



Internal lightning protection

6.1 Equipotential bonding for metal installations

Equipotential bonding according to IEC 60364-4-41 (HD 60364-4-41) and IEC 60364-5-54 (HD 60364-5-54)

Equipotential bonding is required for all electrical consumer's installations installed. Equipotential bonding according to the IEC 60364 series removes potential differences, in other words it prevents hazardous touch voltages, for example, between the protective conductor of the low-voltage consumer's installation and metal water, gas and heating pipes.

According to IEC 60364-4-41 (HD 60364-4-41), equipotential bonding consists of **protective equipotential bonding** and **supplementary protective equipotential bonding**.

Every building must be equipped with a protective equipotential bonding system in accordance with the standards stated above (**Figure 6.1.1**).

Supplementary protective equipotential bonding is intended for those cases where the conditions for disconnection of supply cannot be met or for special areas which conform to the IEC 60364 series Part 7.

Protective equipotential bonding

The following extraneous conductive parts must be **directly** integrated in the protective equipotential bonding system:

- ➔ Protective bonding conductor in accordance with IEC 60364-4-41 (HD 60364-4-41) (in the future: earthing conductor)

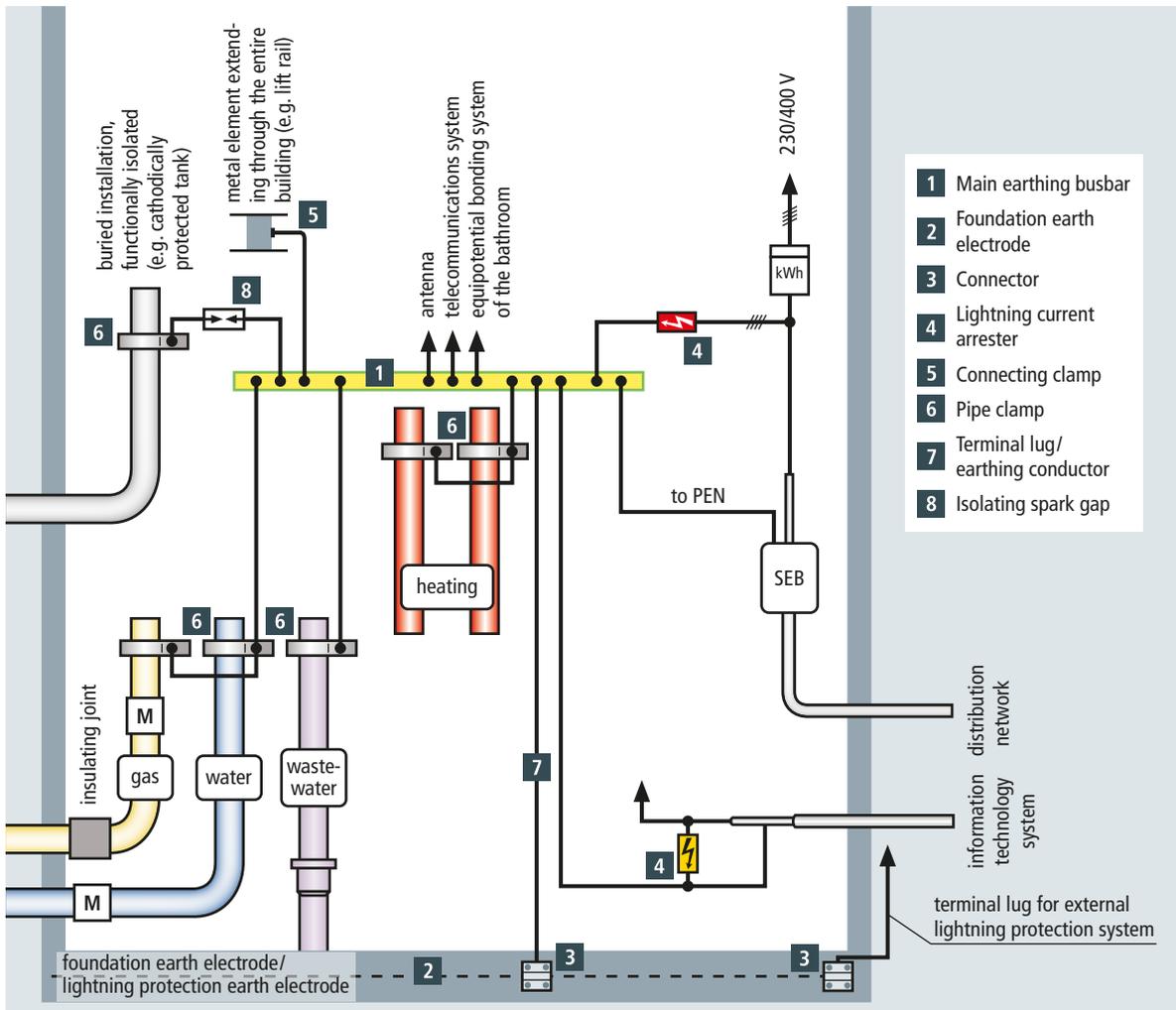


Figure 6.1.1 Principle of lightning equipotential bonding consisting of lightning and protective equipotential bonding

- ➔ Foundation earth electrode or lightning protection earth electrode
- ➔ Central heating system
- ➔ Metal water supply pipe
- ➔ Conductive parts of the building structure (e.g. lift rails, steel frame, ventilation / air conditioning ducts)
- ➔ Metal drain pipe
- ➔ Internal gas pipe
- ➔ Earthing conductor for antennas (German DIN VDE 0855-300 standard)
- ➔ Earthing conductor for telecommunication systems (German DIN VDE 0800-2 standard)
- ➔ Protective conductor of the electrical installation in accordance with the IEC 60364 series (PEN conductor in case of TN systems and PE conductor in case of TT systems or IT systems)
- ➔ Metal shields of electrical and electronic conductors
- ➔ Metal sheaths of power cables up to 1000 V
- ➔ Earth-termination systems of power installations exceeding 1 kV according to IEC 61936-1 (EN 61936-1), EN 50522 if no impermissibly high earthing voltage can be produced

Normative definition of an extraneous conductive part according to IEC 60050-826 (HD 60050-826): A conductive part not forming part of the electrical installation and liable to introduce a potential generally the earth potential.

Note: Extraneous conductive parts also include conductive floors and walls if an electric potential including the earth potential can be introduced via them.

The following installation parts must be integrated **indirectly** in the protective equipotential bonding system via isolating spark gaps:

- ➔ Installations with cathodic corrosion protection and stray current protection measures in accordance with EN 50162
- ➔ Earth-termination systems of power installations exceeding 1 kV in accordance with IEC 61936-1 (EN 61936-1), EN 50522 if impermissibly high earthing voltages can be produced (in rare cases)
- ➔ Traction system earth in case of a.c. and d.c. railways in accordance with EN 50122-1 (tracks of Deutsche Bahn (German Railways) may only be connected with prior written approval)
- ➔ Signal earth for laboratories if it is separated from the protective conductors

Figure 6.1.1 shows the connections and the relevant components of the protective and lightning equipotential bonding system.

Earth-termination system for equipotential bonding

Since the electrical low-voltage consumer's installation requires certain earth resistances (disconnection conditions of the protection elements) and the foundation earth electrode provides good earth resistances when installed cost-effectively, the foundation earth electrode complements the equipotential bonding in an optimum and effective way. In Germany, the design of foundation earth electrodes is governed by DIN 18014, which, for example, requires terminal lugs for the equipotential bonding bar. More detailed information and designs of foundation earth electrodes can be found in chapter 5.5.

If a foundation earth electrode is used as lightning protection earth electrode, additional requirements may have to be considered. These requirements can also be found in chapter 5.5.

Protective bonding conductors according to IEC 60364-5-54 (HD 60364-5-54)

Equipotential bonding conductors should, as long as they fulfil a protective function, be labelled as protective conductors, namely green / yellow.

Equipotential bonding conductors do not carry operating currents and can therefore be either bare or insulated.

The minimum cross-section of protective bonding conductors for connection to the main earthing busbar is:

- ➔ 6 mm² (copper) or
- ➔ 16 mm² (aluminium) or
- ➔ 50 mm² (steel)

The minimum cross-section for earthing conductors of antennas (according to IEC 60728-11 (EN 60728-11)), is 16 mm² (copper), 25 mm² (aluminium) or 50 mm² (steel).

Equipotential bonding bars

Equipotential bonding bars are a central component of the equipotential bonding system and must clamp all connecting cables and cross-sections which occur in practice so that they have high contact stability; they must be able to carry currents safely and have sufficient corrosion resistance.

The German DIN VDE 0618-1 standard describes requirements on equipotential bonding bars for protective equipotential bonding. It defines the following connection possibilities as a minimum:

- ➔ 1 x flat conductor (4 x 30 mm) or round conductor (Ø 10 mm)
- ➔ 1 x 50 mm²
- ➔ 6 x 6 mm² to 25 mm²
- ➔ 1 x 2.5 mm² to 6 mm²



Figure 6.1.2 K12 equipotential bonding bar, Part No. 563 200



Figure 6.1.3 R15 equipotential bonding bar, Part No. 563 010



Figure 6.1.4 Earthing pipe clamp, Part No. 407 114

K12 and R15 meet these requirements on an equipotential bonding bar (**Figures 6.1.2 and 6.1.3**).

This standard also includes requirements for testing the lightning current carrying capability of clamping points with cross-sections greater than 16 mm². The standard refers to the test for lightning protection components described in IEC 62561-1 (EN 62561-1).

If the requirements of the previously mentioned standard are met, this component can also be used for lightning equipotential bonding in accordance with IEC 62305-1 to 4 (EN 62305-1 to 4).

Equipotential bonding connections

Equipotential bonding connections must provide good and permanent contact.

Integrating pipes in the equipotential bonding system

In order to integrate pipes in the equipotential bonding system, earthing pipe clamps which correspond to the diameters of the pipes are used (**Figure 6.1.4**).

Stainless steel earthing pipe clamps with tensioning straps, which can be universally adapted to the diameter of the pipe, offer enormous installation benefits (**Figure 6.1.5**).

These earthing pipe clamps can be used to clamp pipes made of different materials (e.g. steel, copper and stainless steel) and also allow through-wiring.

Figure 6.1.6 shows the equipotential bonding system of heating pipes with through-wiring.



Figure 6.1.5 Earthing pipe clamp, Part No. 540 910



Figure 6.1.6 Through-wired equipotential bonding bar

Testing and monitoring the equipotential bonding system

Before the electrical consumer's installation is commissioned, the connections must be tested to ensure their proper condition and effectiveness.

Low-impedance continuity to the various installation parts and to the equipotential bonding system is recommended. A value of < 1 Ω is considered to be sufficient for the equipotential bonding connections. In a continuity test according to IEC 60364-6 (HD 60364-6), test equipment with a test current of 200 mA as per IEC 61557-4 (EN 61557-4) must be used.

Supplementary protective equipotential bonding

If the disconnection conditions of the relevant system configuration cannot be met for an installation or a part thereof, a local supplementary protective equipotential bonding is required. The reason behind this is to interconnect all simultaneously accessible parts as well as the stationary equipment and to connect extraneous conductive parts to keep any touch voltage which may occur as low as possible.

Moreover, supplementary protective equipotential bonding must be used for installations or installation parts of IT systems with insulation monitoring.

Supplementary protective equipotential bonding is also required if the environmental conditions in special installations or parts thereof present a particular risk.

The IEC 60364 series Part 7 draws attention to supplementary protective equipotential bonding for special operating areas, rooms and installations.

These are, for example,

- ➔ IEC 60364-7-701 (HD 60364-7-701) Locations containing a bath or shower (no longer generally required)
- ➔ IEC 60364-7-702 (HD IEC 60364-7-702) Basins of swimming pools and other water basins
- ➔ IEC 60364-7-705 (HD 60364-7-705) Agricultural and horticultural premises

Minimum cross-sections for the supplementary protective bonding copper conductor of 2.5 mm² (in case of protected installation) and 4 mm² (in case of unprotected installation) are required.

The difference to the protective equipotential bonding consists in the fact that the cross-sections of the conductors can be chosen to be smaller and this supplementary protective equipotential bonding can be limited to a particular location.

6.1.1 Minimum cross-section for equipotential bonding conductors according to IEC 62305-3 (EN 62305-3)

The cross-sections of conductors used for lightning protection purposes must be dimensioned for high stress since these conductors must be capable of carrying lightning currents. Therefore, they must have larger cross-sections.

Irrespective of the class of LPS, the minimum cross-sections according to **Table 6.1.1.1** must be used for connecting equipotential bonding bars with one another and to the earth-termination system.

The minimum cross-sections of equipotential bonding conductors, which allow to connect internal metal installations to the equipotential bonding bar, can be smaller since only low partial lightning currents flow through these conductors (**Table 6.1.1.2**).

Note: If standards provide different information on the minimum cross-sections of conductors, the cross-sections stated in IEC 62305-3 (EN 62305-3) must be used for lightning protection purposes.

6.2 Equipotential bonding for power supply systems

Equipotential bonding for low-voltage consumer's installations as part of the internal lightning protection represents an extension of the protective equipotential bonding (previously: main equipotential bonding) according to IEC 60364-4-41 (HD 60364-4-41) (**Figure 6.1.1**).

In addition to all conductive systems, the feeder cables of the low-voltage consumer's installation are also integrated in the equipotential bonding system. A special feature of this equipotential bonding system is the fact that connection to the equipotential bonding system is only possible via adequate surge protective devices. The requirements made on such surge protective devices are described in more detail in section 7 and Annexes C and D of the IEC 62305-4 (EN 62305-4) standard.

Analogous to the equipotential bonding for metal installations (see chapter 6.1), equipotential bonding for the feeder cables of the low-voltage consumer's installation should also be established directly at the entry point into the object. The requirements governing the installation of the surge protective devices upstream of the meter of the low-voltage consumer's installation (main power supply system) are described in the guideline published by the German VDN (Association of German Network Operators) "Surge Protective Devices Type 1 – Guideline for the use of surge protective devices (SPDs) Type 1 in main power supply systems" (see chapter 7.5.2 and 8.1) (**Figures 6.2.1 and 6.2.2**).

Class of LPS	Material	Cross-section
I to IV	Copper	16 mm ²
	Aluminium	25 mm ²
	Steel	50 mm ²

Table 6.1.1.1 Minimum dimensions of conductors connecting different equipotential bonding bars with one another or with the earth-termination system (according to IEC 62305-3 (EN62305-3), Table 8)

Class of LPS	Material	Cross-section
I to IV	Copper	6 mm ²
	Aluminium	10 mm ²
	Steel	16 mm ²

Table 6.1.1.2 Minimum dimensions of conductors connecting internal metal installations to the equipotential bonding bar (according to IEC 62305-3 (EN62305-3), Table 9)



Figure 6.2.1 DEHNbloc M for installation in conformity with the lightning protection zone concept at the boundaries from O_A-1

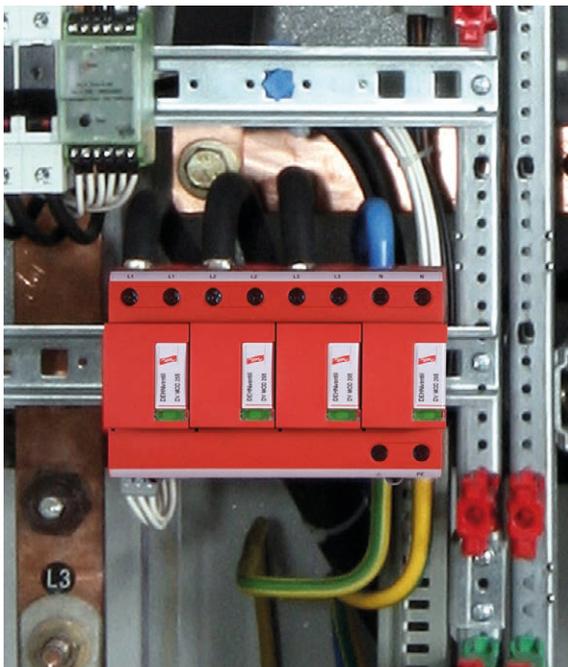


Figure 6.2.2 DEHNventil combined arrester for installation in conformity with the lightning protection zone concept at the boundaries from O_A-2

6.3 Equipotential bonding for information technology systems

Lightning equipotential bonding requires that all metal conductive parts such as cable cores and shields at the entrance point into the building be integrated in the equipotential bonding system so as to cause as little impedance as possible. Examples of such parts include antenna lines (Figure 6.3.1), telecommunication lines with metal conductors and also optical fibre installations with metal elements. The lines are connected with the help of lightning current carrying elements (arresters and shield terminals). An adequate place of installation is the point where the cabling extending beyond the building transfers to cabling inside the building. Both the arresters and the shield terminals must be chosen according to the lightning current parameters to be expected.

In order to minimise induction loops within buildings, the following additional steps are recommended:

- ➔ Cables and metal pipes should enter the building at the same location
- ➔ Power and data lines should be laid spatially close, but shielded
- ➔ Unnecessarily long cables should be prevented by laying lines directly

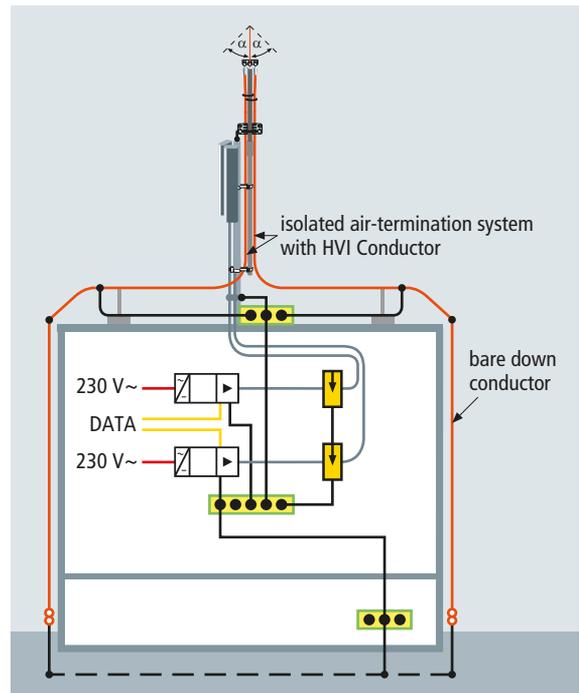


Figure 6.3.1 Lightning equipotential bonding with an isolated air-termination system and a HVI Conductor for professional antenna installations according to IEC 62305-3 (EN 62305-3)

Antenna systems

For reasons concerning radio communication, antenna systems are generally mounted in an exposed location. Therefore, they are more affected by lightning currents and surges, especially in the event of a direct lightning strike. In Germany they must be integrated in the equipotential bonding system according to DIN VDE 0855-300 (German standard) and must reduce the risk of being affected by means of their design (cable structure, connectors and fittings) or suitable additional measures. Antenna elements that are connected to an antenna feeder and cannot be connected directly to the equipotential bonding system for functional reasons should be protected by lightning current carrying arresters.

Expressed simply, it can be assumed that 50 % of the direct lightning current flows away via the shields of all antenna lines. If an antenna system is dimensioned for lightning currents up to 100 kA (10/350 μ s) (lightning protection level (LPL) III), the lightning current splits so that 50 kA flow through the earthing conductor and 50 kA via the shields of all antenna cables. Antenna systems which are not capable of carrying lightning currents must therefore be equipped with air-termination systems in whose protected volume the antennas are located. When choosing a suitable cable, the relevant partial lightning current ratio must be determined for each antenna line sharing the down conductor. The required dielec-

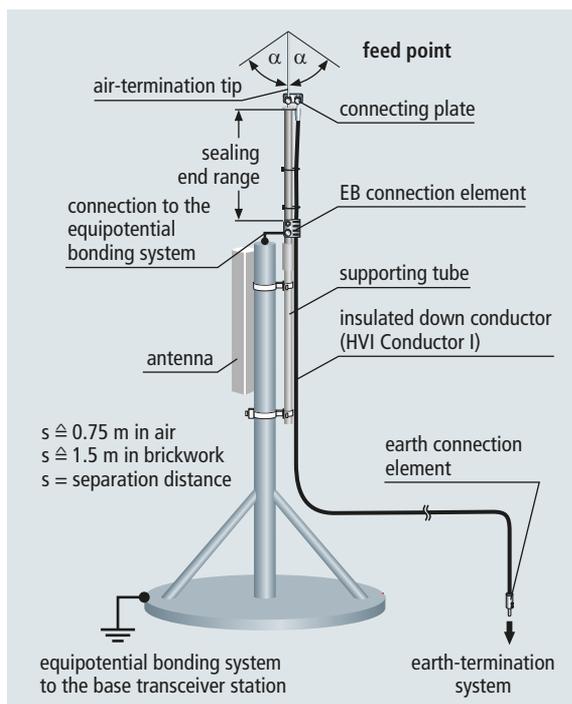


Figure 6.3.2 Isolated installation of a lightning protection system and a mobile phone antenna

tric strength of the cable can be determined from the transfer impedance, the length of the antenna line and the amplitude of the lightning current.

According to the latest IEC 62305-3 (EN 62305-3) lightning protection standard, antenna systems on buildings can be protected by means of

- ➔ Air-termination rods
- ➔ Elevated wires
- ➔ Or spanned cables.

In each case, the separation distance s must be maintained.

The electrical isolation of the lightning protection system from conductive parts of the building structure (metal structural parts, reinforcement etc.) and the isolation of the lightning protection system from electrical lines in the building prevent partial lightning currents from entering control and supply lines and thus prevent that sensitive electrical and electronic devices are affected or destroyed (Figures 6.3.1 and 6.3.2).

Optical fibre installations

Optical fibre installations with metal elements can normally be divided into the following types:

- ➔ Cables with metal-free core, but with metal sheath (e.g. metal vapour barrier) or metal supporting elements
- ➔ Cables with metal elements in the core and with metal sheath or metal supporting elements
- ➔ Cables with metal elements in the core, but without metal sheath.

For all types of cable with metal elements, the minimum peak value of the lightning current, which adversely affects the transmission characteristics of the optical fibre cables, must be determined. Cables which are capable of carrying lightning currents must be chosen and the metal elements must be connected to the equipotential bonding bar either directly or via an SPD.

- ➔ Metal sheath: Connection by means of shield terminals e.g. shield terminal at the entrance point into the building
- ➔ Metal core: Connection by means of an earthing clamp e.g. protective conductor terminal near the splice box
- ➔ Prevention of equalising currents: Indirect connection via a spark gap e.g. DEHNgap CS, BLITZDUCTOR XT with indirect shield earthing (Figure 6.3.3)

Telecommunication lines

Telecommunication lines with metal conductors typically consist of cables with balanced or coaxial stranding elements of the following types:



Figure 6.3.3 EMC spring terminals for the protected and unprotected side of a BLITZDUCTOR XT for permanent low-impedance shield contact with a shielded signal line; with snap-on insulating cap for indirect shield earthing, cable ties and insulating strips.

- ➔ Cables without additional metal elements
- ➔ Cables with metal sheath (e.g. metal vapour barrier) and/or metal supporting elements
- ➔ Cables with metal sheath and additional lightning protection reinforcement

The splitting of the partial lightning current between information technology lines can be determined using the procedures in Annex E of the IEC 62305-1 (EN 62305-1) standard. The individual cables must be integrated in the equipotential bonding system as follows:

- a) Unshielded cables must be connected by SPDs which are capable of carrying partial lightning currents. Partial lightning current of the cable divided by the number of single cores = partial lightning current per core.
- b) If the cable shield is capable of carrying lightning currents, the lightning current flows via the shield. However, capacitive/ inductive interferences can reach the cores and make it necessary to use surge arresters. Requirements:
 - ➔ The shield at both cable ends must be connected to the main equipotential bonding system in such a way that it can carry lightning currents (Figure 6.3.4).
 - ➔ The lightning protection zone concept must be used in both buildings where the cable ends and the active cores must be connected in the same lightning protection zone (typically LPZ 1).
 - ➔ If an unshielded cable is laid in a metal pipe, it must be treated as if it were a cable with a lightning current carrying cable shield.
- c) If the cable shield is not capable of carrying lightning currents, then:
 - ➔ If the shield is connected at both ends, the procedure is the same as for a signal core in an unshielded cable. Par-

tial lightning current of the cable divided by the number of single cores + 1 shield = partial lightning current per core

- ➔ If the shield is not connected at both ends, it must be treated as if it were not there: Partial lightning current of the cable divided by the number of single cores = partial lightning current per core

If it is not possible to determine the exact core load, it is advisable to use the threat parameters given in IEC 61643-22 (CLS/TS 61643-22). Consequently, the maximum lightning current load per cable core for a telecommunications line is a category D1 impulse of 2.5 kA (10/350 μs).

Of course not only the SPDs used (Figure 6.3.5) must be capable of withstanding the expected lightning current load, but also the discharge path to the equipotential bonding system. This can be illustrated based on the example of a multi-core telecommunications line:



Figure 6.3.4 Lightning current carrying shield connection system (SAK)

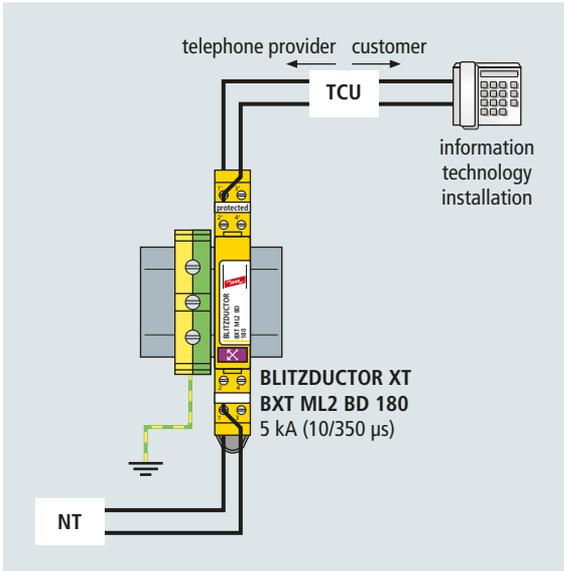


Figure 6.3.5 Lightning equipotential bonding for the connection of a telecommunications device by means of BLITZDUCTOR XT (use permitted by Deutsche Telekom)

- ➔ A telecommunications cable with 100 pairs coming from LPZ 0_A is connected in an LSA building distributor and should be protected by arresters.



Figure 6.3.6 Lightning current carrying DEHN equipotential bonding enclosures (DPG LSA) for LSA-2/10 technology

- ➔ The lightning current load on the cable was assumed to be 30 kA (10/350 µs).
- ➔ The resulting symmetrical splitting of the lightning current to the single cores is $30 \text{ kA} / 200 \text{ cores} = 150 \text{ A/core}$.

This means no special requirements are placed on the discharge capacity of the protection elements to be used. After flowing through the discharge elements, the partial currents of all cores add up to 30 kA again and stress, for example, terminal enclosures, earthing clamps or lightning equipotential bonding conductors in the discharge path. Lightning-current-tested enclosure systems can be used to prevent destruction in the discharge path (Figure 6.3.6).

