fig. 8.1.7.6 Example: DEHNrail

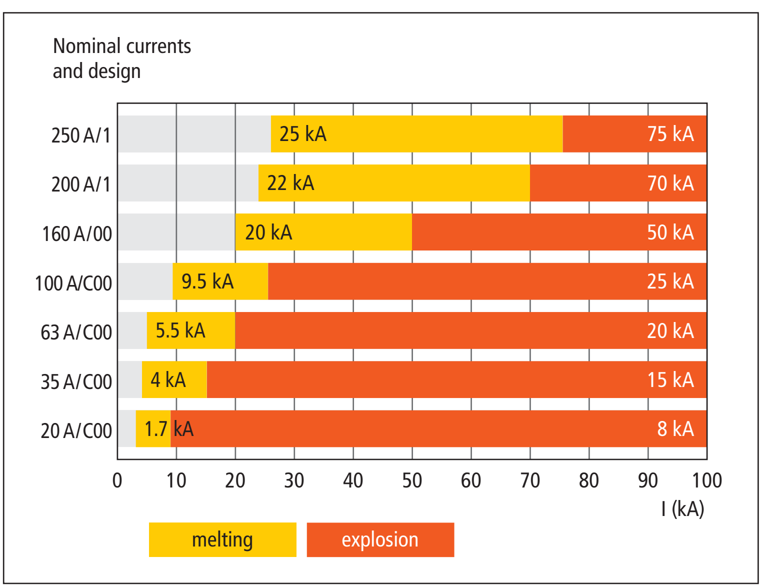


Fig. 8.1.7.7 Performance of NH fuses bearing impulse current loads

$$k^2 \cdot S^2 = I^2 \cdot t$$

- t Permissible time for disconnection in the event of a short circuit in s
- S Conductor cross section in mm^2
- I Current at complete short circuit in A
- k Material coefficient in $A \cdot s/mm^2$ according to **Table 8.1.7.1**

Furthermore, it must be ensured that the information concerning the maximum permissible overcurrent protection circuits in the data sheet of the surge protective device is only valid up to the value of the stated short-circuit withstand capability of the protective device. If the short circuit current at the installation site is greater than the stated short-circuit withstand capability of the protective device, a backup fuse must be chosen which is smaller than the maximum backup fuse stated in the data sheet of the arrester by a ratio of 1:1.6.
For surge protective devices installed as shown in **Figure 8.1.7.2**, the maximum operating current must not exceed the nominal load current stated for the protective device. To protective devices which can be connected in series, applies the maximum current for through-wiring (**Figure 8.1.7.3**).

Figure 8.1.7.4 shows examples of cross-sectional areas and backup protection for lightning current arresters and combined lightning current and surge arresters Type 1.
Figure 8.1.7.5 shows examples of cross-sectional areas and backup protection for surge protective devices Type 2. **Figure 8.1.7.6** shows the same for surge protective devices Type 3.

The behaviour of the impulse current must be taken into consideration when rating the backup fuses for surge protective devices. There is a noticeable difference in the way fuses disconnect short circuit currents compared to the way they disconnect loads with impulse currents, particularly with lightning impulse currents, waveform 10/350 µs.
The performance of fuses was determined as a function of the rated current of the lightning impulse current (**Figure 8.1.7.7**).

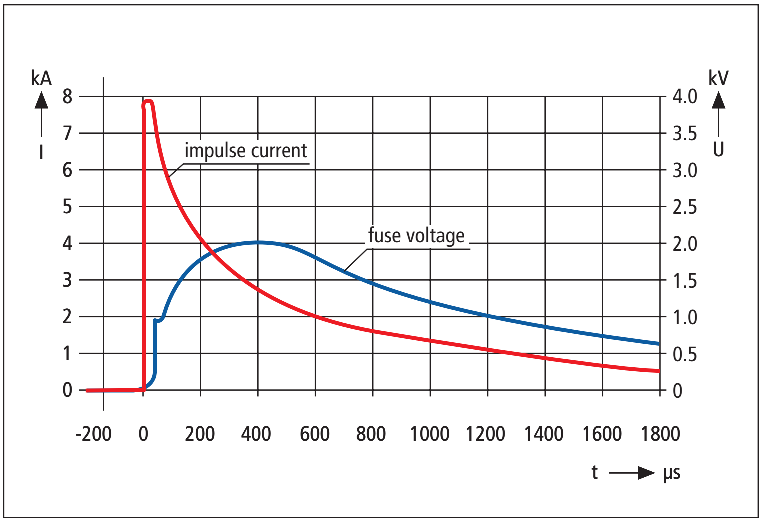


Fig. 8.1.7.8 Current and voltage of a blowing 25 A NH fuse being charged with lightning impulse currents (10/350 µs)

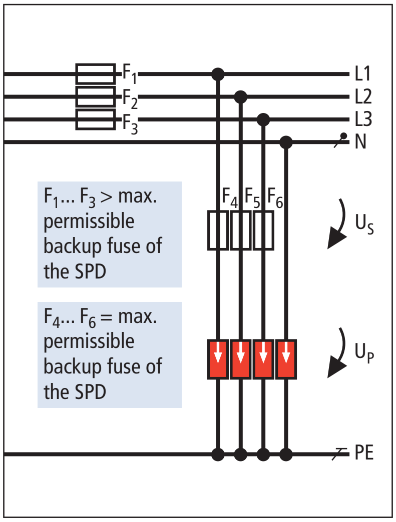


Fig. 8.1.7.9 Use of a separate backup fuse for surge protective devices

Field 1: No melting
The energy brought into the fuse by the lightning impulse current is too low to cause a melting of the fuse.

Field 2: Melting
The energy of the lightning impulse current is sufficient to melt the fuse and hence interrupt the current path through the fuse (**Figure 8.1.7.8**).
It is characteristical for the performance of the fuse that the lightning impulse current, since it is injected, continues to flow, unaffected by the performance of the fuse. The fuse disconnects only after the lightning impulse current has decayed. The fuses are therefore not selective with respect to the disconnection of lightning impulse currents. Therefore it must be ensured that, because of the behaviour of the impulse current, the maximum permissible backup fuse as per the data sheet and/or installation instructions of the protective device is always used.

From **Figure 8.1.7.8** it can also be seen that, during the melting process, a voltage drop builds up across the fuse which in part can be significantly above 1 kV. For applications as illustrated in **Figure 8.1.7.9**, a melting of the fuse can also result in the voltage protection level of the installation being significantly higher than the voltage protection level of the surge protective device employed.

Field 3: Explosion

If the energy of the lightning impulse current is so high to be much higher than the pre-arcing of the fuse, then the fuse strip can vaporise explosively. This often results in a bursting fuse box. Apart from the mechanical consequences, it must be noted that the lightning impulse current continues to flow through the bursting fuse in the form of an electric arc; the lightning impulse current can thus not be interrupted nor, linked to this, can the required impulse current carrying capability of the employed arrester be reduced.

Selectivity to the protection of the installation

When using spark-gap based surge protective devices, care must be taken that any starting mains follow current is limited to the extent that overcurrent protective devices such as fuses and/or arrester backup fuses cannot trip. This characteristic of the protective devices is called follow current limitation or follow current suppression. Only by using technologies such as the RADAX Flow technology allows to develop arresters and combinations of arresters which, even for installations with high short circuit currents, are able to reduce and extinguish the current to such a degree that upstream fuses for lower rated currents do not trip (**Figure 8.1.7.10**).

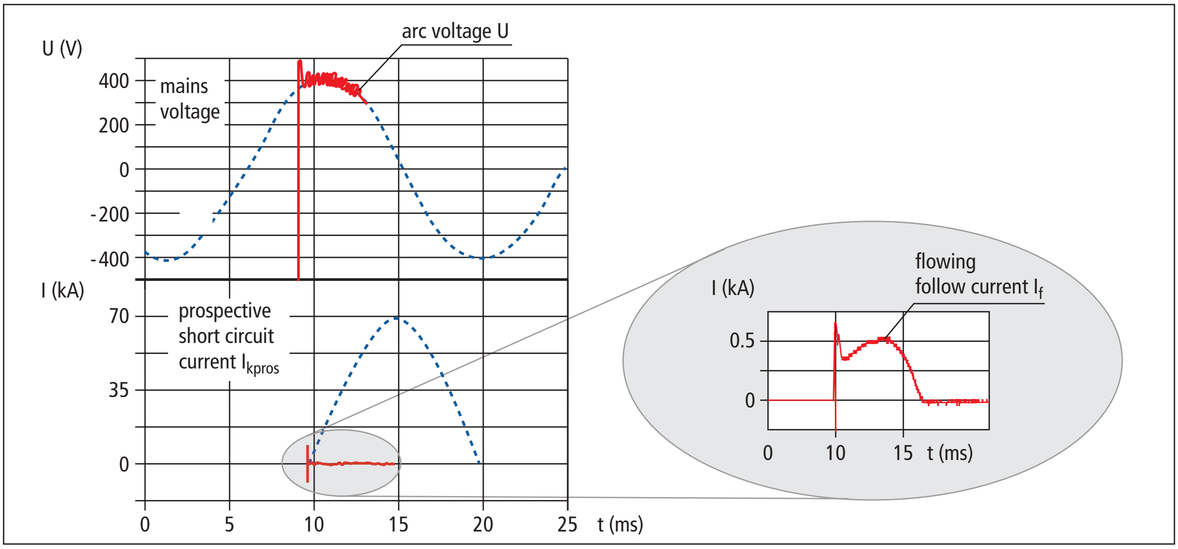


Fig. 8.1.7.10 Reduction of the follow current with the patented RADAX Flow principle

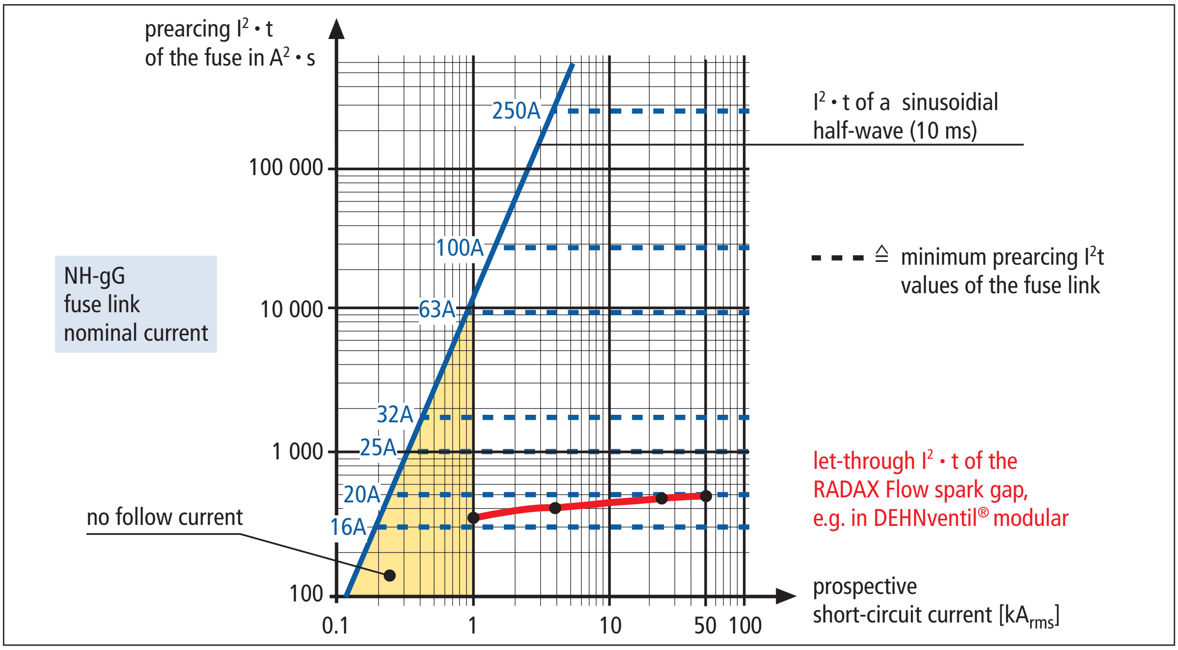


Fig. 8.1.7.11 Disconnection selectivity of DEHNventil to NH fuse holders with different rated currents

The system availability required by EN 60439-1, even in the event of responding surge protective devices, can be fulfilled by the aforementioned "follow current suppression" characteristic of the device. For surge protective devices with low sparkover voltage, in particular, designed to not only take on the function of the lightning equipotential bonding but also that of surge protection in the installation, the performance of the follow current limitation is more important than ever for the availability of the electrical installation (**Figure 8.1.7.11**).

8.2 Information technology systems

The primary function of arresters is to protect downstream terminal devices. They also reduce the risk of cables from being damaged.
The choice of arresters depends, among other things, on the following considerations:

⇒ Lightning protection zones of the installation site, if existing

⇒ Energies to be discharged

⇒ Arrangement of the protective devices

⇒ Immunity of the terminal devices

⇒ Protection against differential-mode and/or common-mode interferences

⇒ System requirements, e.g. transmission parameters

⇒ Compliance with product or user-specific standards, where required

⇒ Adaption to the environmental conditions/installation conditions

Protective devices for antenna cables are classified according to their suitability for coaxial, balanced or hollow conductor systems, depending on the physical design of the antenna cable.

In the case of coaxial and hollow conductor systems, the outer conductor can generally be connected directly to the equipotential bonding. Earthing couplings specially adapted to the respective cables are suitable for this purpose.

Procedure for selection and installation of arresters: Example BLITZDUCTOR CT

Opposite to choosing surge protective devices for power supply systems (see Chapter 8.1), where uniform conditions can be expected with respect to voltage and frequency in 230/400 V systems, the types of signals to be transmitted in automation systems differ with respect to their

⇒ voltage (e.g. 0 – 10 V)

⇒ current (e.g. 0 – 20 mA, 4 – 20 mA)

⇒ signal reference (balanced, unbalanced)

⇒ frequency (DC, NF, HF)

⇒ type of signal (analogue, digital).

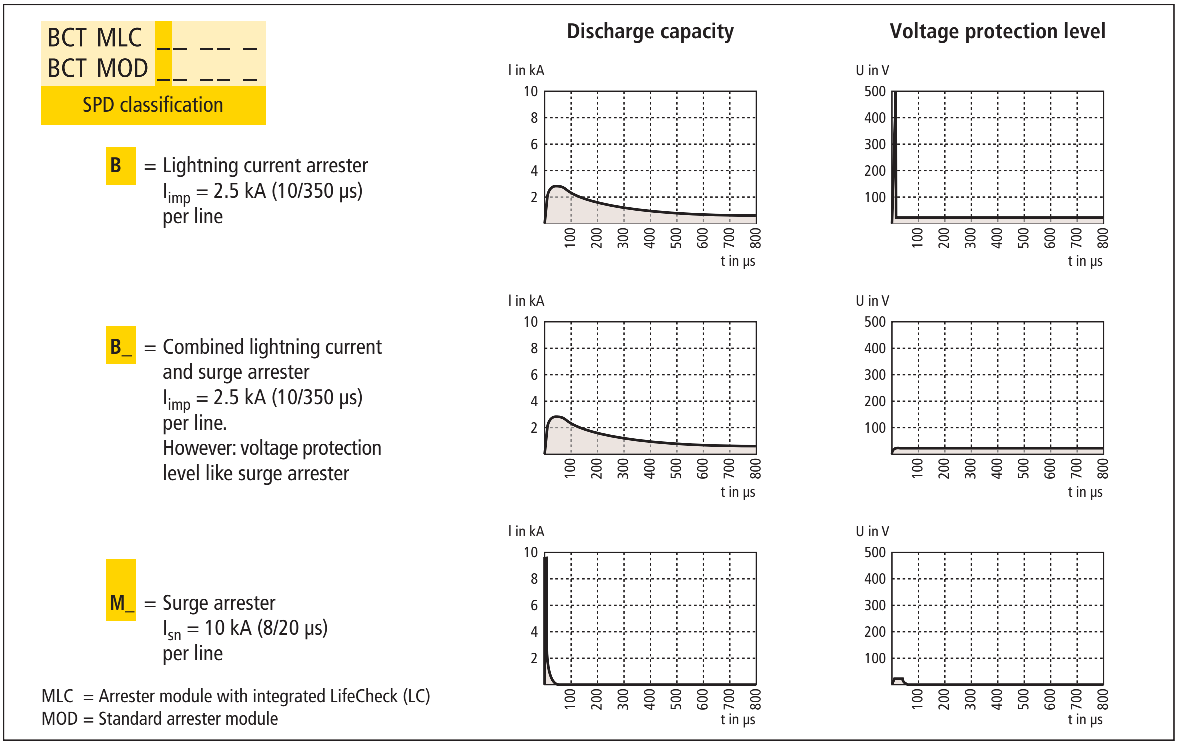
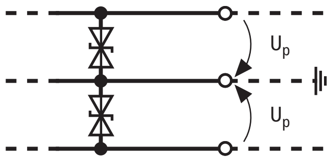


Fig. 8.2.1 SPD classification

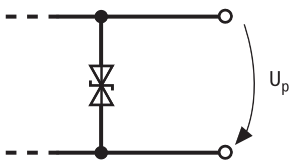
BCT MLC _ _ _ _ _
BCT MOD _ _ _ _ _

SPD classification

E = Fine limiting of surges line ⇒ earth (limiting of common-mode interferences)



D = Fine limiting of surges line ⇒ line (limiting of differential-mode interferences)



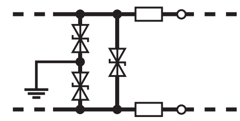
MLC = Arrester module with integrated LifeCheck (LC)
MOD = Standard arrester module

Fig. 8.2.2 Limiting performance

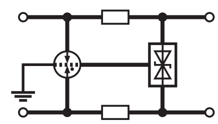
BCT MLC _ _ _ _ _
BCT MOD _ _ _ _ _

SPD classification

C = Additional limiting of differential-mode interferences and additional decoupling resistors in the BLITZDUCTOR CT output for decoupling the BLITZDUCTOR protective diodes from eventually existing diodes in the input of the device to be protected (e.g. clamping diodes, optocoupler diodes)



HF = Design for protection of high-frequency transmission lengths (use of a diode matrix for fine limiting of surges), limiting of common-mode and differential-mode interferences



EX = Protective device for use in intrinsically safe circuits (a.c. voltage resistance to earth 500 V a.c.)

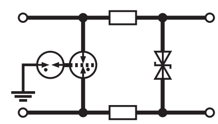


Fig. 8.2.3 Note on special applications

Each of these electrical characteristics for the signal to be transmitted can contain the actual information to be transferred.

Therefore, the signal must not be influenced intolerably by the use of lightning current and surge arresters in measuring and control installations. Several points must be taken into account when choosing protective devices for measuring and control systems. They are described below for our universal BLITZDUCTOR CT protective devices and illustrated by means of application examples (**Figures 8.2.1 – 8.2.4** and **Table 8.2.1**).

Type designation of the protective modules

C Supplementary limiting of differential-mode interferences and supplementary decoupling resistors in the BLITZDUCTOR CT output for decoupling the BLITZDUCTOR protective diodes from any diodes possibly present at the input of the device to be protected (e.g. clamping diodes, optocoupler diodes)

HF Design for protection of high frequency transmission paths (use of a diode matrix for fine limiting of surges), limiting of common-mode and differential-mode interferences

BCT MLC _ _ _ _ _
BCT MOD _ _ _ _ _

SPD classification

The indication of the nominal voltage characterises the range of a typical signal voltage which has no limiting effect on the protective device under nominal conditions. The value of nominal voltage is indicated as d.c. value. Transmitting a.c. voltages, the peak value of the a.c. voltage must not exceed the nominal voltage value.

The nominal voltages for the individual types are indicated as follows:

Type		Nominal voltage U_N
_E	=	Voltage between line-earth
_D	=	Voltage between line-line
_E C	=	Voltage between line-line as well as line-earth
_D HF	=	Voltage between line-line
_D HFD	=	Voltage between line-line
_D EX	=	Voltage between line-line

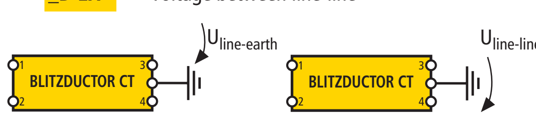


Fig. 8.2.4 Nominal voltage

MLC B	110	MOD B	110
MLC BE	5	MOD ME	5
MLC BE	12	MOD ME	12
MLC BE	15	MOD ME	15
MLC BE	24	MOD ME	24
MLC BE	30	MOD ME	30
MLC BE	48	MOD ME	48
MLC BE	60	MOD ME	60
MLC BE	110	MOD ME	110
MLC BD	5	MOD MD	5
MLC BD	12	MOD MD	12
MLC BD	15	MOD MD	15
MLC BD	24	MOD MD	24
MLC BD	30	MOD MD	30
MLC BD	48	MOD MD	48
MLC BD	60	MOD MD	60
MLC BD	110	MOD MD	110
MLC BD	250	MOD MD	250
MLC BE C	5	MOD ME C	5
MLC BE C	12	MOD ME C	12
MLC BE C	24	MOD ME C	24
MLC BE C	30	MOD ME C	30
MLC BD HF	5	MOD MD HF	5
MLC BD HFD	5	MOD MD HFD	5
MLC BD HFD	24	MOD MD HFD	24
		MOD MD EX	24
		MOD MD EX	30
		MOD MD EX HFD	6

Table 8.2.1 Type designation of the protection modules

EX Protective device for use in intrinsically safe circuits approved by, ATEX and FISCO (a.c. voltage resistance to earth 500 V a.c.)

Technical Data:

Voltage protection level U_p

The voltage protection level is a parameter that characterises the performance of a surge protective device in limiting the voltage at its terminals. The voltage protection level must be higher than the maximum limiting voltage measured.

The measured limiting voltage is the maximum voltage measured at the terminals of the surge protective device when exposed to a surge current and/or surge voltage of a certain waveform and amplitude.

Measured limiting voltage with a steepness of the applied test voltage waveform of 1 kV/µs

This test is to determine the response characteristics of gas discharge tubes (GDT). These protective elements have a "switching characteristic". The mode of functioning of a GTD can be compared to a switch whose resistance can "automatically" switch from > 10 GΩ (in non-ignited state) to values < 0.1 Ω (in ignited state) when a certain voltage value is exceeded and the surge applied is nearly short circuited. The response voltage of the GDT depends on the steepness of the incoming voltage (du/dt).

Generally applies:

The higher the steepness du/dt, the higher is the response voltage of the gas discharge tube. The

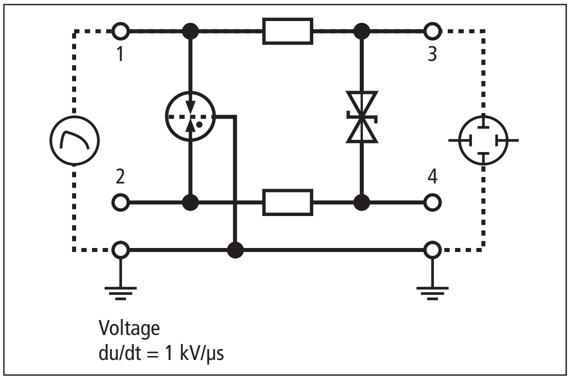


Fig. 8.2.5 Test arrangement for determining the limiting voltage at a rate of voltage rise of du/dt = 1kV/µs

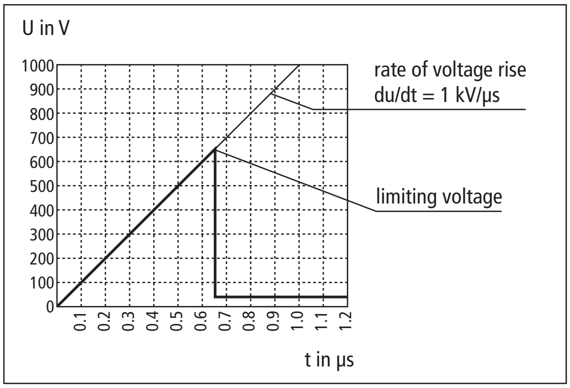


Fig. 8.2.6 Sparkover performance of an SPD at du/dt = 1kV/µs

B	1 A		
BE	1 A	ME	1 A
BD	1 A	MD	1 A
BE C	0.1 A	ME C	0.1 A
BD HF	0.1 A	MD HF	0.1 A
BD HFD	0.1 A	MD HFD	0.1 A
		MD EX	0.5 A
		MD EX HFD	4.8 A

Table 8.2.2 Nominal currents of the protection modules BCT

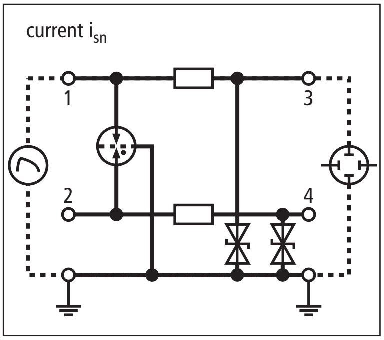


Fig. 8.2.7 Test arrangement for determining the limiting voltage at nominal discharge current

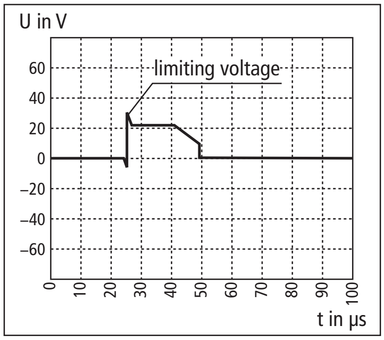


Fig. 8.2.8 Limiting voltage at nominal discharge current

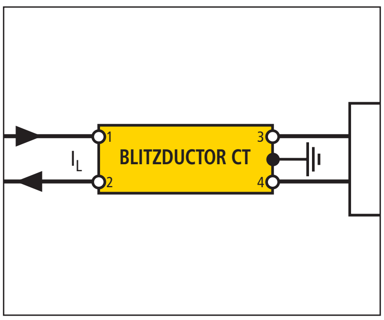


Fig. 8.2.9 Nominal current of BLITZDUCTOR CT

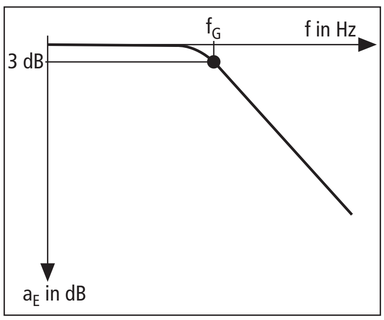


Fig. 8.2.10 Typical frequency response of a BLITZDUCTOR CT

To the different types of protection modules of BLITZDUCTOR CT apply the nominal currents according to **Table 8.2.2**:

Cut-off frequency f_G

The cut-off frequency describes the performance of an SPD depending on the frequency. It is that frequency which gives an insertion loss (a_E) of 3 dB under certain test conditions (see EN 61643-21)

If there is no other indication in the catalogue, this frequency stated applies to a 50 Ohm system (**Figure 8.2.10**).

Selection features (SF)

1. **Which discharge capacity is required?**

The rating of the discharge capacity of BLITZDUCTOR CT is determined by the protective task to be fulfilled. For easy selection, the following cases a to d are explained.

comparability of different gas discharge tubes is made possible by applying a voltage rise of 1 kV/µs at the gas discharge tube for determination of the dynamic response voltage (**Figures 8.2.5** and **8.2.6**).

Measured limiting voltage at nominal discharge current

This test is carried out to determine the limiting behaviour of protective elements with constant limiting characteristics (**Figures 8.2.7** and **8.2.8**).

Nominal current I_L

The nominal current of BLITZDUCTOR CT characterises the permissible continuous operating current. The nominal current of BLITZDUCTOR CT is determined by the current carrying capability and the insertion loss of the impedances used for decoupling of gas discharge tubes and fine protection elements as well as by the follow current extinguishing capability. The value is stated as d.c. value (**Figure 8.2.9**).

Case a: In this case the terminal equipment to be protected is located in a building structure with an external lightning protection system or the roof of the building is equipped with metal roof structures exposed to lightning (e.g. antenna masts, air-conditioning systems). The measuring and control or telecommunications cable connecting the terminal equipment (**Figure 8.2.11**) to the transformer is mounted outside the building structure. Due to the fact that the building structure is fitted with an external lightning protection, the installation of a lightning current arrester TYPE 1 is necessary. The **modules BCT MLC B...** or **B...** of the BLITZDUCTOR CT family can be used for this purpose.

Case b: Case b is similar to case a, only the building structure, where the terminal equipment to be protected is located, has no external lightning protection system: The arising of lightning currents or partial lightning currents is not assumed here. The installation of a lightning current carrying capable

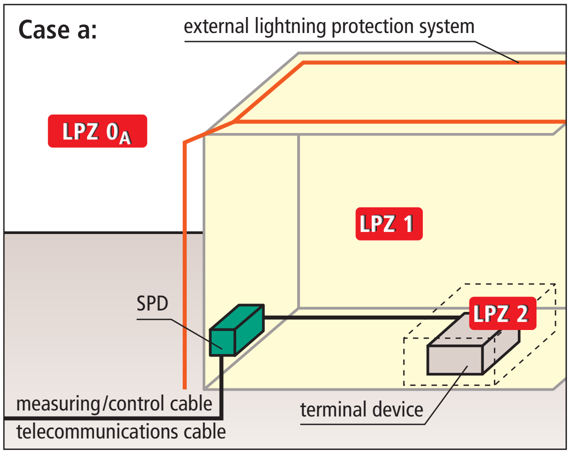


Fig. 8.2.11 Building with external lightning protection system and cables installed between buildings

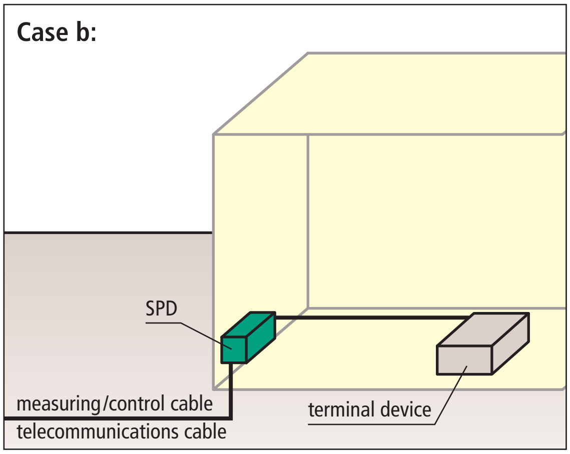


Fig. 8.2.12 Building without external lightning protection system and cables installed between buildings

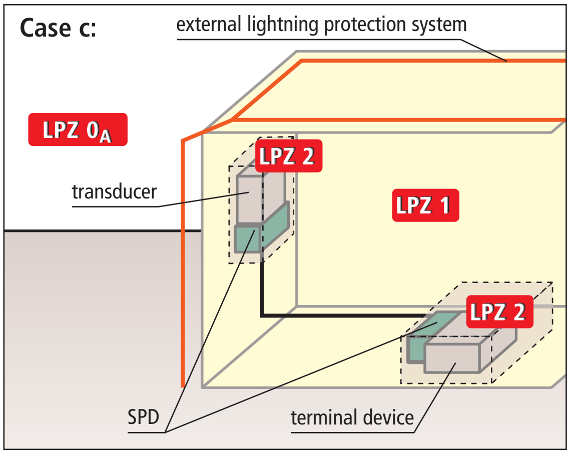


Fig. 8.2.13 Building with external lightning protection system and cables installed inside of the building

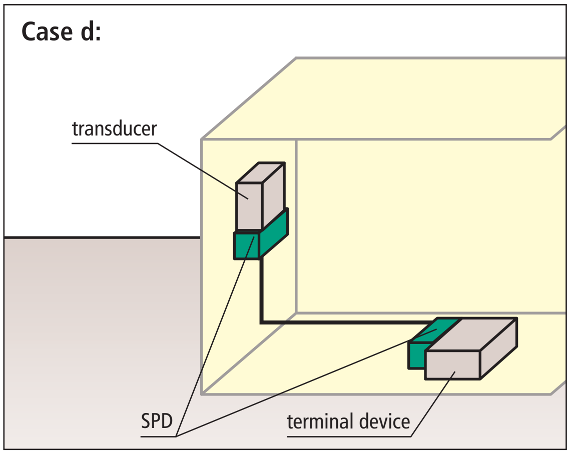


Fig. 8.2.14 Building without external lightning protection system and cables installed inside of the building

Type 1 arresters is only necessary if the measuring and control cable can be influenced by lightning striking adjacent building structures. If this can be excluded, BLITZDUCTOR CT module **BCT MOD M...** as surge protective device TYPE 2 is used (**Figure 8.2.12**).

Case c: In case c, no cable of the data and telecommunications system is mounted outside the building. Although the building structure is fitted with an external lightning protection system, direct lightning currents cannot be injected into this part of the telecommunications system. Therefore, surge protective devices **BCT MOD M...** of the BLITZDUCTOR CT family are installed here (**Figure 8.2.13**).

Case d: The difference between case d and case c is that the building structure concerned has neither an external lightning protection system nor are cables of the data and telecommunications system mounted outside the building structure. Therefore only the installation of surge arresters is necessary for protection of the equipment. As in cases b and c, protection modules **BCT MOD M...** of the BLITZDUCTOR CT family are installed (**Figure 8.2.14**).

2. Which kinds of interferences have to be controlled?

Basically, interferences are classified into **common-mode and differential-mode interferences. Common-mode interferences** always arise **between the signal line and earth** whereas **differential-mode interferences** only arise **between two signal lines.** The majority of interferences arising in communication/signalling systems are common-mode interferences. Therefore protective surges devices limiting between signal line and earth (**Type ...E**) should normally be chosen. Some input modules of devices, as e.g. isolating transformers, do not need fine protection of the line-to-earth connection against surges. Only gas discharge tubes protect them against common-mode interferences. Due to their different response characteristics, the response of gas discharge tubes might cause a common-mode interference to change to a differential-mode interference. Therefore, fine protection elements are integrated between the signal lines (**Type ...D**).

3. Are there special requirements to adopt the protection circuit to the input circuit of the equipment to be protected?

In some cases it is necessary to protect the equipment against common-mode and differential-mode interferences. The input modules of such electronic equipment are normally fitted with their own protection circuit or contain optocoupler inputs for control-to-load isolation of signalling circuit and internal circuit of the automation equipment. Therefore additional measures are required for decoupling BLITZDUCTOR CT and input circuit of the equipment to be protected. This decoupling is realised with additional decoupling elements between the fine protection elements and output terminals of BLITZDUCTOR CT.

4. How high is the signal frequency/data transmission rate to be transmitted?

As every transmission system, the protection circuit of BLITZDUCTOR CT has certain low-pass characteristics. The cut-off frequency indicates the frequency value from which the frequency to be transmitted is attenuated in its amplitude (above 3 dB). In order to keep the feedback effects of BLITZDUCTOR CT on the communication/signalling system in the limits, the signal frequency of the signalling circuit must be below the cut-off frequency of BLITZDUCTOR CT. The cut-off frequency is indicated for sinusoids. However, sinusoid signals are not very common in data transmissions. With respect to this fact, a BLITZDUCTOR is to be chosen with a higher cut-off frequency than the nominal frequency of the signalling circuit. When transmitting waveshape signals evaluating the rising or sinking pulse edge, it must be considered that this edge changes from L to H or from H to L within the appropriate interval. This time interval is important for the identification of an edge and for passing "restricted areas". This signal therefore requires a frequency bandwidth which is considerably higher than the fundamental of this wave. That is why the frequency of the protective device must be rated that high. As a general rule applies that the cut-off frequency must not be lower than five times the fundamental wave.

5. How high is the operating current of the installation to be protected?

Due to the electrical features of the components used in the protection circuit of BLITZDUCTOR CT, the signal current which can be transmitted by the protective device is limited. For practical applications this means that the operating current of a signalling system has to be lower than or equal to the nominal current of the protective device.

6. Which maximum continuous operating voltage can arise in the installation to be protected?

The maximum continuous operating voltage in signalling systems must be lower than or equal to the nominal voltage of BLITZDUCTOR CT, so that the protective device has no limiting effects with normal operating conditions.

The maximum continuous operating voltage in signalling systems is normally the nominal voltage of a transmission system regarding also tolerances. When current loops (e.g. 0 – 20 mA) are used, the open circuit voltage of the installation is to be applied to the maximum continuous operating voltage.

7. Which reference has the maximum continuous operating voltage?

Different signal current circuits have different signal references (balanced/unbalanced). On one hand, the continuous operating voltage of the installation can be stated as line/line voltage, on the other hand, as line/earth voltage. This is to be

considered when choosing the protective devices: Different nominal voltages are stated on the basis of the different circuit of the fine protection elements in the protection module of BLITZDUCTOR CT.
These are shown in **Figure 8.2.4** and **Table 8.2.1**.

8. Do the integrated decoupling elements of BLITZDUCTOR CT affect the signal transmission?

Decoupling elements are used inside of BLITZDUCTOR CT in order to coordinate the energy load of the integrated protection elements. They are mounted directly in the signalling circuit and may influence it. Especially with current loops (0 ... 20 mA, 4 ... 20 mA), the operation of a BLITZDUCTOR CT can cause the overrange of the permissible load of the signalling circuit when it is already operated with its maximum load. This has to be considered before use!

9. Which protection level is required?

Basically it is possible to dimension the protective level of a surge protective device to be lower than the immunity level of an automation/telecommunications equipment. However, the problem is that this level is often unknown. Therefore it is necessary to use other means of comparison. In the tests for electromagnetic compatibility (EMC), electrical and electronic equipment must have a certain immunity level against line-conducted interferences. The requirements for testing and test set-up are stipulated in IEC 61000-4-5: 2005. Different test levels are determined with respect to the immunity to pulse-shaped interferences for the various devices used under varying electromagnetic environmental conditions. These test levels bear the designation 1 to 4, whereby test level 1 contains the lowest immunity requirements (on the devices to be protected) and test level 4 ensures the highest immunity requirements of a device.

With regard to the protection provided by the surge protective devices this means that the "let-through energy" must be below the immunity level of the equipment to be protected. Therefore the Yellow/Line devices were classified according to certain characteristics allowing a coordinated installation of the SPDs for protection of automation engineering equipment. The surge immunity test of this equipment was taken as a basis of determining Yellow/Line SPD class symbols (**Table 7.8.2.1**). If, for example, automation engineering equipment is tested according to test level 1, the equipment may only have a let-through energy corresponding to this test level. In practice this means that an equipment tested with level 4 can only discharge overvoltages without damaging the equipment if the output of the surge protective device corresponds to a let-through energy of 1, 2, 3, or 4. This makes it very easy for the user to choose suitable protective devices.

10. Shall there be one or two stages of protection?

Depending on the building structure and the protection requirements stipulated by the Lightning Protection Zones Concept it may be necessary to install lightning current and surge arresters locally separated from each other or at one point of the installation. In the first case, the protection module Type BCT MLC B of BLITZDUCTOR CT is installed as lightning current arrester and the protection module Type BCT MOD M... as surge arrester. If lightning and surge protective measures are required at one point of the installation, the use of a combined lightning current and surge arrester BLITZDUCTOR CT, Type B... is required.

Remark:

The following examples show the choice of surge protective devices of the BLITZDUCTOR CT family in accordance with the 10 selection features described in **Table 8.2.3**. The result of each single stage is indicated in the column "intermediate result".
The column "final result" shows the influence of the intermediate result on the total result.

Surge protection for electrical temperature control systems

The electrical temperature control of media in technological processes is applied in all branches of industry. The branches differ a lot from each other: They stretch from food industry via chemical processes up to ventilation systems of building structures and building services control systems. However, they have something in common: the distance between measuring sensor and indicator or measured-value processing is long. Due to the long connection cables, overvoltages can be coupled which are not only caused by atmospheric discharges. Therefore a possible protection concept

SF	Application	Intermediate result	Final result
1	The measuring sensor is situated at a process framework in a production hall and the measuring transducer is installed in a control room inside of the production building. The building has no external lightning protection system. The measuring lines are inside the building. This example corresponds to **case d** (**Figure 8.2.14**).	BLITZDUCTOR CT BCT MOD M...	BLITZDUCTOR CT BCT MOD M...
2	The threat to the measuring sensor Pt 100 as well as the measuring transducer Pt 100 by surges arises between signal line and earth. This requires a **fine limiting of common-mode interferences**.	BLITZDUCTOR CT BCT MOD ME	BLITZDUCTOR CT BCT MOD ME
3	There are no special requirements on the adjustment of the protective circuit to the input circuit of the devices to be protected (Pt 100, Pt 100 measuring transducer).	no influence	BLITZDUCTOR CT BCT MOD ME
4	The temperature measuring equipment is a system supplied by d.c. current. The temperature-related measuring voltage is also a d.c. voltage variable. Thus no signal frequencies have to be considered.	no influence	BLITZDUCTOR CT BCT MOD ME
5	The operating current of the supply circuit is limited to 1 mA due to the physical measuring principle of Pt 100. The operating current of the measuring signal amounts to some µA due to the very high impedance measurement tapping.	I_L type ME = 1 A 1 mA < 1 A ⇒ ok µA < 1 A ⇒ ok	BLITZDUCTOR CT BCT MOD ME
6	The maximum arising operating voltage in this system results from the following consideration: According to IEC 60751, Pt 100 measuring resistors are designed for a maximum temperature of up to 850 °C. The respective resistance is 340 Ω. Considering the load-independent measuring current of 1 mA, results a measuring voltage of **approx. 340 mV.**	BLITZDUCTOR CT BCT MOD ... 5 V	BLITZDUCTOR CT BCT MOD ME 5
7	The operating voltage of the system arises **from line to line**.	BCT MOD ME 5 V has nominal voltage 5 V d.c. line ⇒ earth, this allows line ⇒ line 10 V d.c. ⇒ no influence on the measuring signal	BLITZDUCTOR CT BCT MOD ME 5
8	Using the four-wire circuit for measuring the temperature with Pt 100, the influence of the cable resistance and its temperature-related fluctuations on the measuring result are completely eliminated. This also applies to the increasing of the cable resistance by the decoupling impedances of BLITZDUCTOR CT.	no influence	BLITZDUCTOR CT BCT MOD ME 5
9	The Pt 100 measuring transducer has an immunity against conducted interferences according to test level 2 according to IEC 61000-4-5: 2005. The "transmitted energy" being related to the voltage protection level of the surge protective device may correpond to max. test level 2 of IEC 61000-4-5: 2005.	BLITZDUCTOR CT BCT MOD ME 5 TYPE 2 P1 "transmitted energy" corresponds to level 1 "transmitted energy" of the protective device is less than immunity of the terminal device ⇒ TYPE 2 P1 is ok	BLITZDUCTOR CT BCT MOD ME 5
10	The surge protection shall be performed in **one** stage.	BLITZDUCTOR CT BCT MOD ME 5 ⇒ surge arrester	BLITZDUCTOR CT BCT MOD ME 5
		Result of selection:	**BLITZDUCTOR CT BCT MOD ME 5**

Table 8.2.3 Selection features for an electrical temperature measuring equipment

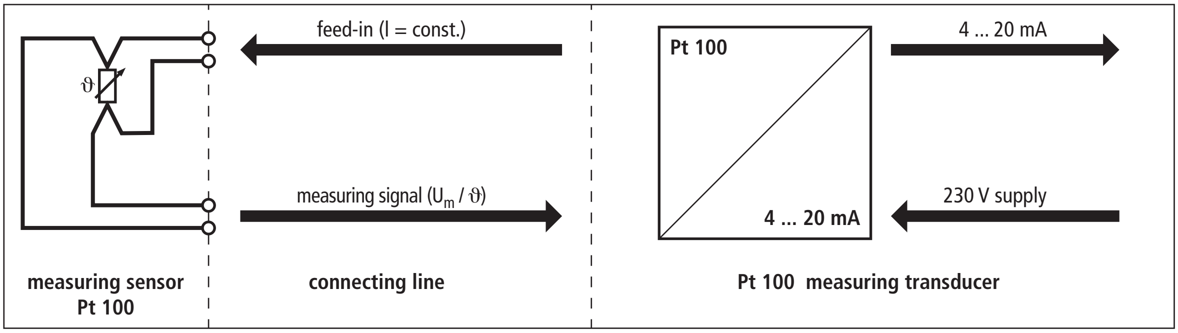


Fig. 8.2.15 Block diagram of temperature measuring

of temperature measurements against surges by a standard type Pt 100 shall be worked out in the following. The building structure where the measuring instrument is located has no external lightning protection system.

The temperature is controlled indirectly by measuring the electrical resistance. The resistance thermometer Pt 100 has a resistance of 100 Ω at 0 °C. This value varies by around 0.4 Ω/K depending on the temperature. The temperature is controlled by injecting a constant current causing a voltage drop proportional to the temperature rise at the resistance thermometer. In order to prevent the the self-heating of the resistance thermometer, the current is limited to 1 mA. In this case, a voltage drop of 100 mV appears at the Pt 100 at 0 °C. This measured voltage must now be transmitted to the indicator or receiver (**Figure 8.2.15**). Out of many various connections of Pt 100 measuring sensors to the measuring transformer, the four-wire configuration is chosen. It represents the best connection for resistance thermometers. By this configuration, the interfering effects of the conductor resistance and its temperature sensitivity on the measured result are excluded. The Pt 100 sensor is supplied with an injected current. Alternations of the conductor resistance are compensated by automatic adjustment of the supply voltage. If the conductor resistance does not alter, the measured voltage U_m remains unchanged. This measured voltage is only influenced by the alternation of the measuring resistance depending on the temperature. It is measured at the transformer using a high-resistance voltage detector. Line compensation is therefore not necessary with this configuration. (**Table 8.2.3**)

Remark:

For ease of assembly, power supply and measuring lines of the temperature control system are fitted with the same type of surge protective device. In practice it has proved that the balanced lines for supply, compensation and measurement are allocated to one protected device each (**Table 8.2.3**).

Surge protection of the 230 V power supply of the Pt 100 receiver as well as the 4 ... 20 mA current loop coming from the receiver is also necessary but not shown here in order to retain clearness.

8.2.1 Measuring and control systems

The large separations between the measuring sensor and the evaluation unit in measuring and control systems allow a coupling of surges. The consequential destruction of components and the breakdown of complete control units can severely interfere with a process technology procedure. The extent of a surge damage caused by a lightning strike often becomes apparent only some weeks later because more and more electronic components have to be replaced because they no longer operate safely. Such kind of damage can have serious consequences for the operator who uses a so-called field bus system because all intelligent field bus components together in one segment can break down simultaneously.

The situation can be improved by installing lightning and surge protective devices (SPDs) which have to be chosen to suit the specific interface.

Typical interfaces and the protective devices appropriate to the system can be found in our “Surge Protection” product catalogue or at www.dehn.de.

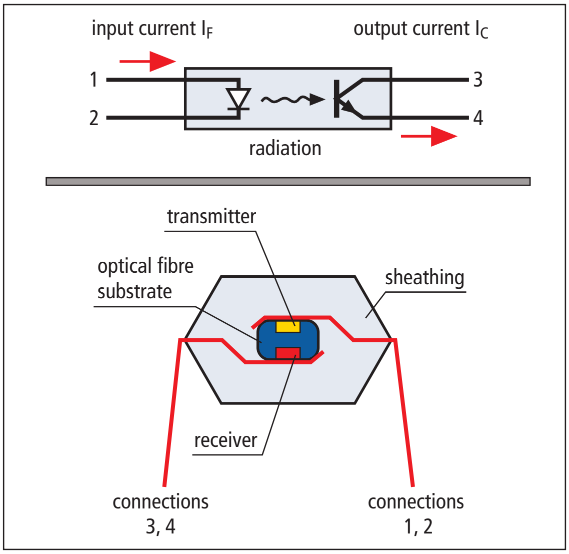


Fig. 8.2.1.1 Optocoupler – Schematic diagram

Electrical isolation using optocouplers:

Optoelectronic components (**Figure 8.2.1.1**), which typically produce a dielectric strength between the input and output of a few 100 V to 10 kV, are frequently installed to transmit signals in process technology systems in order to isolate the field side electrically from the process side. Thus their function is similar to that of transmitters and they can primarily be installed to block low common-mode interferences. However, they cannot provide sufficient protection against arising common-mode and differential-mode interferences. When being affected by a lightning strike (> 10 kV) above their transmitter/receiver surge withstand capability.

Many designers and operators of such installations misleadingly assume that this also realises lightning and surge protection. At this point it is expressly emphasised that this voltage only provides the insulating resistance between input and output (common-mode interference). This means that, when installed in transmission systems attention must be paid not only to the limitation of common-mode interferences but also to sufficient limitation of differential-mode interferences. Furthermore, the integration of supplementary decoupling resistors at the output of the SPD achieves an energy coordination with the optocoupler diode.

Hence, in this case, common-mode and differential-mode interference limiting SPDs, e.g. BLITZDUCTOR XT Type BXT ML BE C 24, must be installed.
Detailed designs for the application-specific choice of protective devices for measuring and control systems can be found in Chapter 9.

8.2.2 Technical property management

The pressure of rising costs is forcing the owners and operators of buildings in both the public and the private sector to look more and more for cost saving opportunities for building services management. Technical property management can help to reduce costs on a permanent basis. Technical property management is a comprehensive instrument to make technical equipment in buildings continuously available, to keep it operative and to adapt it to changing organisational requirements. This facilitates optimum management which increases the profitability of a property.

Building automation (BA) has grown out of measuring and control systems on the one hand, and central control systems on the other. The function of building automation is to automate the technical processes within the building in their entirety. This involves networking the complete installation comprising room automation, the M-bus measuring system and the heating-ventilation-air-conditioning and alarm systems via powerful computers on the management level (**Figure 8.2.2.1**), where also data archiving takes place. Long term data storage allows evaluations concerning the energy consumption and the adjustment of the installations in the building to be obtained.

The actual control devices are at the automation level. DDC stations (Direct Digital Control) are increasingly being installed. They implement the complete control and switching functions from a software point of view. All operating modes, control parameters, nominal values, switching times and alarm trigger levels and the corresponding software is filed at the automation level.
Process field devices such as actuators and sensors are located at the lowest level, the field level. They represent the interface between the electrical control and the process. Actuators transform an electrical signal into another physical value (engines, valves, etc.). Sensors transform a physical value

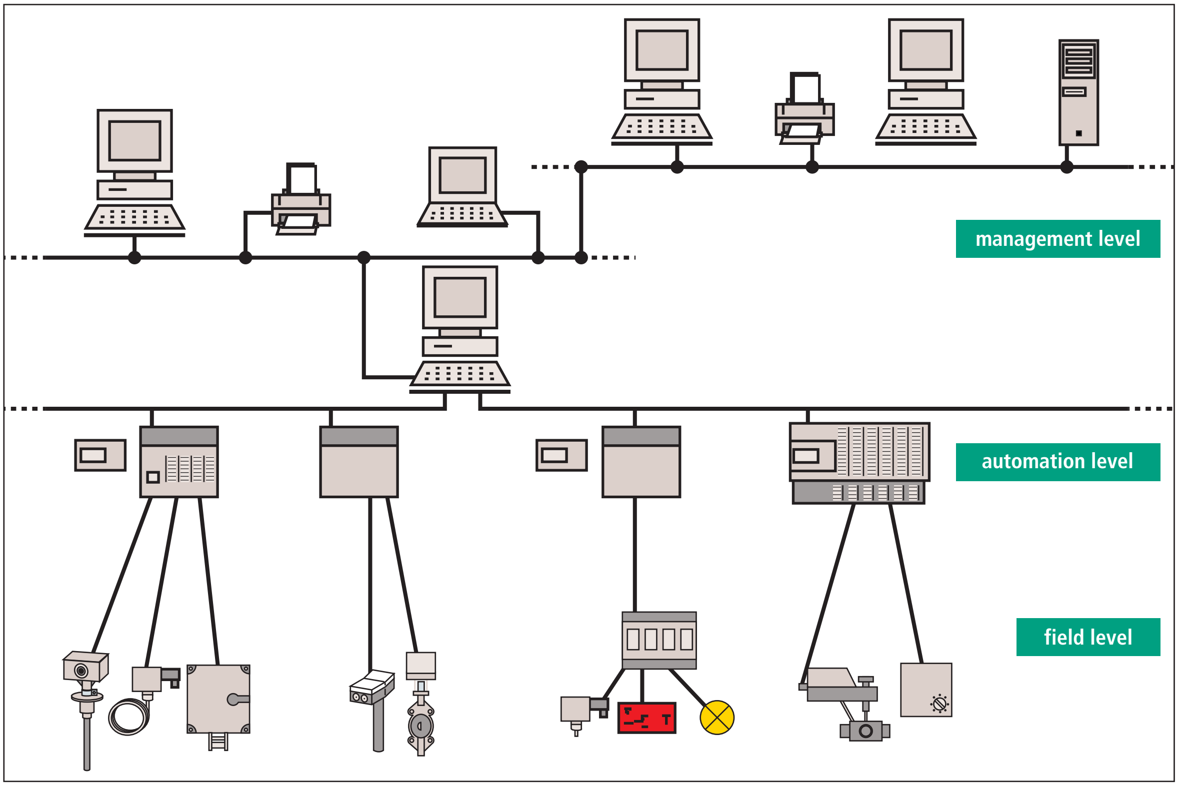


Fig. 8.2.2.1 Levels of building automation

into an electrical signal (temperature sensor, limit switch, etc.).

It is precisely the diffuse branched network of DDC stations and the consequential integration into building control systems which offer a large contact area for interferences caused by lightning currents and surges. If this causes a breakdown of the complete lighting, air-conditioning or heating control, this not only incurs primary costs for the equipment, it is also precisely the consequences of this system breakdown which make a difference. They can significantly increase the energy costs because peak loads can no longer be analysed and optimised due to the fault in the control electronics. If production processes are integrated into the BA, damage to the BA can lead to breakdowns in production and hence quite possibly to large economic losses. To ensure permanent availability, protective measures are required, whose exact nature depends on the risk to be controlled.

8.2.3 Generic cabling systems (EDP networks, TC installations)

The European standard EN 50173 "Information technology – Generic cabling systems" defines a universal cabling system which can be used in sites of one or more buildings. It deals with cable systems with balanced copper cables and optical fibre cables (OF cables). This universal cabling supports a wide range of services including voice, data, text and images.

It provides:

⇒ users with an application independent generic cabling system and an open market for (active as well as passive) cabling components;

⇒ users with a flexible cabling scheme that allows to carry out modifications in a both easy and economical way;

⇒ building professionals (for example, architects) with guidance allowing the accommodation

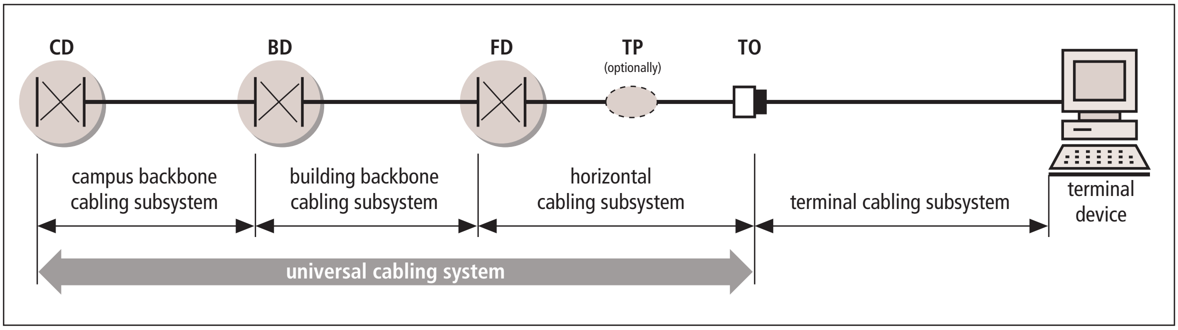


Fig. 8.2.3.1 Universal cabling structure

of cabling before specific requirements are known; i.e. in the initial design stage either for construction or refurbishment,

⇒ industry and standardisation bodies for applications with a cabling system which supports current products and provides a basis for future product development.

The universal cabling system comprises the following functional elements:

⇒ Campus distributors (CD),
⇒ Campus backbone cables,
⇒ Building distributors (BD),
⇒ Building backbone cables,
⇒ Floor distributors (FD),
⇒ Horizontal cables,
⇒ Transition points (optional),
⇒ Telecommunication outlet (TO).

Groups of these functional elements are connected together to form cabling subsystems.
Generic cabling schemes contain three cabling subsystems: campus backbone, building backbone and horizontal cabling. The cabling subsystems are connected together to create a generic cabling structure as shown in **Figure 8.2.3.1**. The distributors provide the means to configure the cabling to support different topologies like bus, star and ring.
The campus backbone cabling subsystem extends from the campus distributor to the building distributor(s) usually located in separate buildings. When present, it includes the campus backbone cables, the mechanical termination of the campus backbone cables (at both the campus and building distributors) and the cross-connections at the campus distributor.

A building backbone cabling subsystem extends from building distributor(s) to the floor distributor(s). The subsystem includes the building backbone cables, the mechanical termination of the building backbone cables (at both the building and floor distributors) and the cross connections at the building distributor.

The horizontal cabling subsystem extends from the floor distributor to the telecommunications outlet(s) connected to it. The subsystem includes the horizontal cables, the mechanical termination of the horizontal cables at the floor distributor, the cross connections at the floor distributor and the telecommunications outlets.

Optical fibre cables are usually used as data connection between the CD and the BD. This means that no surge arrester (SPD) is required for the field side. If, however, the OF cables have a metal rodent protection, this must be integrated into the lightning protection system. The active OF components for the distribution of the optical fibre cables, however, are supplied with 230 V on the power side. In this case, SPDs can be used for the power supply system.

Nowadays, building backbone cables (BD to FD) are equipped almost exclusively with OF cables for the transmission of data. Balanced copper cables (so-called master cables), however, are still used to transmit voice (telephone).
With a few exceptions, balanced copper cables are used today for the horizontal cables (FD to TO).

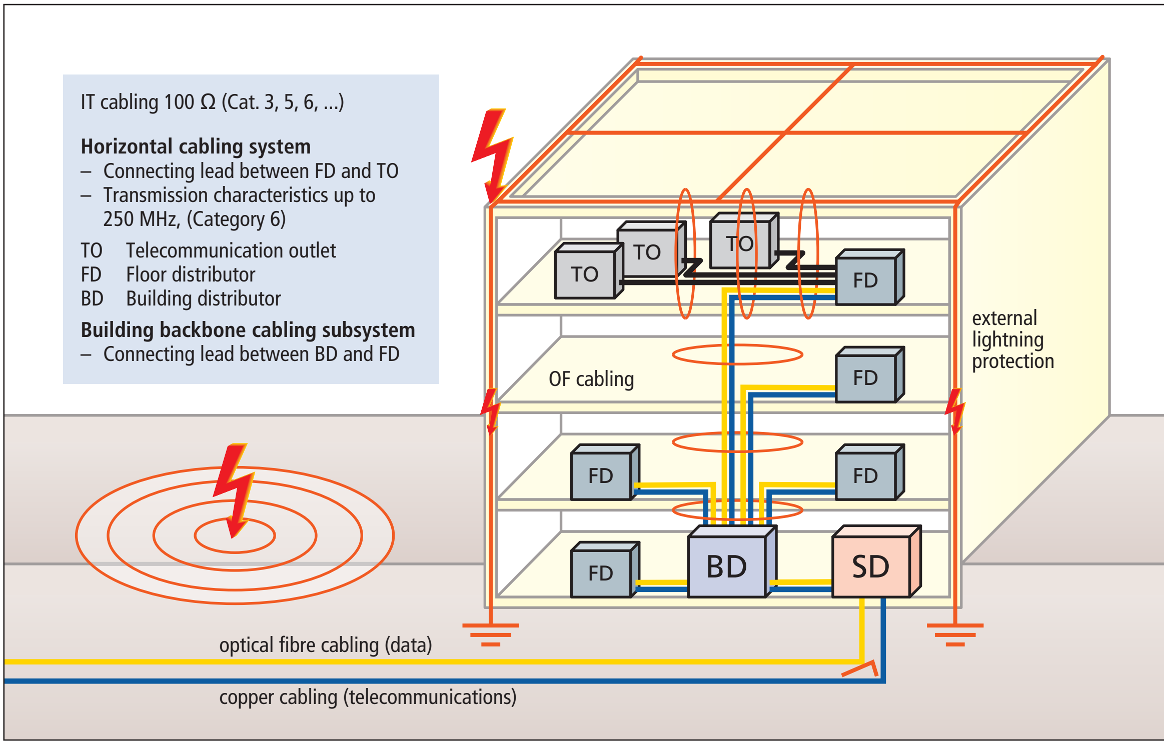


Fig. 8.2.3.2 Influence of lightning on IT cabling subsystems

For cable lengths of around 500 m (building backbone cables) or 100 m (horizontal cables) direct lightning strikes to the structure (**Figure 8.2.3.2**) can induce common-mode interferences which would overload the insulation capacity of a router or an ISDN card in the PC. Both the building/floor distributors (hub, switch, router) and the terminal equipment must be equipped with protective measures in this case.

The protective devices required here must be chosen according to the network application. Common network applications are:

- ⇒ Token Ring,
- ⇒ Ethernet 10 Base T,
- ⇒ Fast Ethernet 100 Base TX,
- ⇒ Gigabit Ethernet 1000 Base TX.

An appropriate protection concept for choosing the appropriate protective devices can be found in Chapter 9.11 "Surge protection for ETHERNET networks".

8.2.4 Intrinsically safe circuits

In all fields of industry where combustible materials are processed or transported gases, vapors, mist or dust will be produced. These, when mixed with air, can form a potentially explosive atmosphere of hazardous proportions. Therefore special measures must be taken to protect against explosions.

Depending on the possibility and the duration of the occurrence of a potentially explosive atmosphere, sections of the installation are divided into hazardous areas – so-called Ex-zones.

Hazardous areas:

Areas where hazardous potentially explosive atmospheres arise due to gases, vapors and mist, for example, are divided into zones 0 to 2. Those where hazardous potentially explosive atmospheres can arise due to dust are divided into zones 20, 21 or 22.

Explosion groups I, IIA, IIB and IIC provide a system of classification according to the explosiveness of the combustible materials used in the respective field of application. Classification criteria are the "Maximum Experimental Safe Gap (MESG)" and the "Minimum Ignition Current (MIC)". The MESG and MIC are determined for the various gases and vapors according to a stipulated testing arrangement.

Explosion group IIC contains the most highly combustible materials such as hydrogen and acetylene. When heated, these materials have different ignition temperatures classified into temperature classes (T1 ... T6).

To avoid electrical equipment from being sources of ignition in explosive atmospheres, these are designed with different types of protection. One type of protection used all over the world, particularly in measuring and control systems, is the type of protection "Intrinsic safety" Ex(i).

Ignition protection type – intrinsic safety:

Intrinsic safety being a type of protection is based on the principle of current and voltage limitation in an electric circuit. With this system, the energy of the circuit or a part of the circuit, which is in a position to ignite potentially explosive atmospheres, is kept so low to ensure that neither sparks nor intolerable surface heating of the electrical components can cause an ignition of the surrounding potentially explosive atmosphere. Apart from voltages and currents of the electrical equipment, the inductances and capacitances in the complete circuit acting as energy storage devices must be limited to safe maximum values.

For the safe operation of a measuring and control system circuit, for example, this means that neither the sparks arising during the operational opening and closing of the circuit (e.g. at a make-or-break contact in an intrinsically safe circuit), nor those arising in the event of a fault (e.g. a short circuit or earth fault) must be capable of causing an ignition. Moreover, both for normal operation and also in the event of a fault, heat ignition as a result of overheating of the equipment and cables in the intrinsically safe circuit, must also be excluded.

This basically limits intrinsic safety as a type of protection to circuits requiring relatively little power. These are circuits of measuring and control systems and also data systems. Intrinsic safety which can be achieved by limiting the energies available in the circuit does not relate to individual devices – as is the case with other types of protection – but to the complete circuit. This produces a number of considerable advantages compared to other types of protection.

Firstly, no expensive special constructions are required for the electrical equipment used in the field, for example flame-proof encapsulation or embedding in cast resin, which results mainly in more cost-effective solutions. Another advantage is that the intrinsic safety is the only type of protection which allows the user to work freely at all live intrinsically safe installations in a hazardous area without having an adverse effect on the protection against explosion.

The economic advantage of using intrinsically safe circuits lies in the fact that, even in the hazardous areas, conventional non-certified passive equipment can be used. Thus this type of protection is also one of the simplest types of installation.

Intrinsic safety has therefore considerable significance, particularly in measuring and control systems, not least because of the increased use of electronic automation systems. However, intrinsic safety demands more from the designer or constructor of an installation than other types of protection. The intrinsic safety of a circuit not only depends on compliance with the design provisions for the individual pieces of equipment, but also on the correct connection of all equipment in the intrinsically safe circuit and the correct installation.

Transient surges in hazardous areas:

Intrinsic safety as type of protection considers all electrical energy storage devices present in the system but not energy from outside, such as coupled surges resulting from atmospheric discharges.

Coupled surges come up in expanded industrial installations mainly as a result of close and distant lightning strikes. In the event of a direct lightning strike, the voltage drop across the earth-termination system causes a potential rise between some 10 and 100 kV. This potential rise acts as a potential difference on all equipment connected via cables to distant equipment. These potential differences are considerably greater than the insulation resistance of the equipment and can easily be sparked over. For distant lightning strikes it is mainly the coupled surges in conductors that can destroy the inputs of electronic equipment by acting as differential-mode interferences (differential voltage between the lines).

Classification of electrical equipment into category ia or ib

An important aspect of intrinsic safety for explosion protection is the issue of the reliability with respect to maintaining of voltage and current limits, even assuming certain faults. There are two categories of reliability.

Category ib specifies that the intrinsic safety must be maintained if a fault occurs in the intrinsically safe circuit.

Category ia requires that the intrinsic safety must be maintained if two independent faults occur.

The classification of the BLITZDUCTOR CT or DEHNconnect DCO as category ia is the classification in the highest category. This means that the BLITZDUCTOR may also be used with other equipment located in zones 0 and 20. Extra attention must be paid to the special conditions of zones 0 and 20 and clarified in each individual case.

Figure 8.2.4.1 shows the principle use of SPDs in measuring and control circuits

Maximum values of current I_0, voltage U_0, inductance L_0 and capacitance C_0

At the interface between hazardous area and safe area, safety barriers or transmitters with Ex(i) output circuit are used to separate these two different zones.

The safety-related maximum values of a safety barrier or a measuring transformer with Ex(i) output circuit are defined by the test certificates of an authorised testing laboratory:

⇒ Maximum output voltage U_0

⇒ Maximum output current I_0

⇒ Maximum external inductance L_0

⇒ Maximum external capacitance C_0

The designer/constructor must test whether these safety-related permissible maximum values of the equipment connected and located in the intrinsically safe circuit (i.e. process field devices, conductors and SPD) are maintained for each individual case. The corresponding values have to be taken from the rating plate of the pertinent equipment or the type examination certificate.

Classification in explosion groups

Explosive gases, vapors and mist are classified according to the spark energy required to ignite the most explosive mixture with air.

Equipment is classified according to the gases which it can be used with.

Group II C applies to all fields of application, e.g. chemical industry, coal and grain processing, with exception of underground mining.

Group II has the highest risk of explosion, since this group considers a mixture with the lowest ignition energy.

The certification of BLITZDUCTOR for explosion group II C means that it fulfils the highest, i.e. most sensitive, requirements for a mixture of hydrogen in air.

Classification into temperature classes

When a potentially explosive atmosphere is ignited as a result of the hot surface of a piece of equip-

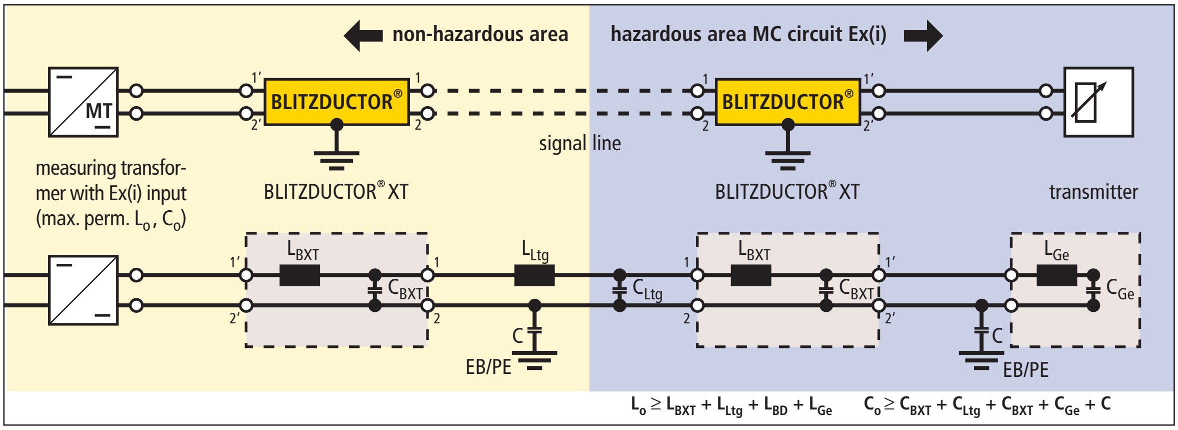


Fig. 8.2.4.1 Calculating of L_0 and C_0

ment, a minimum temperature specific to the material is required to cause the explosion. The ignition temperature is a characteristic of the material characterising the ignition behaviour of the gases, vapors or dust on a hot surface. For economic reasons, gases and vapors are therefore classified into certain temperature classes. Temperature class T6 specifies that the maximum surface temperature of the component must not exceed 85 °C either in operation or in the event of a fault, and that the ignition temperature of the gases and vapors must be higher than 85 °C.
With its T6 classification, BLITZDUCTOR CT also fulfils the highest stipulated requirements in this aspect.

In accordance with the certificate of conformity issued by KEMA, the following electrical parameters must also be taken into consideration.

Selection criteria for SPD – BLITZDUCTOR XT
Using the example of BLITZDUCTOR XT, BXT ML4 BD EX 24, the specific selection criteria for this component are explained below (**Figures 8.2.4.2a** and **8.2.4.2b**).
This component has already a certificate of conformity issued by KEMA.

The SPD has the following classification:

II 2(1) G EEx ia IIC T4 ,T5, T6

This classification states the:

II Group of devices – the SPD may be used in all fields apart from mining.

2(1) G Device category – the SPD may be installed in potentially explosive gas atmospheres in zone 1 and also in conductors from zone 0 (to protect terminal devices in zone 0)

EEx Testing laboratory certifies that this electrical equipment conforms to the harmonised European standards.

EN 50014: General Principles

EN 50020: Intrinsic safety "i"

BLITZDUCTOR CT equipment has passed a type examination successfully.

ia Type of protection – the SPD controls even a combination of two arbitrary faults in an intrinsically safe circuit without causing ignition itself.

IIC Explosion group – the SPD fulfils the requirements of explosion group IIC and may also be used with ignitable gases such as hydrogen or acetylene.

T4 between -40 °C and +80 °C

T4 between -40 °C and +75 °C

T6 between -40 °C and +60 °C

Further important electrical data:

⇒ Maximum external inductance L_0 and maximum external capacitance (C_0):

The special choice of components in BLITZDUCTOR XT means that the values of the internal inductance and capacitance of the various individual components are negligibly small.

⇒ Maximum input current (I_i):

The maximum permissible current which may be supplied via the connections is 500 mA, without overriding the intrinsic safety.

Fig. 8.2.4.2a Intrinsically safe SPD

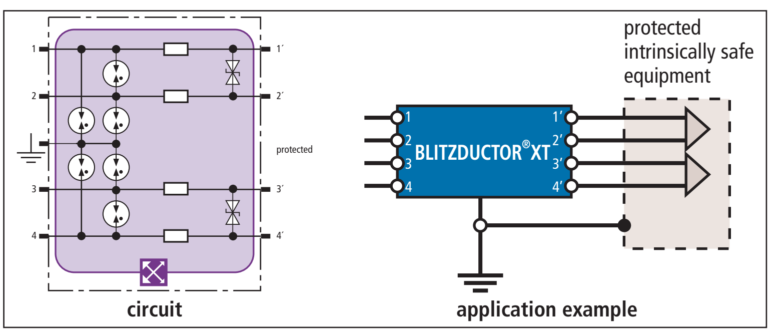


Fig. 8.2.4.2b Schematic diagram of BXT ML4 BD EX 24

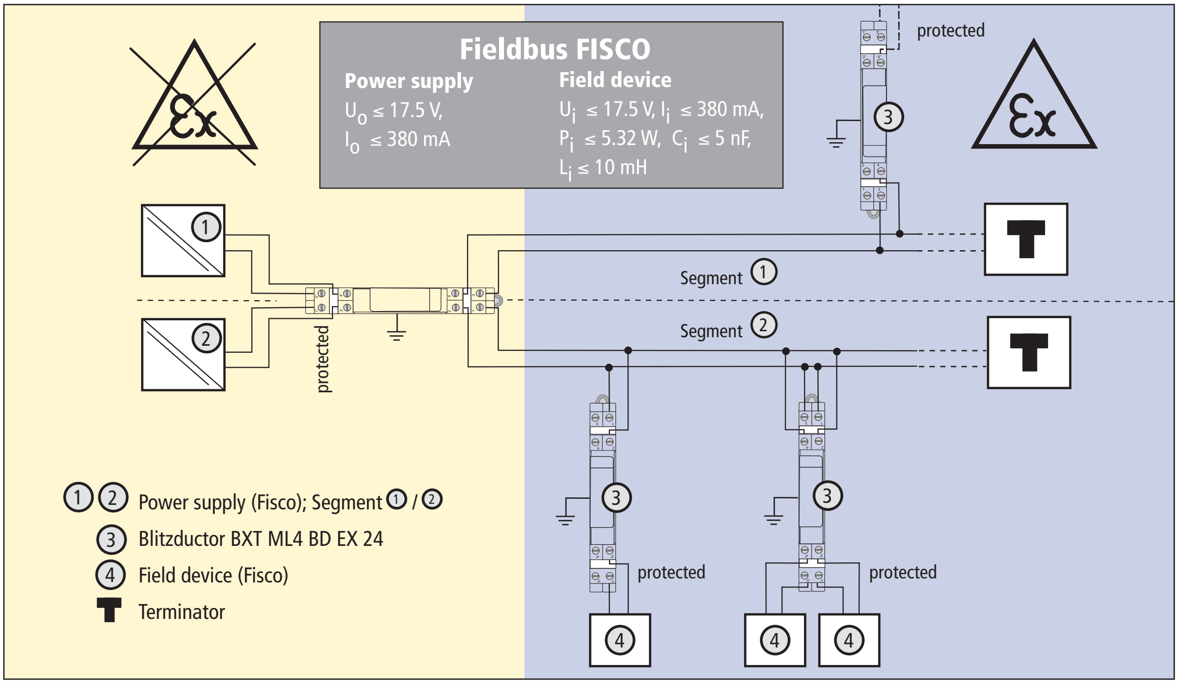


Fig. 8.2.4.3 SPD in hazardous location – Insulation resistance > 500 V a.c.

⇒ Maximum input voltage (U_i):

The maximum voltage which may be applied to BLITZDUCTOR XT is 30 V, without overriding the intrinsic safety.

Insulation resistance

The insulation between an intrinsically safe circuit and the frame of the electrical equipment or other components which can be earthed must usually be able to withstand the root mean square value of an a.c. test voltage which is twice as high as the voltage of the intrinsically safe circuit, or 500 V, whichever value is higher.

Equipment with an insulation resistance < 500 V a.c. is considered to be earthed. Intrinsically safe equipment (e.g. cables, sensors, transmitters) generally have an insulating strength > 500 V a.c. (**Figure 8.2.4.3**).

Intrinsically safe circuits must be earthed if this is required for safety reasons. They may be earthed if this is required for functional reasons. This earthing must be carried out at only one point by connection with the equipotential bonding. SPDs with a d.c. sparkover voltage to earth < 500 V d.c. represent an earthing of the intrinsically safe circuit.

If the d.c. sparkover voltage of the SPD is > 500 V d.c., the intrinsically safe circuit is considered to be non-earthed. This requirement corresponds to BLITZDUCTOR XT, BXT ML4 BD EX 24.

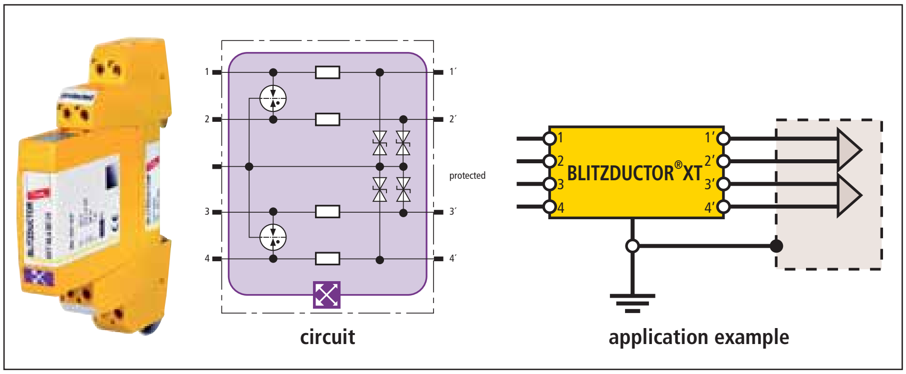


Fig. 8.2.4.4 Application – Insulation resistance < 500 V a.c.

In order to coordinate the dielectric strength of the devices to be protected (transmitter and sensor) with the voltage protection level of the SPDs, it must be ensured that the insulation resistance of the devices to be protected is considerably higher than the requirements for an a.c. test voltage 500 V a.c..
In order to avoid that the voltage drop of the interference current to be discharged in the earth connection does not degrade the voltage protection level, it must be ensured that the equipotential bonding between the device to be protected and the SPD is consistent.

Figure 8.2.4.4 illustrates a special type of application. This particular application arises if the terminal device to be protected has an insulation resistance < 500 V a.c.. In this case, the intrinsically safe measuring circuit is not floating.

A BLITZDUCTOR XT, BXT ML4 BE, which is not certified for use in hazardous areas, is used as the SPD in the hazardous area and realises a voltage protection level between lines to earth/equipotential bonding which is considerably less than 500 V. This is necessary in this particular application since the insulating strength of the transmitter corresponds to < 500 V a.c..

This example illustrates particularly the importance of a common consideration of the conditions of intrinsic safety and the EMC/surge protection to be brought into line with each other in systems engineering.

Earthing/Equipotential bonding
A consistent equipotential bonding and an intermeshing of the earth-termination system in the hazardous area of the installation must be ensured.
The cross section of the earth conductor from the SPD to the equipotential bonding must be at least 4 mm^2 Cu.

Installation of SPD BLITZDUCTOR CT in Ex(i)-circuits
The normative stipulations for Ex(i)-circuits from the point of view of the protection against explosion and of electromagnetic compatibility (EMC) correspond to different positions, a situation which occasionally causes consternation among designers and building constructors.

Chapter 9.15 "Installation of surge protective devices in intrinsically safe circuits", lists the most important selection criteria for both intrinsic safety and EMC/surge protection in installations in order to detect the interaction on the other requirement profile in each case.

8.2.5 Special features of the installation of SPDs

The protective effect of an SPD for a device to be protected is provided if a source of interference is reduced to a specified value below the interference or destruction limit and above the maximum operating voltage of a device to be protected. Generally, the protective effect of an arrester is indicated by the manufacturer in form of the voltage protection level U_p (see IEC 61643-21, EN 61643-21). The effectiveness of a surge protective device, however, depends on additional parameters, which are determined by the installation. During the discharge, the current flow through the installation (e.g. L and R of the equipotential bonding conductor) can cause a voltage drop $U_L + U_R$ which must be added to U_p and results in the residual voltage at the terminal device U_r.

$$U_r = U_p + U_L + U_R$$

Optimal surge protection is possible under the following conditions:

⇒ The maximum operating voltage U_c of the SPD is just above the open circuit voltage of the system

⇒ U_p of the SPD should be as low as possible, since additional voltage drops through the installation have less effect

⇒ The equipotential bonding should be designed to have the lowest impedance possible

⇒ Installing the SPD as close as possible to the terminal device has a favourable effect on the residual voltage

Installation examples:

Example 1: Correct installation
(Figure 8.2.5.1)

The terminal device is only earthed directly via the earth connection point of the arrester. The consequence is that the U_p of the SPD is in fact available at the terminal device. This form of installation illustrates the most favourable application of the SPD for protection of the terminal device.

$$U_r = U_p$$

$U_L + U_R$ have no effect

Example 2: Most common installation
(Figure 8.2.5.2)

The terminal device is earthed directly via the earth connection point of the arrester and is also connected via the protective conductor. The consequence is that a part of the discharge current, depending on the impedance ratio, flows away via the connection to the terminal device. To prevent a coupling of the interference from the connecting equipotential bonding conductor to the protected lines, and to keep the residual voltage low, this equipotential bonding conductor must be installed separately, if possible, and/or be designed to have extremely low impedance (e.g. metal mounting plate). This form of installation illustrates current installation practice for terminal devices protection class I.

$$U_r = U_p + U_v$$

Example 3: Wrong method of equipotential bonding (**Figure 8.2.5.3**)

The terminal device is only earthed directly via the protective conductor terminal, for example. There is no low impedance equipotential bonding to the surge protective device. The path of the equipotential bonding conductor from protective device to where it meets the protective conductor terminal of the terminal device (e.g. equipotential bonding bar) has considerable effect on the residual voltage. Depending on the length of the conductor, voltage drops up to a few kV can arise which add up to U_p and can lead to the destruction of the terminal device during the discharge of surges.

$$U_r = U_p + U_L + U_R$$

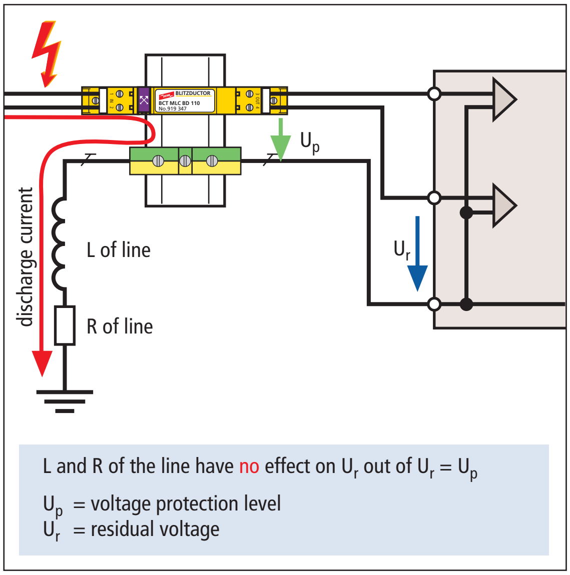


Fig. 8.2.5.1 Correct installation

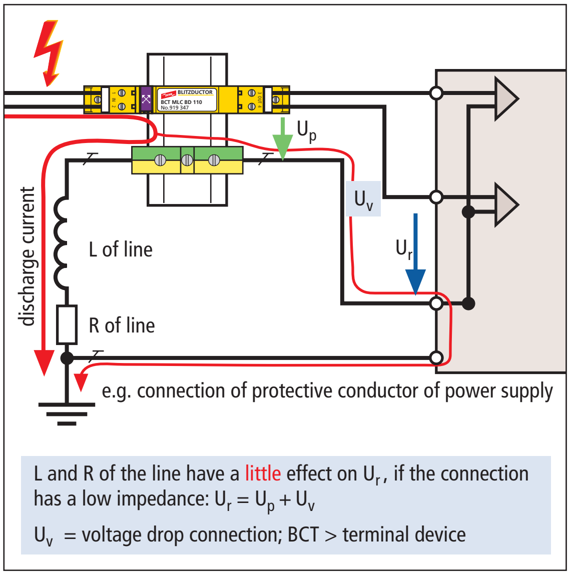


Fig. 8.2.5.2 Most frequent installation

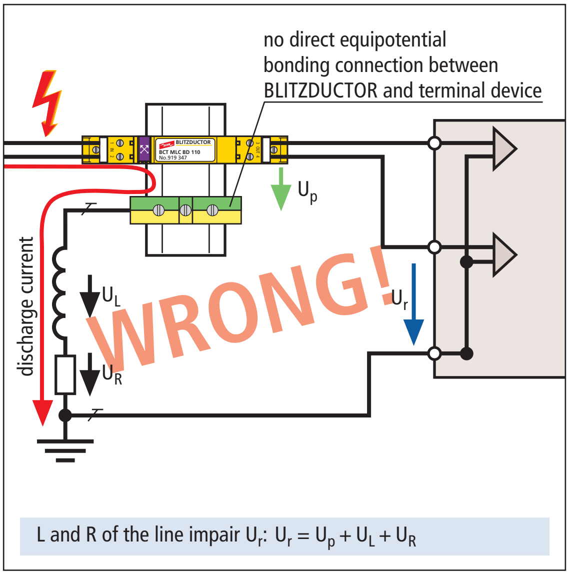


Fig. 8.2.5.3 Wrong method of equipotential bonding

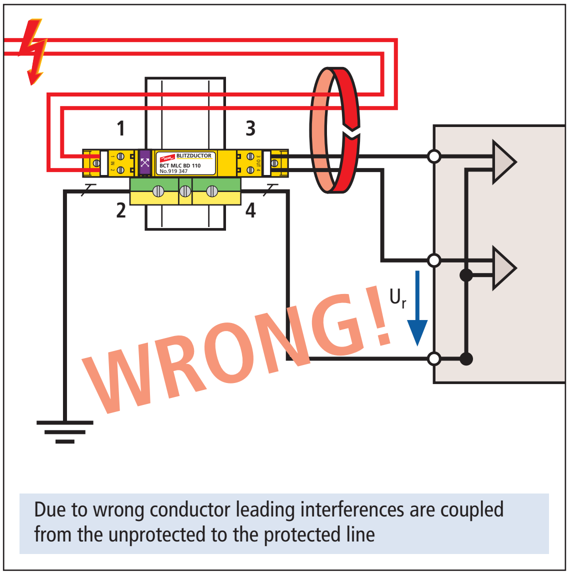


Fig. 8.2.5.4 Wrong conductor leading

Example 4: Wrong conductor leading **(Figure 8.2.5.4)**

Even if the equipotential bonding is carried out correctly, a wrong conductor leading can interfere with the protective effect or even result in damage to the terminal device. If strict spatial separation or shielding of an unprotected conductor upstream of the SPD, and protected conductor downstream of the SPD, is not maintained, then the electromagnetic interference field can cause coupling of interference impulses on the protected conductor.

Shielding

The shielding of cables is described under 7.3.1.

Recommendations for installation:
The use of metal shields or cable ducts reduces the interaction between line pair and surroundings. For shielded cables, please note the following:

⇒ Shield earthing at one end reduces the irradiation of electric fields

⇒ Shield earthing at both ends reduces the irradiation of electromagnetic fields

Type of installation	**Distance**		
	Without divider or non-metallic divider	**Aluminium divider**	**Steel divider**
Unshielded l.v. supply lines and unshielded telecommunications lines	200 mm	100 mm	50 mm
Unshielded l.v. supply lines and shielded telecommunications lines	50 mm	20 mm	5 mm
Shielded l.v. supply lines and unshielded telecommunications lines	30 mm	10 mm	2 mm
Shielded l.v. supply lines and shielded telecommunications lines	0 mm	0 mm	0 mm

Table 8.2.5.1 Separation of telecommunications and low voltage supply lines (based on EN 50174-2)

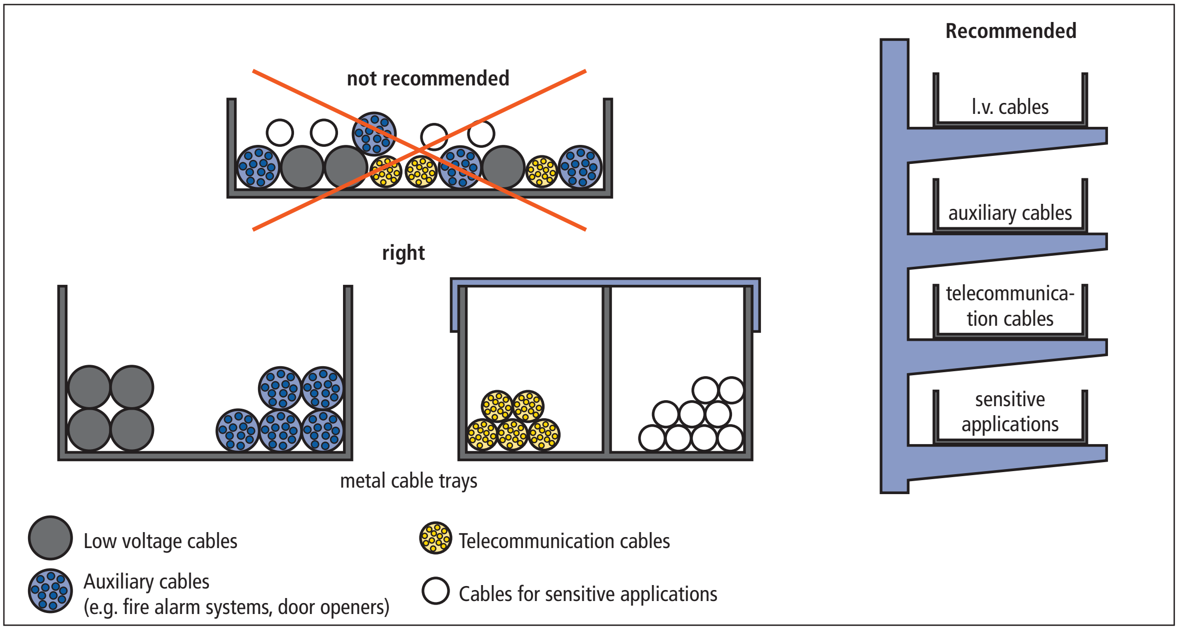


Fig. 8.2.5.5 Separation of cables in cable duct systems

⇒ Conventional shields offer no significant protection against low frequency magnetic fields.

Recommendations:
Shields should run continuously between IT installations, have a low coupling resistance and be conducted around the complete circumference, if possible. The shield must enclose the conductors completely, if possible. Interruptions in the shield and high impedance earth connections and “pig tails“ of cables should be avoided.
The extent to which low voltage lines can affect telecommunication lines depends on a multitude of factors. The recommended guide values for the spatial distances to low voltage lines are described in EN 50174-2. For a cable length less than 35 m no distance is generally required. In all other cases, **Table 8.2.5.1** gives the distances applying.
It is recommended to install telecommunication lines in metal ducts which are electrically connected and completely enclosed. The metal cable duct systems should be connected with low impedance to earth as frequently as possible, at least at the beginning and the end **(Figure 8.2.5.5)**.