7. Protection of electrical and electronic systems against LEMP

7.1 Lightning protection zones concept

A lightning protection system (LEMP Protection Measures System (LPMS)) according to IEC 62305-3 (EN 62305-3) protects persons and material assets of value in the buildings, but it does not protect the electrical and electronic systems in the buildings which are sensitive to transient high-energy surges resulting from the lightning discharge. It is precisely such systems – in the form of building management, telecommunications, control and security systems – which are rapidly becoming common in practically all areas of residential and functional buildings. The owner/operator places very high demands on the permanent availability and reliability of such systems.

The protection of electrical and electronic systems in buildings and structures against surges resulting from the lightning electromagnetic pulse (LEMP) is based on the principle of Lightning Protection Zones (LPZ). According to this principle, the building or structure to be protected must be divided into internal lightning protection zones according to the level of threat posed by LEMP (**Figure 7.1.1**). This enables areas with different LEMP risk levels to be adjusted to the immunity of the electronic system.

With this flexible concept, suitable LPZs can be defined according to the number, type and sensitivity of the electronic devices/systems. From small local zones to large integral zones which can encompass the whole building. Depending on the type of threat posed by lightning, the following lightning protection zones are defined:

External zones

⇒ **LPZ 0_A** – at risk from direct lightning strikes, from impulse currents up to the whole lightning current and from the whole electromagnetic field of the flash of lightning.

⇒ **LPZ 0_B** – protected against direct lightning strikes, at risk from the whole electromagnetic

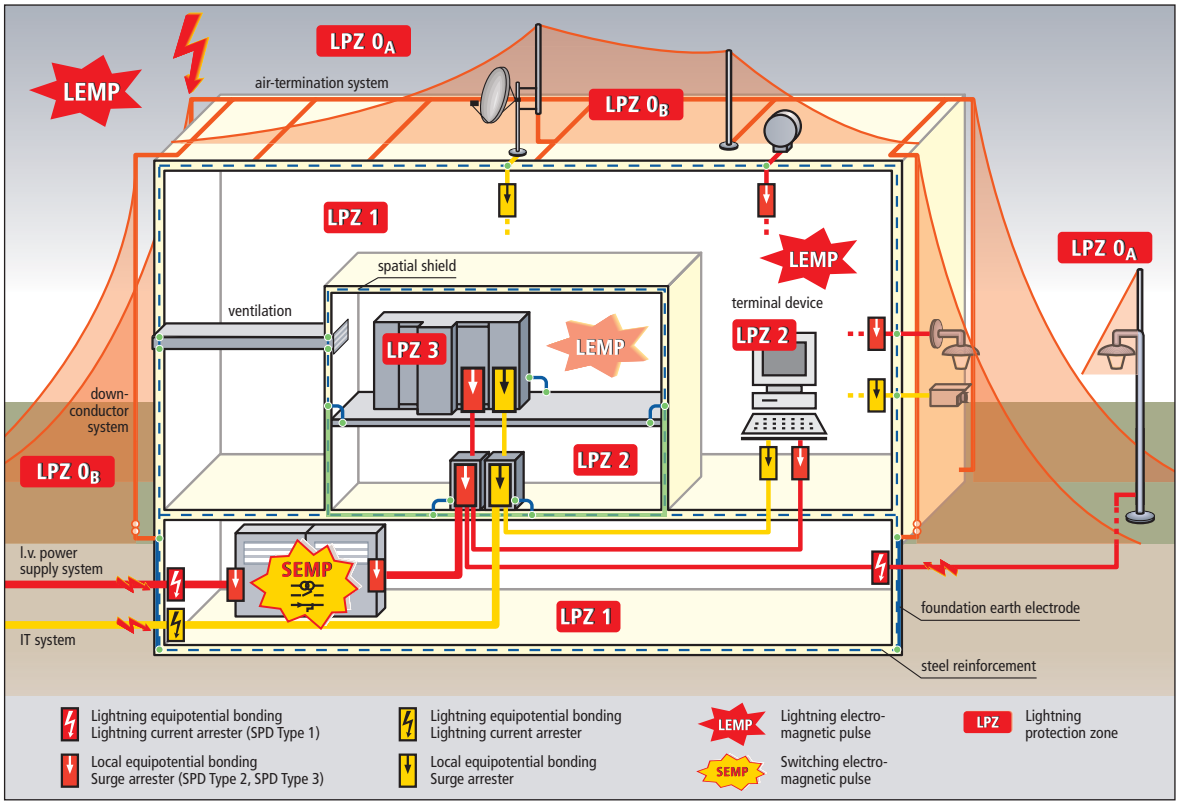


Fig. 7.1.1 Lightning protection zones concept according to IEC 62305-4 (EN 62305-4)

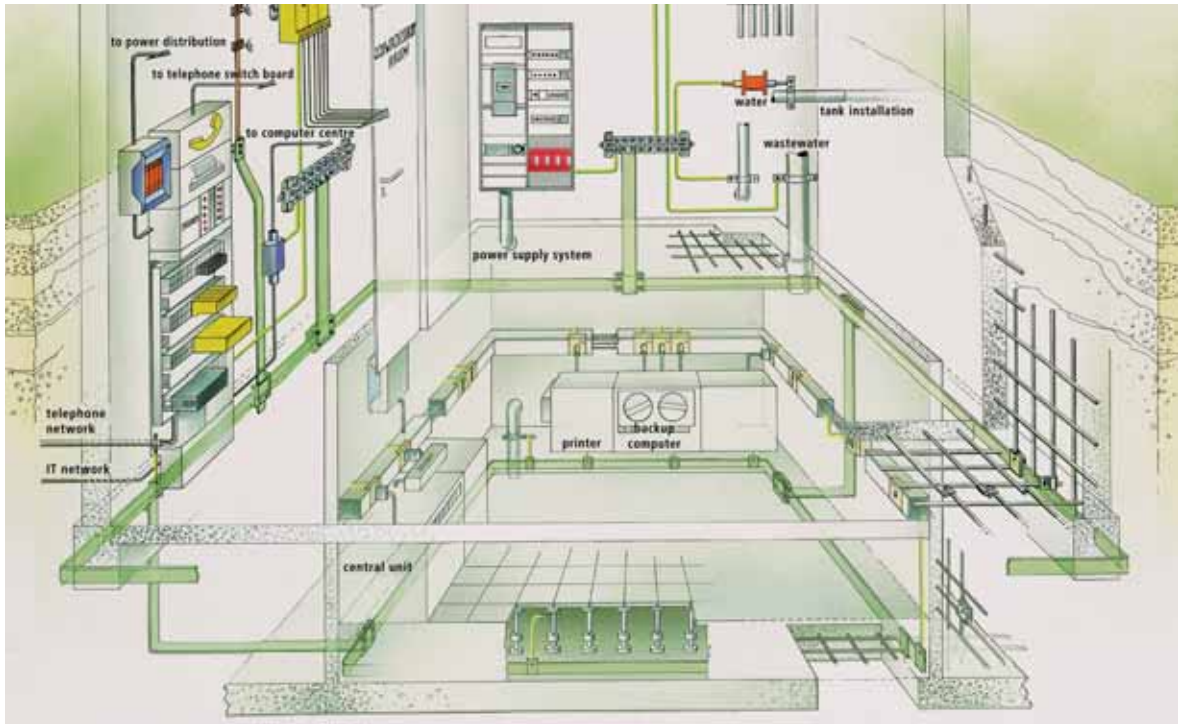


Fig. 7.1.2 Example for realisation of the lightning protection zones concept

field of the flash of lightning. Internal systems can be exposed to (partial) lightning currents.

Internal zones

⇒ **LPZ 1** – impulse currents limited by the splitting of the current and by surge protective devices (SPDs) at the zones boundaries. The electromagnetic field of the lightning flash can be attenuated by spatial shielding.

⇒ **LPZ 2 ... n** – impulse currents further limited by the splitting of the current and by surge protective devices (SPDs) at the zone boundaries. The electromagnetic field of the lightning flash is usually attenuated by spatial shielding.

The requirements on the internal zones must be defined according to the immunity of the electrical and electronic systems to be protected.
At the boundary of each internal zone, the equipotential bonding must be carried out for all metal components and utility lines entering the building or structure. This is done directly or with suitable SPDs. The zone boundary is formed by the shielding measures.

Figure 7.1.2 illustrates an example of how to realise the measures described for the lightning protection zones concept.

7.2 LEMP protection management

For new buildings and structures, optimum protection of electronic systems can only be achieved with a minimum of expense if the electronic systems are designed together with the building and before its construction. In this way, building components such as the reinforcement, the metal girders and metal buttresses can be integrated into the LEMP protection management.
For existing buildings and structures, the cost of the LEMP protection is usually higher than for new buildings and structures. If, however, the LPZs are chosen appropriately and existing installations are used or upgraded, the costs can be reduced.

If the risk analysis in accordance with IEC 62305-2 (EN 62305-2) shows that LEMP protection is required, this can only be achieved if:

Step	Aim	Measure must be taken by (if relevant)
Initial risk analysis [a]	Assessing of the necessity of an LEMP protection. If necessary an appropriate LEMP Protection Measures System (LPMS) based on a risk assessment has to be chosen.	• Lightning protection specialist [b] • Owner
Final risk analysis [a]	The cost/benefit ratio of the chosen protection measures should be optimised again by a risk assessment. Accordingly to be determined: • Lightning protection level (LPL) and the lightning parameters • LPZ and their boundaries	• Lightning protection specialist [b] • Owner
Design of LEMP Protection Measures System (LPMS)	Definition of the LPMS: • Measures of spatial shielding • Equipotential bonding networks • Earth-termination systems • Leading and shielding of conductors • Surge protective devices system	• Lightning protection specialist [b] • Owner • Architect • Designer of the electronic systems • Designer of the important installations
Design of the LPMS	General drawings and descriptions Preparation of the tender documentation Detailed drawings and schedules for the installation	• Engineering office or equivalent
Installation and inspection of the LPMS	Quality of the installation Documentation Possible revision of detailed drawings	• Lightning protection specialist [b] • Installer of the LPMS • Engineering office • Inspection representative
Acceptance of the LPMS	Inspection and documentation of the system	• Independent lightning protection expert [b] • Authorised inspector
Repeat inspections	Ensuring of an appropriate LPMS	• Lightning protection specialist [b] • Authorised inspector
[a] see IEC 62305-2 (EN 62305-2) [b] with profound knowledge of EMC and installation practice		

Table 7.2.1 LEMP protection management for new buildings and for comprehensive modifications of the construction or the utilisation of building according to IEC 62305-4 (EN 62305-4)

⇒ the measures are designed by a lightning protection specialist having profound knowledge of EMC,

⇒ there is close coordination on all aspects of the work between the building experts (e.g. civil and electrical engineers) and those experts in LEMP protection and

⇒ the management plan according to **Table 7.2.1** (IEC 62305-4 (EN 62305-4) Subclause 8.1) is adhered to.

A concluding risk analysis must prove that the residual risk is less than the tolerable risk.

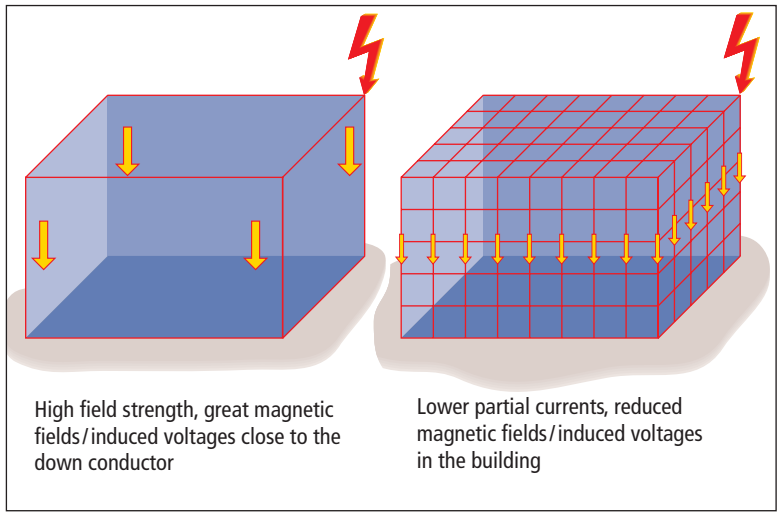


Fig. 7.3.1 Reduction of the magnetic field by means of lattice shields

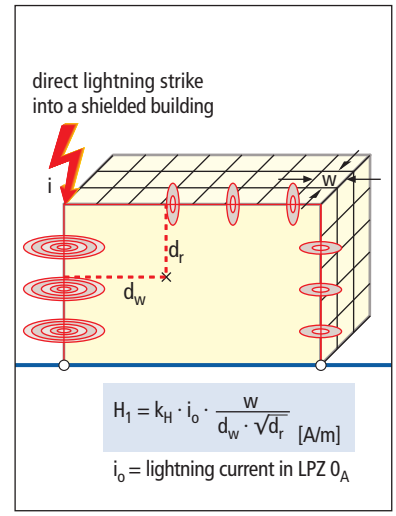


Fig. 7.3.2 Magnetic field at a lightning strike (LEMP) IEC 62305-4 (EN 62305-4)

7.3 Calculation of the magnetic shield attenuation of building / room shielding

Lightning current and the associated electromagnetic field represent the primary source of interference for devices and installations requiring protection in a property. **Figure 7.3.1** shows the principle of how lattice structures work. The fundamentals of the calculation are described in the IEC 62305-4 (EN 62305-4) standard.

The fundamentals of the calculation are based on assumptions and estimates. The complex distribution of the magnetic field inside lattice-shaped shields is determined with a first approximation. The formulae for the determination of the magnetic field are based on numerical calculations of the magnetic field. The calculation takes into account the magnetic field coupling of each rod in the lattice-shaped shield with all other rods, including the simulated lightning channel.

To consider whether it is the effect of the electromagnetic field of the first partial lightning strike or the subsequent lightning strike which is the more critical interference variable for the electric installation requiring protection, the calculations must be done with the maximum value of the current of the short strike ($i_{f/max}$) and the maximum value of the current of the long strike ($i_{s/max}$) corresponding to the lightning protection level derived from Table 5, IEC 62305-1 (EN 62305-1).

The shielding effect of lattice-shaped shields in the event of direct lightning strikes can be calculated using the formula shown in **Figure 7.3.2**. This view is based on the fact that the lightning strike can happen at any point on the roof.

The values calculated for the magnetic field apply to the safety volume V_s inside lattice-shaped shields, which are defined by the separation distance $d_{s/...}$ (**Figure 7.3.3**).

This safety volume takes into account maximum values of the magnetic field strength directly at the lattice structure, a factor which the approximation formula does not sufficiently take into account. IT devices may only be installed inside of volume V_s.

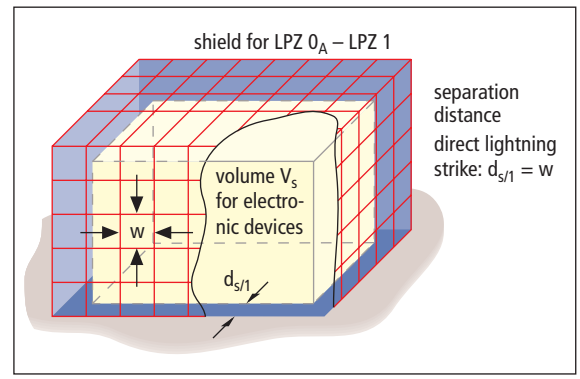


Fig. 7.3.3 Volume for electronic devices within LPZ 1

The fundamentals of the calculation of the shielding effect of lattice-shaped shields for nearby lightning strikes are explained more in detail by **Figures 7.3.4** and **7.3.5**.

Figure 7.3.4 shows the formation of the electromagnetic field whose reduction in field strength is indirectly proportional to the distance s_a. The magnitude of the magnetic field inside a protected volume, e.g. lightning protection zone LPZ 1 (**Figure 7.3.5**), can be described by the quality of the shielding.

The shielding factor SF can be calculated as shown in **Table 7.3.1**.

The results of this calculation of the magnetic field are valid for a safety volume V_s (**Figure 7.3.3**), located within the lightning protection zone with a separation distance $d_{s/1}$ from the shielding.

The separation distance $d_{s/1}$ (for SF < 10) results in:

$$d_{s/1} = w\ [m]$$

w corresponds to the mesh size of the lattice-shaped shield in metres

Implementation of the magnetic shield-attenuation of building / room shielding

Particularly important when shielding against magnetic fields, and hence for the installation of lightning protection zones, are extended metal components, e.g. metal roofs and facades, steel reinforcements in concrete, expanded metals in walls, lattices, metal supporting structures and pipe systems existing in the building. The meshed connection creates an effective electromagnetic shield.

Figure 7.3.6 shows the principle how a steel reinforcement can be developed into an electromagnetic cage (hole shield). In practice, however, it will not be possible to weld or clamp together every junction in large buildings and structures. The usual practice is to install a meshed system of conductors into the reinforcement, said system typically having a size of a ≤ 5 m. This meshed network is connected in an electrically safe way at the cross-points, e.g. by means of clamps. The reinforcement is "electrically hitched" onto the meshed network at a typical distance of b ≤ 1 m. This is done on the building side, for example by means of tie connections.

Mats made of construction steel in concrete are suitable

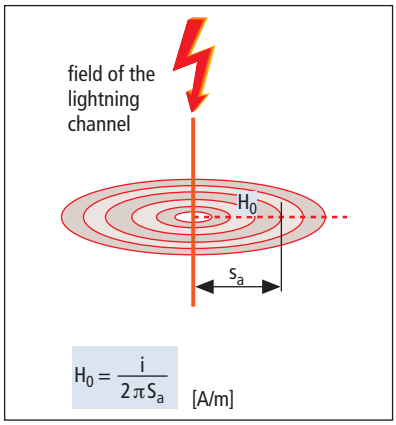


Fig. 7.3.4 Magnetic field at a lightning strike (LEMP) IEC 62305-4 (EN 62305-4)

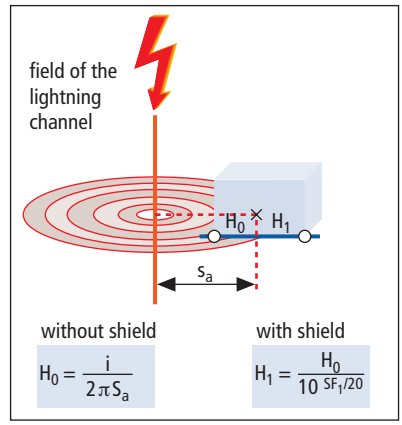


Fig. 7.3.5 Magnetic field at a distant lightning strike (LEMP) IEC 62305-4 (EN 62305-4)

Material	**Shielding factor SF (dB)**		w = mesh size (m) (w ≤ 5 m) r = rod radius (m) $\mu_r \approx 200$ (permeability)
	25 kHz (first short strike)	**1 Mhz** (subsequent strike)	
Copper Aluminium	$20 \cdot \log (8.5/w)$	$20 \cdot \log (8.5/w)$	
Steel	$20 \cdot \log \frac{(8.5/w)}{\sqrt{1+18 \cdot 10^{-6}/r^2}}$	$20 \cdot \log (8.5/w)$	

Example: Steel lattice

w (m)	**r (m)**	**dB at 25 kHz**	**dB at 1 MHz**
0.012	0.0010	44	57
0.100	0.0060	37	39
0.200	0.0090	32	33
0.400	0.0125	26	27

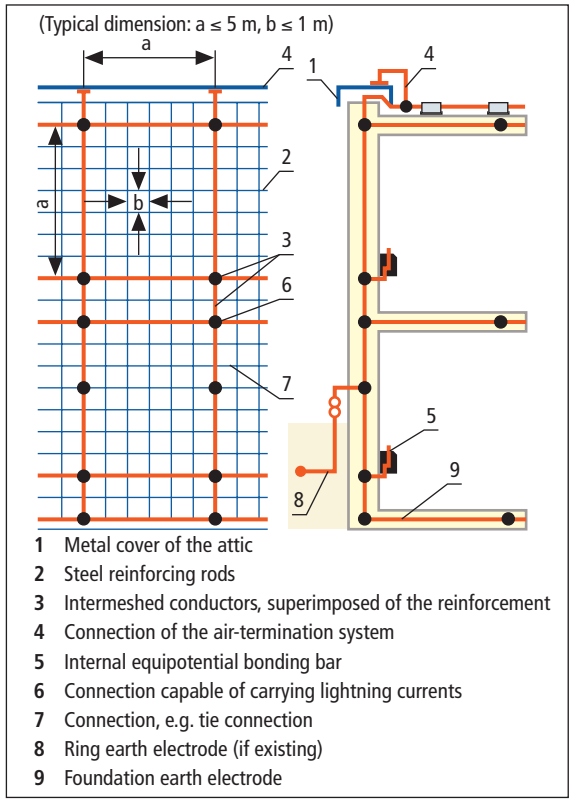
Table 7.3.1 Magnetic attenuation of lattices at a nearby lightning strike acc. to IEC 62305-4 (EN 62305-4)

for shielding purposes. When upgrading existing installations, such steel mats are also laid later. For this type of design, the steel mats must be galvanised to protect them from corrosion.

These galvanised steel mats are then laid on roofs, for example, so that they overlap, or applied either externally or internally to the exterior wall to provide shielding for the building.

Figures 7.3.7a and **7.3.7b** show the subsequent installation of galvanised steel mats on the roof of a building.

To bridge expansion joints, connect the reinforcement of precast concrete components, and for terminals on the external earth-termination system or the internal equipotential bonding system, the building must already be equipped with sufficient fixed earthing points.



1 Metal cover of the attic
2 Steel reinforcing rods
3 Intermeshed conductors, superimposed of the reinforcement
4 Connection of the air-termination system
5 Internal equipotential bonding bar
6 Connection capable of carrying lightning currents
7 Connection, e.g. tie connection
8 Ring earth electrode (if existing)
9 Foundation earth electrode

Fig. 7.3.6 Use of reinforcing rods of a building or structure for shielding and equipotential bonding

Figure 7.3.8 shows an installation of this type, which must be taken into consideration for designing the preliminary building works.

The magnetic field inside the building or structure is reduced over a wide frequency range by means of reduction loops, which arise as a result of the meshed equipotential bonding network. Typical mesh sizes are a ≤ 5 m. The interconnection of all metal components both inside, as well as on the buildings and structures results in a three-dimensional meshed equipotential bonding network.

Figure 7.3.9 shows a meshed equipotential bonding network with appropriate terminals.

If an equipotential bonding network is installed in the lightning protection zones, the magnetic field calculated according to the formulae stated above is typically further reduced by a factor of 2 (corresponds to 6 dB).



Fig. 7.3.7a Galvanised construction steel mats for shielding the building



Fig. 7.3.7b Use of galvanised construction steel mats for shielding, e.g. in case of planted roofs

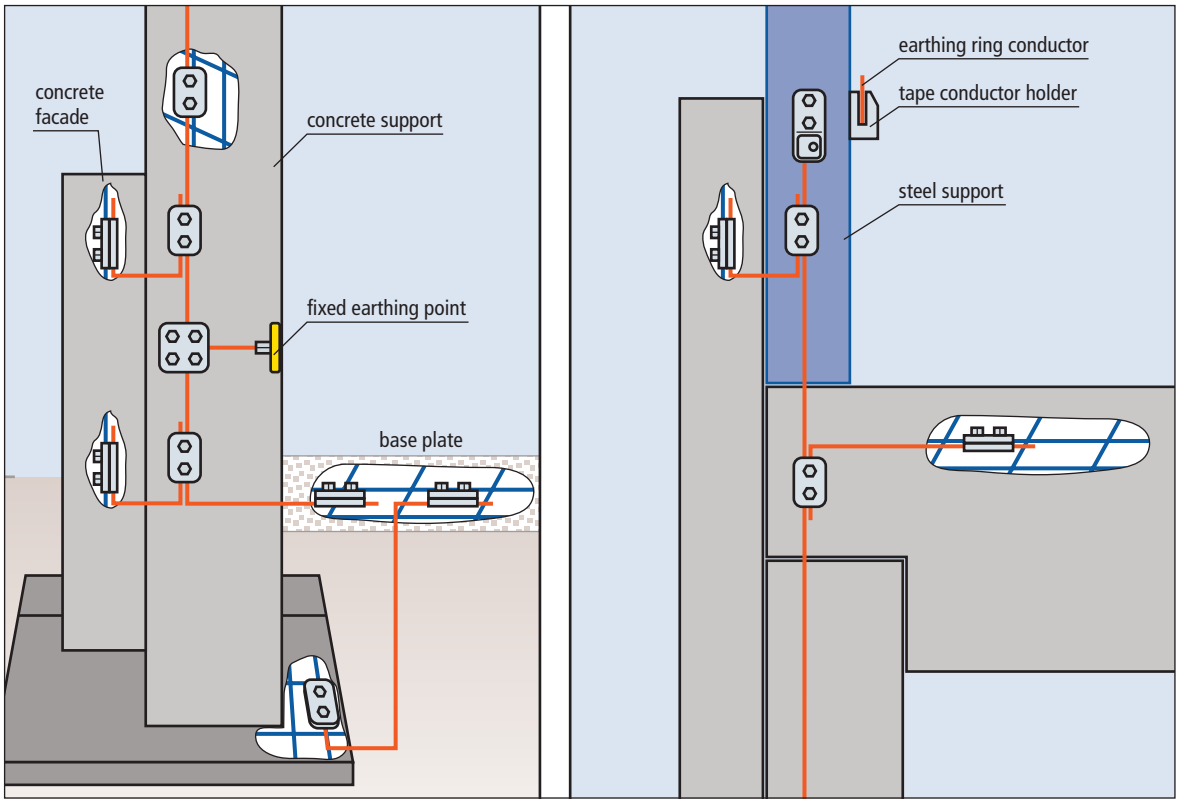


Fig. 7.3.8 Shielding of a structure or building

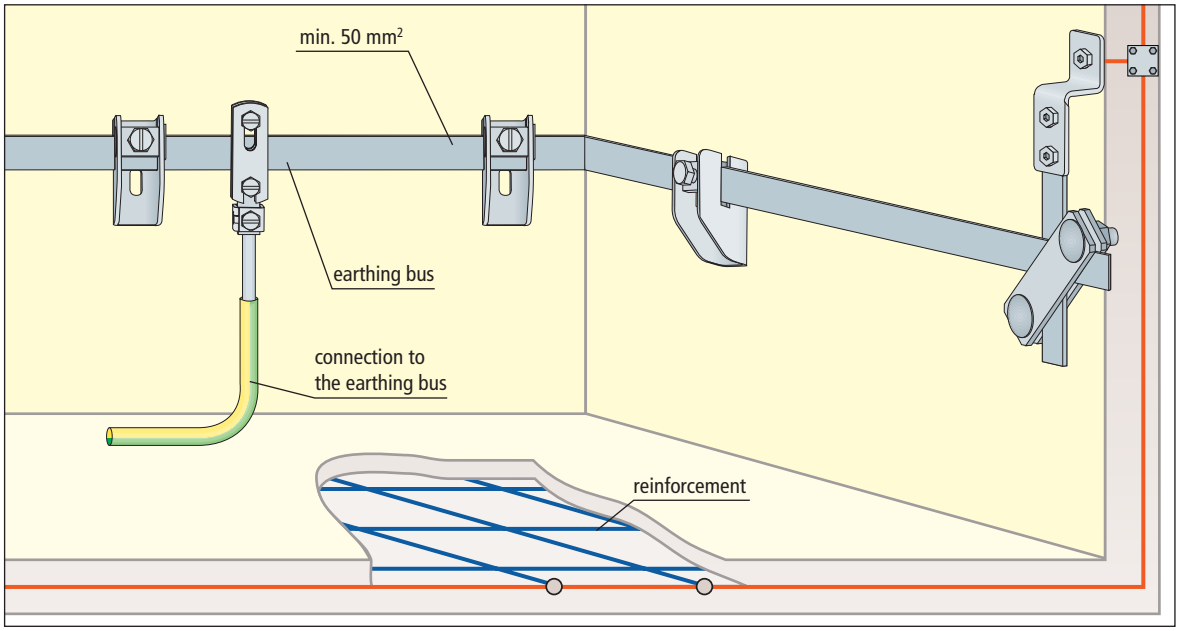


Fig. 7.3.9 Earthing bus according to DIN VDE 0800-2 (German standard)

7.3.1 Cable shielding

Cable shields are used to reduce the effect of the interference on the active lines, and the interference emitted from the active lines to neighbouring systems. From the point of view of lightning and surge protection, attention must be paid to the following applications of shielded lines:

⇒ **No shield earthing**

Some installation systems recommend a shielded cable but, at the same time, forbid shield earthing, (e.g. KNX). If there is no shielding terminal, the shield is not effective against interferences and must therefore be considered as non-existing (**Figure 7.3.1.1**).

⇒ **Double-ended shield earthing**

A cable shield must be continuously connected along the whole of its length for good conducting performance, and earthed at least at both ends. Only a shield used at both ends can reduce inductive and capacitive inputs. Cable shields entering a building or structure must have a certain minimum cross section to avoid the risk of sparking. Otherwise the shields are not considered being capable of carrying lightning current. The minimum cross section of a cable shield (S_{cmin}) laid isolated from earth or air, depends on its specific shield resistance (ρ_c) (**Table 7.3.1.1**) on the lightning current flowing (I_f), on the impulse withstand voltage of the system (U_w), and on the cable length (L_c).

$$S_{cmin} = (I_f \cdot \rho_c \cdot L_c \cdot 10^6 / U_w)[mm^2]$$

I_f can be calculated in accordance with IEC 62305-1 (EN 62305-1). The shield connection technology usually being tested up to 10 kA (10/350 µs), this value, as a first approximation, can be drawn on as maximum value.

U_w can be interpreted quite differently. If the cable shield away from the internal system is interrupted at the building entry then the electric strength of the cable is decisive. The cable shield, however, being uninterrupted up to the terminal device, the electric strength of the terminal device is the important (**Table 7.3.1.2**).

Two examples shall illustrate the difference:

TC cable shield up to the building entry, Al, loaded with 10 kA, length 100 m : $S_{cmin} \approx 6$ mm². It also has to be minded, that the shield terminals at the MEBB must be capable of carrying lightning current.

Shielding material	ρ_c in Ωm
Copper	$17.241 \cdot 10^{-9}$
Aluminium	$28.264 \cdot 10^{-9}$
Lead	$214 \cdot 10^{-9}$
Steel	$138 \cdot 10^{-9}$

Table 7.3.1.1 Specific shield resistance ρ_c for different materials

Examples	Electric strength
LV cable	15 kV
TC cable	5 kV
TC subscriber's side	1.5 kV
Measuring and control equipment	0.5 – 1 kV

Table 7.3.1.2 Electric strength

Bus conductor shield up to the terminal device, Cu, loaded with 5 kA, length 100 m : $S_{cmin} \approx 17$ mm². Such cable shields for bus conductors, however, being not convenient for the practice the described conductor has to be considered as not capable of carrying lightning current.

⇒ **Single-ended and indirect shield earthing**

For operational reasons, cable shields are sometimes earthed at only one end. In fact, a certain attenuation of capacitive interference fields is given. Protection against the electromagnetic induction arising with lightning strikes, however, is not provided. The reason for the single-ended shield earthing is the fear of low frequency equalising currents. In extended installations, a bus cable, for example, can often stretch many hundreds of metres between buildings. Especially with older installations, it can happen that one part of the earth-termination systems is no longer in operation, or that no meshed equipotential bonding is existing. In such cases, interferences can occur as a result of multiple shield earthing. Potential differences of the different building earthing systems can allow low frequency equalising currents (n x 50 Hz), and the transients superimposed thereon, to flow. At the same time, currents measuring up to a few amperes are possible which, in extreme cases, can cause cable fires. In addition, crosstalk can cause signal interference if the signal frequency is in a similar frequency range to the interference signal.

The aim, however, must be to virtually implement the requirements of EMC and prevent equalising

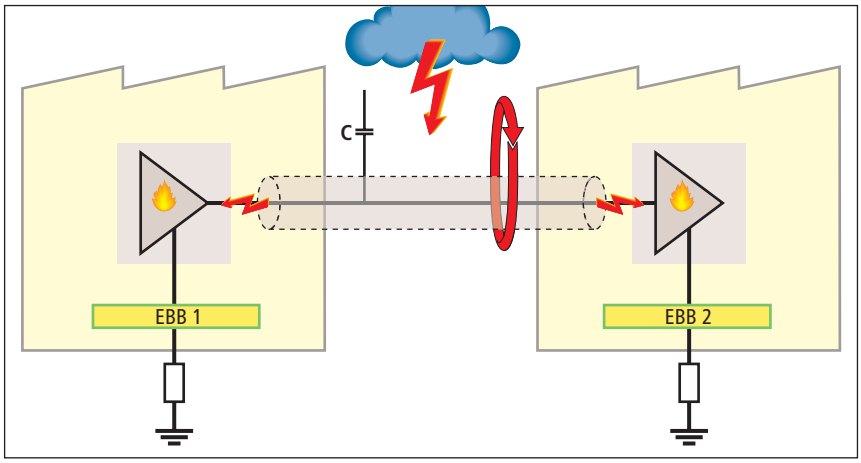


Fig. 7.3.1.1 No shield connection – No shielding from capacitive/inductive couplings

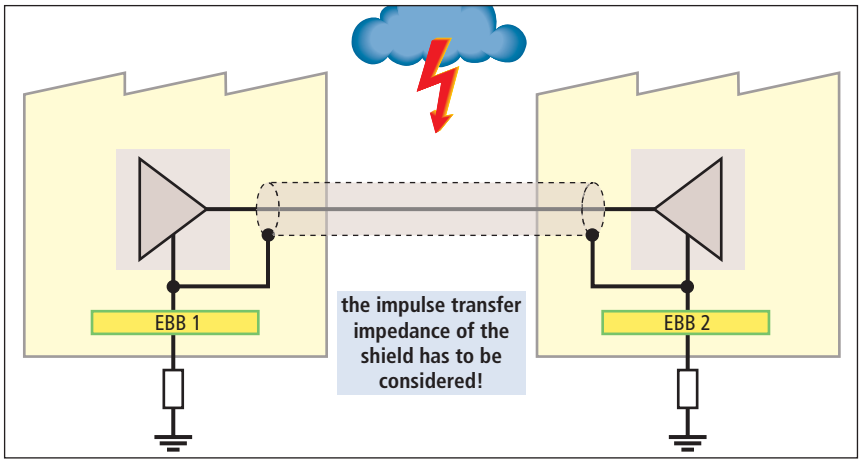


Fig. 7.3.1.2 Shield connection at both ends – Shielding from capacitive/inductive couplings

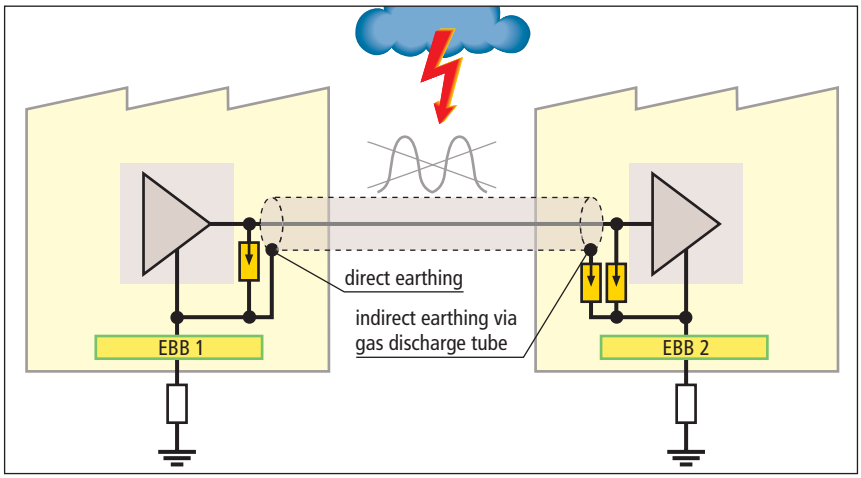


Fig. 7.3.1.3 Shield connection at both ends – Solution: Direct and indirect shield earthing

currents. This can be achieved by combining single-ended and indirect shield earthing. All shields are directly connected with the local equipotential bonding at a central point such as the control room. At the far ends of the cable, the shields are indirectly connected to the earth potential via isolating spark gaps. Since the resistance of a spark gap is around 10 GΩ, equalising currents are prevented in surge-free operation. Should EMC interferences such as lightning strikes occur, the spark gap ignites and discharges the interference pulse without consequential damage to the equipment. This reduces the residual impulse on the active lines and the terminal devices are subject to even less stress. The BLITZDUCTOR CT arrester is equipped with an insert which can take a gas discharge tube, if necessary. This switches between the cable shield and the local earth. The gas discharge tube can be inserted or removed during upgrading or maintenance work in order to change between direct and indirect shield earthing (**Figure 7.3.1.3**).

⇒ **Low impedance shield earthing**

Cable shields can conduct impulse currents of up to several kA. During the discharge, the impulse currents flow through the shield and the shield ter-

minals to earth. The impedance of the cable shield and the shielding terminal creates voltage differences between shield potential and earth. In such a case, voltages of up to some kV can develop and destroy the insulation of conductors or connected devices. Coarse-meshed shields and the twisting of the cable shield (pig tail) to the terminal in a rail clamp are particularly critical. The quality of the cable shield used affects the number of shield earthings required. Under certain circumstances, an earthing is required every 10 metres in order to achieve an efficient shielding effect. Suitable large contacting clamps with slipping spring elements are recommended for the shielding terminal. This is important to compensate for the yield of the synthetic insulation of the conductor (**Figure 7.3.1.4**).

⇒ **Maximum length of shielded cables**

Cable shields have a so-called coupling resistance which roughly corresponds to the d.c. resistance provided by the cable manufacturer. An interference pulse flowing through the resistance creates a potential drop on the cable shield. The permissible coupling resistance for the cable shield can be determined as a function of the dielectric strength of the terminal device and the cable, as well as the cable length. It is crucial that the potential drop is less than the insulation strength of the system. If this is not the case, arresters must be used (**Figure 7.3.1.5**).

⇒ **Extension of LPZs with the help of shielded cables**

IEC 62305-4 (EN 62305-4) states that using a shielded cable between two equal LPZs obviates the need for arresters. This statement applies to interferences to be expected from the spatial surroundings of the shielded cable (e.g. electromagnetic fields) and for meshed equipotential bonding conforming to the standard. But beware. Depending on the conditions the installation is set up in, hazards can still arise and make the use of arresters necessary. Typical potential hazards are: the feeding of the terminal devices from different low voltage main distribution boards (MDB), TN-C systems, high coupling resistances of the cable shields or insufficient earthing of the shield. Further caution must be exercised with cables with poor shield cover, which are often used for economic reasons. The result is residual interferences on the signal lines. Interferences of this type can be controlled by using a high-quality shielded cable or surge protective devices.

7.4 Equipotential bonding network

The main function of the equipotential bonding network is to prevent hazardous potential drops between all devices/installations in the inner LPZs, and to reduce the magnetic field of the lightning.

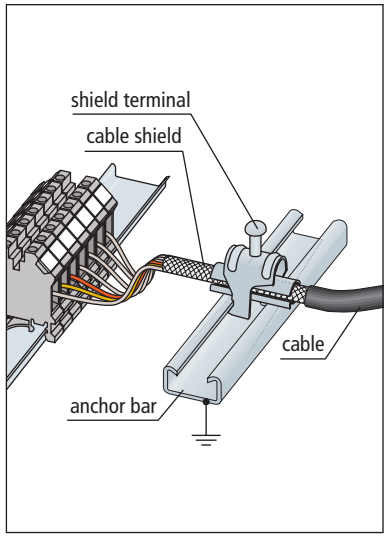


Fig. 7.3.1.4 Shield connection

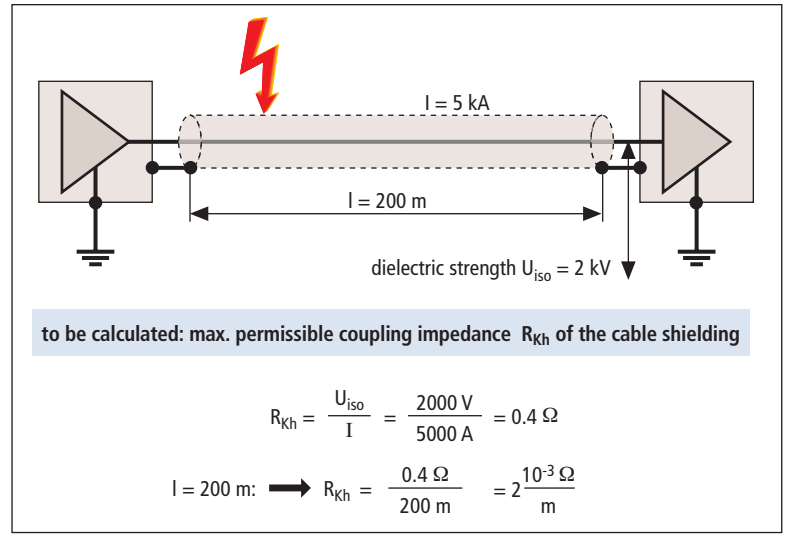


Fig. 7.3.1.5 Shield connection at both ends – Shielding from capacitive/inductive coupling

The low inductance equipotential bonding network required is achieved by means of interconnections between all metal components aided by equipotential bonding conductors inside the LPZ of the building or structure. This creates a three-dimensional meshed network (**Figure 7.4.1**). Typical components of the network are:

⇒ all metal installations (e.g. pipes, boilers),
⇒ reinforcements in the concrete (in floors, walls and ceilings),
⇒ gratings (e.g. intermediate floors),
⇒ metal staircases, metal doors, metal frames,
⇒ cable ducts,
⇒ ventilation ducts,
⇒ lift rails,
⇒ metal floors,
⇒ supply lines.

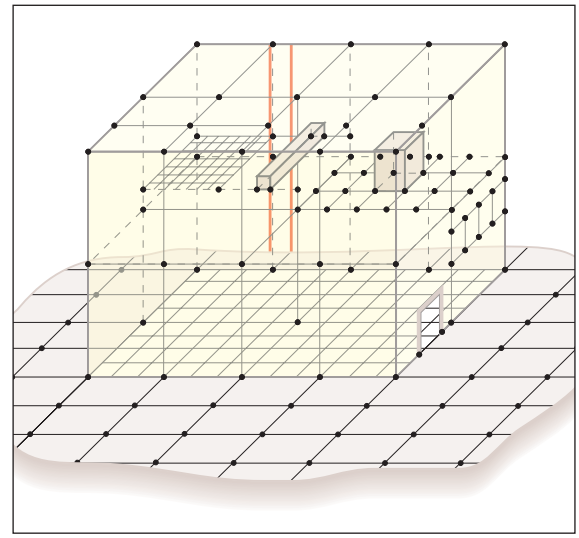


Fig. 7.4.1 Equipotential bonding network in a structure or building

Ideally, a lattice structure of the equipotential bonding network would be around 5 m x 5 m. This would typically reduce the electromagnetic lightning field inside an LPZ by a factor of 2 (corresponding to 6 dB).

Enclosures and racks of electronic devices and systems should be integrated into the equipotential bonding network with short connections. This requires sufficient numbers of equipotential bonding bars and/or ring equipotential bonding bars (**Figure 7.4.2**) in the building or structure. The busbars, in turn, must be connected to the equipotential bonding network (**Figure 7.4.3**).



Fig. 7.4.2 Ring equipotential bonding bar in a computer facility

Protective conductors (PE) and cable shields of the data links of electronic devices and systems must be integrated into the equipotential bonding network in accordance with the instructions of the system manufacturer. The connections can be made as a mesh or in the shape of a star (**Figure 7.4.4**).
When using a star point arrangement S, all metal components of the electronic system must be suitably insulated against the equipotential bonding network. A star-shaped arrangement is therefore usually limited to applications in small, locally confined systems. In such cases, all lines must enter the building or structure, or a room within the building or structure, at a single point. The star point arrangement S must be connected to the equipo-



Fig. 7.4.3 Connection of the ring equipotential bonding bar with the equipotential bonding network via fixed earthing point

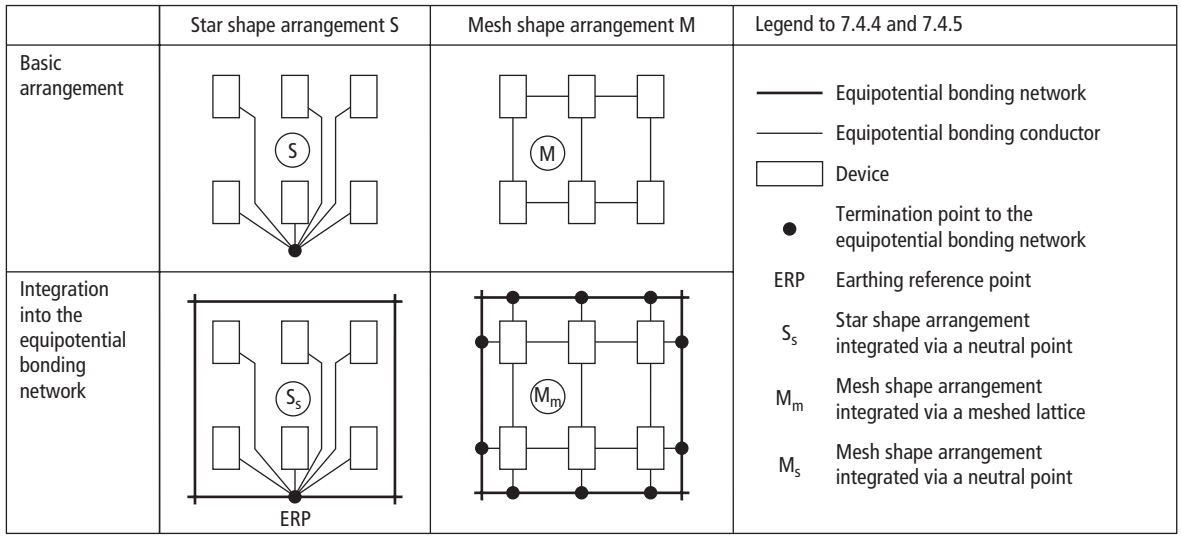


Fig. 7.4.4 Integration of electronic systems into the equipotential bonding network

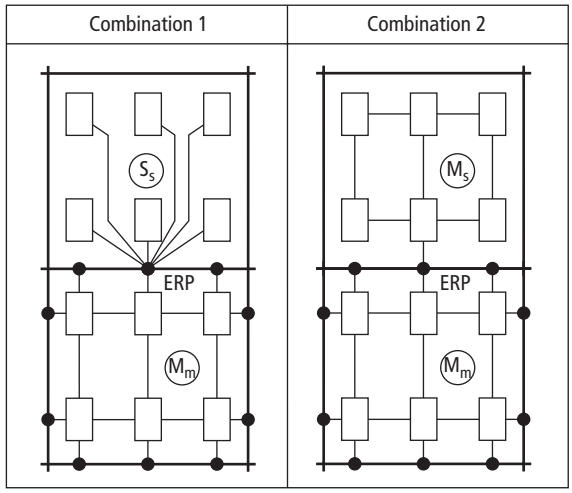


Fig. 7.4.5 Combination of the integration methods according to Figure 7.4.4

tential bonding network at one single earthing reference point (ERP) only. This produces the arrangement S_S.

When using the meshed arrangement M, all metal components of the electronic system do not have to be insulated against the equipotential bonding network. All metal components shall be integrated into the equipotential bonding network at as many equipotential bonding points as possible. The resulting arrangement M_m is used for extended and open systems with many lines between the individual devices. A further advantage of this arrangement is the fact that the lines of the system can enter a building, structure or room at different points.

Complex electronic systems, also allow combinations of star point and meshed arrangements (**Figure 7.4.5**) in order to combine the advantages of both arrangements.

7.5 Equipotential bonding on the boundary of LPZ 0_A and LPZ 1

7.5.1 Equipotential bonding for metal installations

At the boundaries of the EMC lightning protection zones, measures to reduce the radiated electromagnetic field must be realised, and all metal and electrical lines/systems passing through the sectional area must be integrated into the equipotential bonding without exception.

This requirement on the equipotential bonding basically corresponds to that on the main equipotential bonding bar in accordance with IEC 60364-4-41 and IEC 60364-5-54, HD 60364-5-54.

Further towards the main equipotential bonding bar, the lightning equipotential bonding must also be implemented for cables of electrical and electronic systems (see also Chapter 7.5.2) at this boundary of the zones.

This equipotential bonding must be installed as close as possible to the location where the lines and metal installations enter the building or structure. The equipotential bonding conductor should be designed to be as short (low impedance) as possible.

For equipotential bonding, the following minimum cross sections for tying in the equipotential bonding bar to the earth-termination system, interconnecting the different equipotential bonding bars, and tying in the metal installations to the equipotential bonding bar, must be taken into account:

Material	Cross section
Cu	14 mm²
Al	22 mm²
Fe	50 mm²

The following metal installations have to be incorporated into the equipotential bonding:

⇒ Metal cable ducts
⇒ Shielded cables and lines
⇒ Building reinforcement
⇒ Metal water supply pipes
⇒ Metal conduits for lines
⇒ Other metal pipe systems or conductive components (e.g. compressed air)

A corrosion-free earth connection can be easily constructed by using fixed earthing points. During this process, the reinforcement can be connected to the equipotential bonding at the same time (**Figure 7.5.1.1**).

The procedure of tying in the equipotential bonding bar to the fixed earthing point, and connecting the conduits to the equipotential bonding, is shown below (**Figure 7.5.1.1**).

Chapter 7.3 illustrates the tying in of cable shields to the equipotential bonding.

7.5.2 Equipotential bonding for power supply installations

In analogy to metal installations, all electrical power lines and data links at the entrance of the building (lightning protection zone boundary LPZ 0_A to LPZ 1) must be integrated into the equipotential bonding. Whereas the design of data links is described in Section 7.5.3, the following section will look at the design of equipotential bonding with electrical power lines in more detail. The intersections for the equipotential bonding at the LPZ boundary LPZ 0_A to LPZ 1 are defined with the help of the specific design of the property which requires protection. For installations fed by low voltage systems, the LPZ boundary LPZ 0_A/ LPZ 1 is usually taken to be the boundary of the building (**Figure 7.5.2.1**).



Fig. 7.5.1.1 Connection of EBB with fixed earthing point

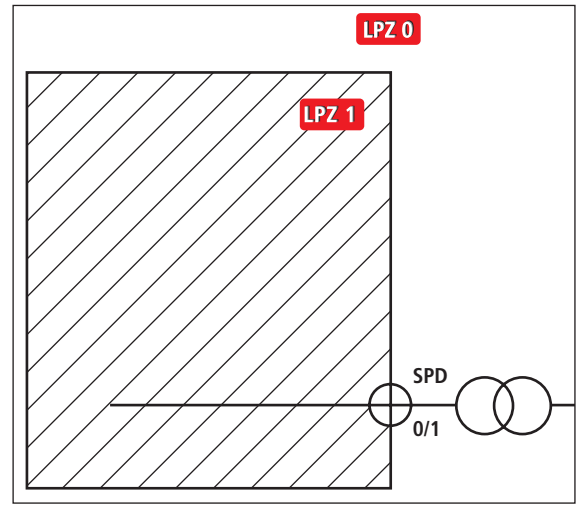


Fig. 7.5.2.1 Transformer outside the structure or building

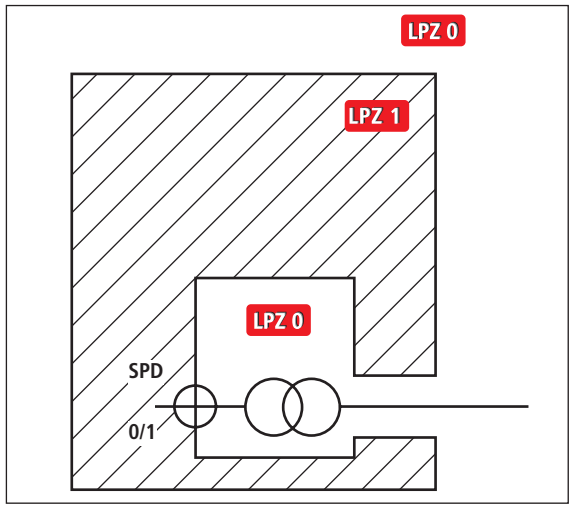


Fig. 7.5.2.2 Transformer inside the structure or building (LPZ 0 integrated in LPZ 1)

For properties fed directly from the medium voltage network, the lightning protection zone LPZ 0_A is extended up to the secondary side of the transformer. The equipotential bonding is carried out on the 230/400 V side of the transformer (**Figure 7.5.2.2**).

To avoid damage at the transformer the additional use of surge protective devices on the high voltage side of the transformer is recommended.

To prevent the flow of partial lightning currents in LPZ 0 from affecting parts of the installation/systems in LPZ 1, additional shielding measures are required for the medium voltage line entering the building or structure.

To prevent equalising currents from occurring between the various equipotential bonding points in an electrical installation, it is recommended to carry out the lightning equipotential bonding of all metal lines and electrical power lines and data links entering the building or structure centrally at one point. If local circumstances do not permit this, the use of a ring equipotential bonding bar (**Figures 7.5.2.3** and **7.5.2.4**) is recommended.

The ability of the lightning current arrester used (SPD, Class 1) to discharge the current must correspond to the loads at the location where it is employed, based on the lightning protection system level used for the property. The lightning protection system level appropriate for the building or structure under consideration must be chosen on the basis of a risk assessment. If no risk assessment is available, or if it is not possible to make detailed statements about the splitting of the lightning current at the LPZ boundary LPZ 0_A to LPZ 1, it is recommended to use the class of lightning protection system with the highest requirements (lightning protection level I) as a basis. The resulting lightning current load of the individual discharge paths is shown in **Table 7.5.2.1**.

When installing lightning current arresters on the LPZ boundary LPZ 0_A to LPZ 1, it must still be borne in mind that, if the recommended installation site is directly at the service entrance box, this can frequently only be done with the agreement of the power supplier (new: distribution network operator). The requirements on lightning current arresters in main distribution systems are laid down in the directive of the Association of the

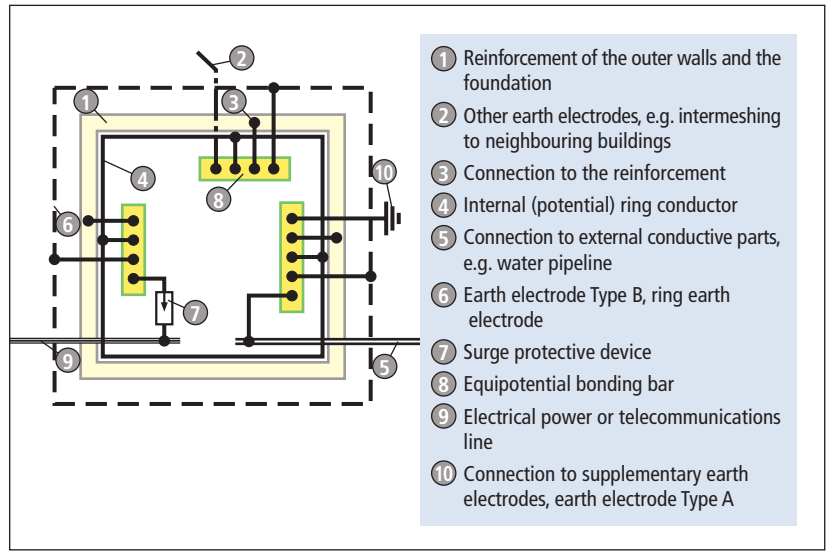


Fig. 7.5.2.3 Example for equipotential bonding in a structure or building with several entries or the external conductive parts and with an internal ring conductor as a connection between the equipotential bonding bars

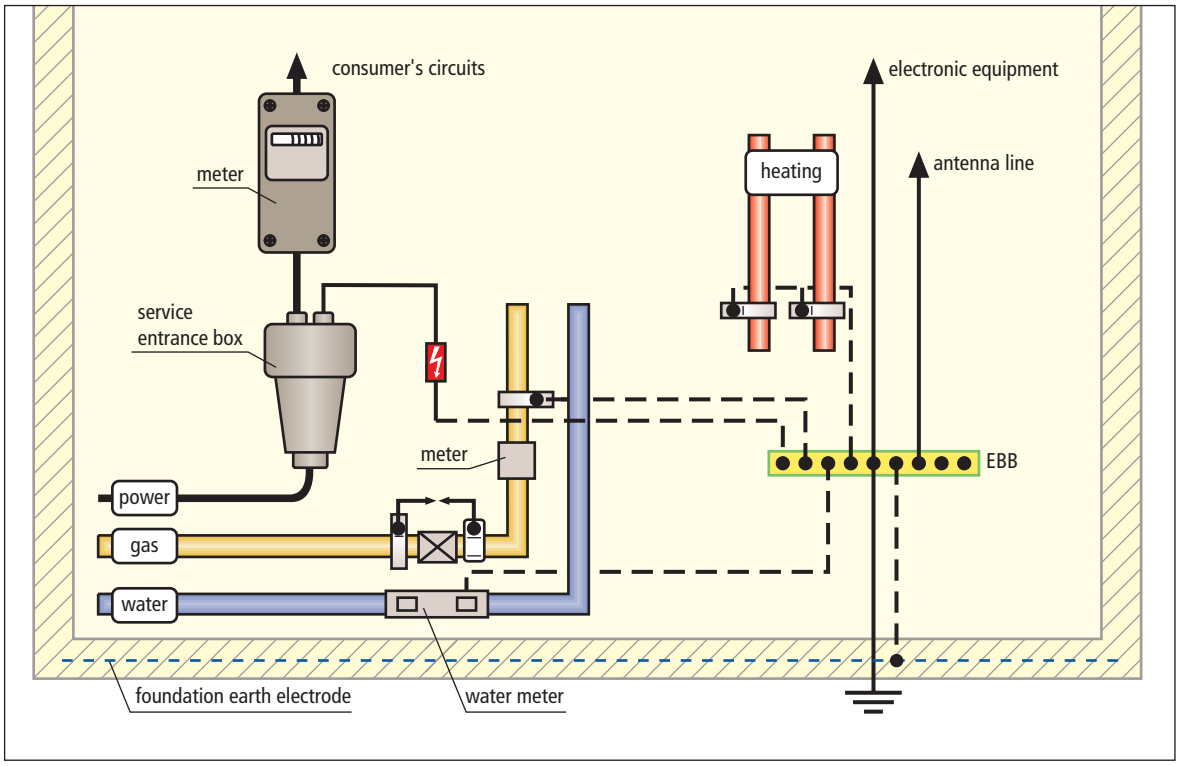


Fig. 7.5.2.4 Internal lightning protection with a common entry of all supply lines

German network operators (VDN) 2004-08: "Surge protective devices Type 1. Directive for the use of surge protective equipment Type 1 (up to now Class B) in main distribution systems" and IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001). When choosing lightning current arresters for the LPZ boundary LPZ 0_A to LPZ 1 then, besides the rating of the discharge capability, the prospective short circuit current to be expected at the installation site must also be taken into account. According to IEC 62305-3 (EN 62305-3) Annex E, Subclause 6.2.1.2, lightning current arresters based on spark gaps should have a high self-quenching capacity and a good ability to limit follow currents, in order to ensure that follow currents at the mains frequency are switched off automatically, and to prevent overcurrent protective devices, e.g. fuses, from false tripping (**Figures 7.5.2.5 – 7.5.2.7**).
The special issues relating to the choice, installation and assembly of lightning current arresters (SPD Type 1) are described in more detail in Chapter 8.1.

Lightning protection level LPL (former: Type of LPS)	Lightning impulse current carrying capability		
	in TN systems	in TT systems (L – N)	in TT systems (N – PE)
I	≥ 100 kA / m	≥ 100 kA / m	≥ 100 kA
II	≥ 75 kA / m	≥ 75 kA / m	≥ 75 kA
III / IV	≥ 50 kA / m	≥ 50 kA / m	≥ 50 kA
m: Quantity of conductors, e.g. for L1, L2, L3, N and PE; m = 5			

Table 7.5.2.1 Required lightning impulse current carrying capability of surge protective devices SPDs Type 1 according to the lightning protection level LPL and the type of low voltage consumer's installation

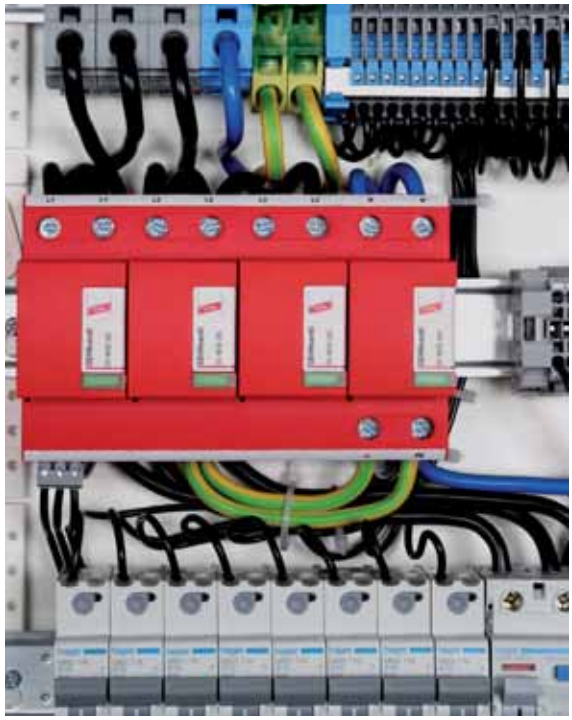


Fig. 7.5.2.5 DEHNventil combined lightning current and surge arrester

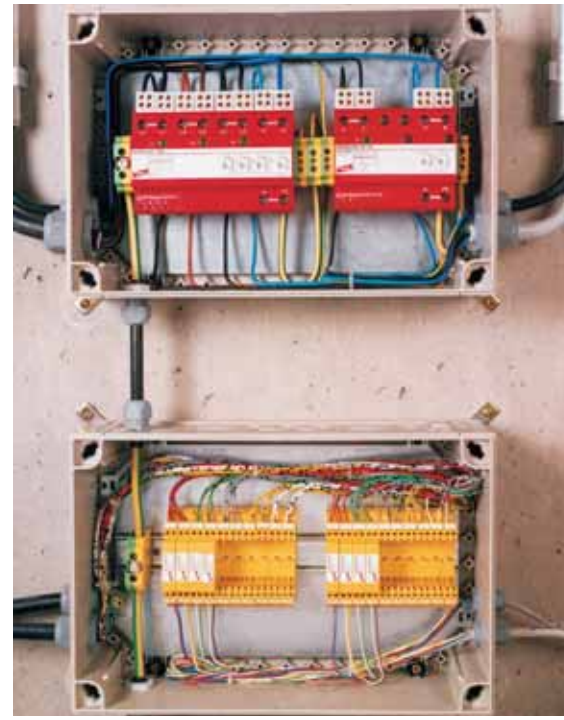


Fig. 7.5.2.6 Lightning equipotential bonding for power supply and information technology systems situated centrally at one point



Fig. 7.5.2.7 Lightning current arrester at LPZ boundary LPZ 0_A – LPZ 1

7.5.3 Equipotential bonding for information technology installations

LPZ 0 – LPZ 1

The lightning equipotential bonding from LPZ 0 to LPZ 1 must be carried out for all metal systems entering a building. IT lines must be connected as close as possible to the point where they enter the building or structure with lightning current arresters providing a suitable discharge capacity. For IT lines a general discharge capability of 2.5 kA (10/350 µs) each wire is required for the boundary from LPZ 0_A to LPZ 1. The generalised approach is not used, however, when designing the discharge capability for installations with a large number of IT lines. After calculating the partial lightning current to be expected for an IT cable (see IEC 62305-3 (EN 62305-3)), the lightning current must then be

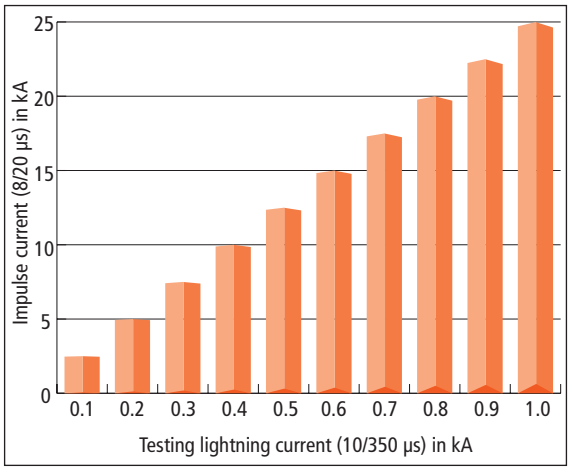


Fig. 7.5.3.1 Comparison of the amplitudes of test currents wave form 10/350 µs and 8/20 µs, each at equal loads

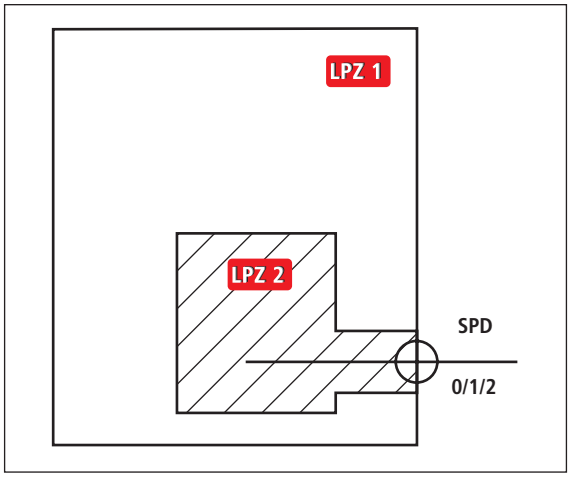


Fig. 7.6.2.1 Only one SPD (0/1/2) required (LPZ 2 integrated in LPZ 1)

divided by the number of individual cores in the cable actually used, in order to arrive at the impulse current per core. The partial lightning current load is lower for multi-core cables than it is for cables with fewer individual cores. For further information please see Chapter 6.3.

The following surge protective devices can therefore be used:

1. Arresters designed for a discharge current of (10/350 µs)
2. Arresters designed for a discharge current of (8/20 µs) if

⇒ they have no inductance as a decoupling element

⇒ the specified nominal discharge current is (8/20 µs) > 25 x the required discharge current (10/350 µs) per core (**Figure 7.5.3.1**).

If the equipotential bonding is carried out for lines on the LPZ boundary 0_B to LPZ 1, it is sufficient to use surge protective devices with a discharge capacity of 20 kA (8/20 µs) since no electrically coupled partial lightning currents flow.

7.6 Equipotential bonding on the boundary of LPZ 0_A and LPZ 2

7.6.1 Equipotential bonding for metal installations

See Chapter 7.5.1.

7.6.2 Equipotential bonding for power supply installations

LPZ 0_A – LPZ 2

Depending on the design of the building or structure, it is often unavoidable to realise a LPZ boundary from LPZ 0_A to LPZ 2, especially with compact installations (**Figure 7.6.2.1**).

Putting such an LPZ transition into practice makes high demands on the surge protective devices employed, and the surroundings of the installation. Besides the parameters previously described in Section 7.5.2, a protection level must be achieved which ensures the safe operation of equipment and systems of LPZ 2. A low voltage protection level and high limiting of the interference energy still transmitted by the arrester, form the basis here for a safe energy coordination to surge protective devices in LPZ 2, or to surge suppressing components in the input circuits of the equipment to be protected. The combined lightning current and surge arresters of the DEHNventil M family are designed for such applications and enable the user to combine lightning equipotential bonding and coordinated terminal device protection in a single device (**Figure 7.6.2.2**).

Since, for the LPZ boundary from LPZ 0 to LPZ 2, it is inevitable for both lightning protection zones to



Fig. 7.6.2.2 DEHNventil M TT 255

border directly on each other, a high degree of shielding at the zone boundaries is absolutely imperative. As a matter of principle, it is recommended to design the area of the lightning protection zones LPZ 0 and LPZ 2, which border directly on each other, to be as small as possible. Provided that the building or structure will permit it, LPZ 2 should be equipped with an additional zone shield which is constructed at the zone boundary LPZ 0, separately from the zone shield flown through by a lightning current, so that, as can be seen in **Figure 7.6.2.1**, LPZ 1 is assembled for a further area of the installation. The attenuation of the electromagnetic field in LPZ 2 this measure brings about, obviates the need for systematic shielding of all lines and systems within LPZ 2, which would otherwise be necessary.

7.6.3 Equipotential bonding for information technology installations

LPZ 0_A – LPZ 2

Generally, a lightning current arrester from LPZ 0 to LPZ 1 acts like a kind of of wave breaker. It conducts a large part of the interference energy away, thus protecting the installation in the building from damage. However, it is frequently the case that the level of residual interference is still too high to protect the terminal devices. In a further step, additional surge protective devices are then installed at the LPZ boundary from LPZ 1 to LPZ 2 to make available a low level of residual interfer-

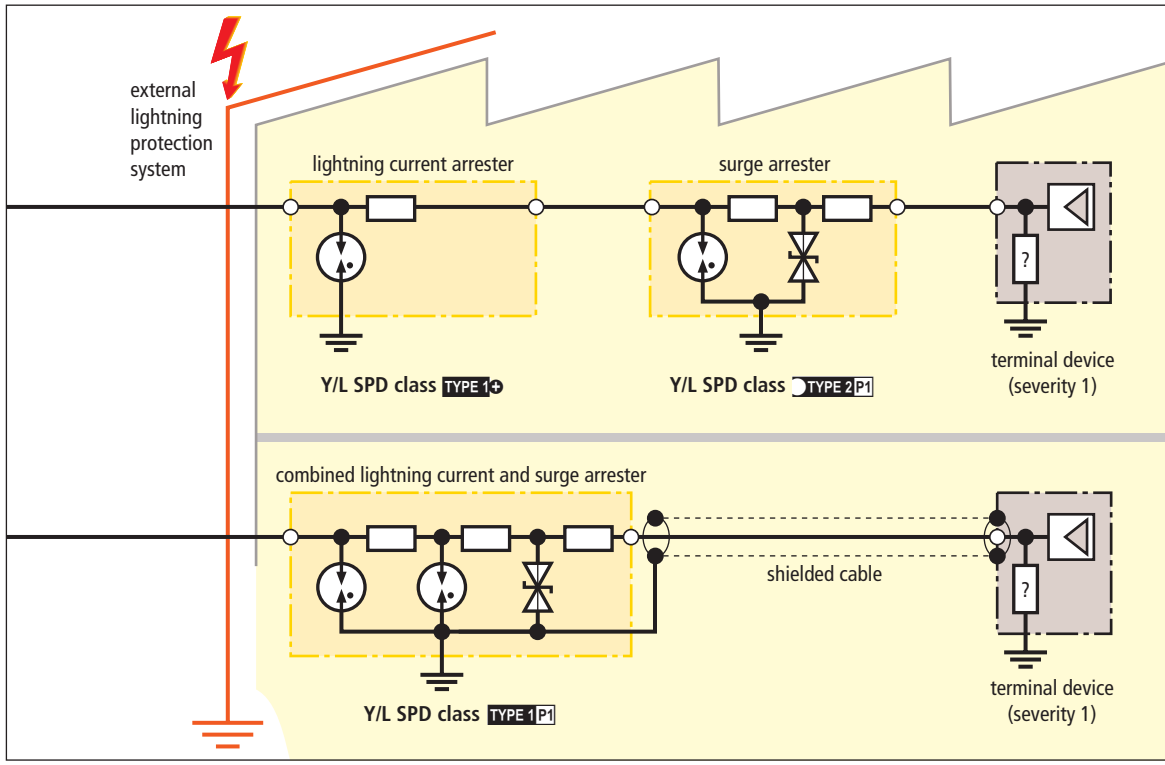


Fig. 7.6.3.1 Combination aid for Yellow/Line SPD classes (see also Figure 7.8.2.2)

ence adjusted to the immunity of the terminal device.

When the equipotential bonding from LPZ 0 to LPZ 2 is carried out, the first thing is to choose the installation site, and determine the partial lightning current of the individual lines and shields, precisely as described in Chapter 6.3.

However, the requirements on an SPD to be installed changes at the LPZ boundary, as do the requirements on the wiring after this boundary. The protective device must be designed as a combined lightning current and surge arrester and its energy must be coordinated with that of the terminal device (**Figure 7.6.3.1**). Combined lightning current and surge arresters have, on the one hand, an extremely high discharge capacity and, on the other, a low level of residual interference to protect the terminal devices. Furthermore, care must be taken that the outgoing line from the protective device to the terminal device is shielded, and that both ends of the cable shield are integrated into the equipotential bonding.

Combined lightning current and surge arresters are recommended

⇒ if the terminal devices are near to the location where the cables enter the building

⇒ if low impedance equipotential bonding from protective device to terminal device can be created

⇒ if the line from the protective device to the terminal device is continuously shielded and earthed at both ends

⇒ if a particularly cost-effective solution is sought.

The use of lightning current arresters and surge arresters is recommended

⇒ if there are long cable distances from the protective device to the terminal device

⇒ if the SPDs for power systems and IT surge protective devices are earthed via different equipotential bonding bars

⇒ if unshielded lines are used

⇒ if large interferences can occur inside LPZ 1.

7.7 Equipotential bonding on the boundary of LPZ 1 and LPZ 2 and higher

7.7.1 Equipotential bonding for metal installations

This equipotential bonding must be done as close as possible to the location where the lines and metal installations enter the zone.

All systems and conductive components must also be connected as described in Chapter 7.5.1.

The equipotential bonding conductors should be designed to be as short (low impedance) as possible.

Ring equipotential bonding in these zones facilitates a low impedance tie-in of the systems into the equipotential bonding.
Figure 7.7.1.1 illustrates the preparation for tying-in a cable trough to the ring equipotential bonding at the zone transition.

The following metal installations have to be integrated into the equipotential bonding:

⇒ metal cable ducts

⇒ shielded cables and lines

⇒ building reinforcement

⇒ metal water supply pipes

⇒ metal conduits for lines

⇒ other metal pipe systems or conductive components (e.g. compressed air)



Fig. 7.7.1.1 Ring equipotential bonding and fixed earthing point for connection of metal installations

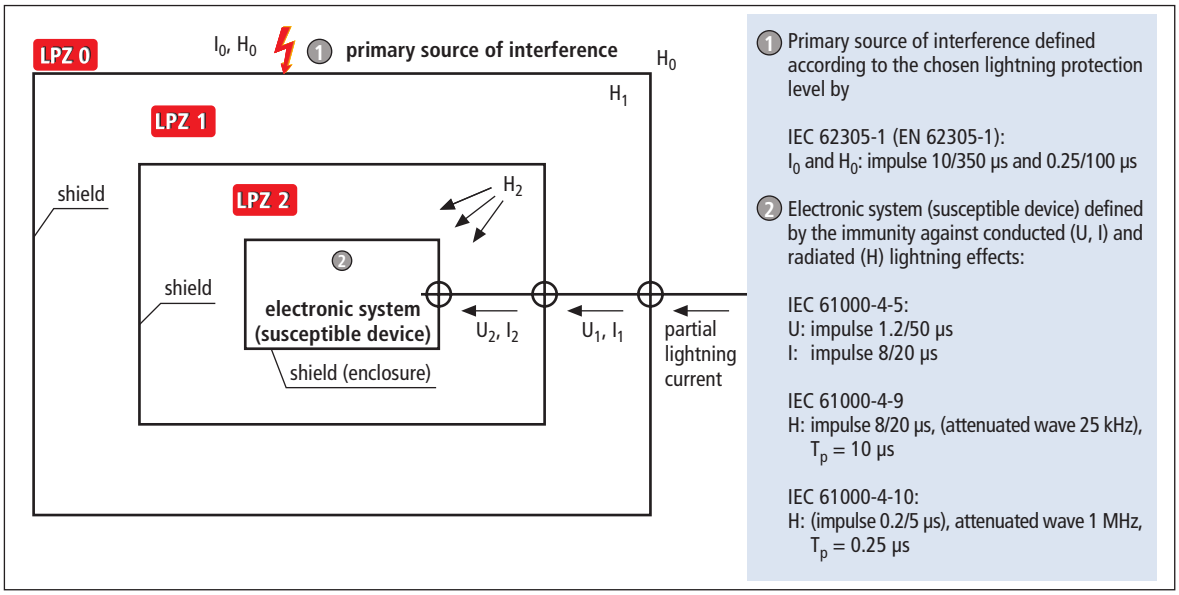


Fig. 7.7.2.1 Electromagnetic compatibility in case of a lightning strike

The cross sections described in Chapter 7.5.1 must again be used for equipotential bonding conductors combining the equipotential bonding bar and the earth-termination systems as well as other equipotential bonding bars.

For the tie-ins of the metal installations to the equipotential bonding, reduced cross sections can be used for these zone boundaries:

Material	Cross section
Cu	5 mm²
Al	8 mm²
Fe	16 mm²

7.7.2 Equipotential bonding for power supply installations

LPZ 1 – LPZ 2 and higher

For LPZ boundaries LPZ 1 to LPZ 2 and higher, as well, surge limitation and field attenuation is achieved by systematical integration of the electrical power lines and data links, also, into the equipotential bonding at each LPZ boundary, as is done with all metal systems (**Figure 7.7.2.1**). Shielding the rooms and devices leads to the attenuation of the electromagnetic effect.

The function of the surge protective devices employed at the LPZ boundaries LPZ 1 to LPZ 2, or at the higher LPZ boundaries, is to minimise the residual values of upstream surge protective devices yet further. They must reduce induced surges affecting the lines laid in the LPZ, and surges generated in the LPZ itself. Depending on the location where the protective measures are taken, they can be either assigned to a device (device protection) (**Figure 7.7.2.2**) or represent the infrastructural basis for the functioning of a device or system in the installation (**Figure 7.7.2.3**).

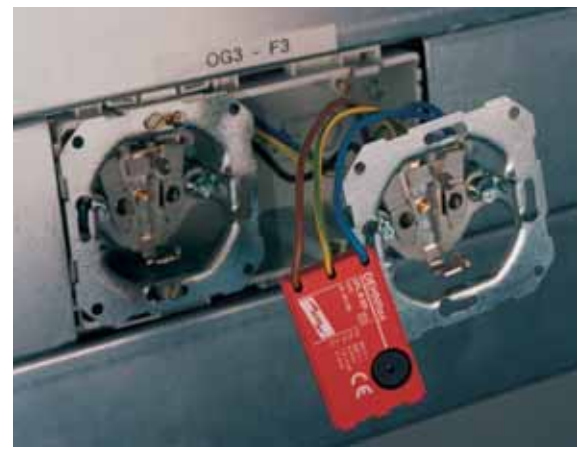


Fig. 7.7.2.2 Surge protective device for terminal circuits DEHNflex M



Fig. 7.7.2.3 Multi-pole surge arrester DEHNguard M TT



Fig. 7.7.3.1 Protection of industrial electronic equipment (e.g. an SPC) by BLITZDUCTOR CT and SPS Protector

The embodiments of the surge protection at the LPZ boundaries LPZ 1 to LPZ 2 and higher can thus be designed in very different ways.

7.7.3 Equipotential bonding for information technology installations

LPZ 1 – LPZ 2 and higher

At the LPZ boundaries inside buildings, further measures must be taken to reduce the level of interference (**Figure 7.7.3.1**). Since, as a rule, terminal devices are installed in LPZ 2 or higher, the protective measures must ensure that the level of residual interference, lies below values the terminal devices can cope with.

⇒ Use of surge protective devices in the vicinity of terminal devices

⇒ Integration of the cable shields into the equipotential bonding

⇒ Low impedance equipotential bonding of the SPD for IT installations to terminal device and SPD for power installations

⇒ Paying attention to the energy coordination of SPD and terminal device

⇒ Telecommunications lines and gas discharge lamps must be installed at least 130 mm apart

⇒ The distribution boards of electrical installations and data should be located in different cabinets

⇒ Low voltage lines and telecommunications lines must cross at an angle of 90 °

⇒ Cable intersection must be carried out using the shortest route

7.8 Coordination of the protective measures at various LPZ boundaries

7.8.1 Power supply installations

Whereas surge protection in the terminal device, or immediately upstream of it, expressly fulfils the function of protecting the device, the function of surge protective devices in the surrounding installation is twofold. On the one hand, they protect the installation, and, on the other, they form the protective link between the threat parameters of the complete system and the immunity of the device of the equipment and systems requiring protection. The threat parameters of the system, and the immunity of the device to be protected, are thus dimensioning factors for the protective cascade to be installed. To ensure that this protective cascade, beginning with the lightning current arrester and ending with the terminal device protection, is able to function, one must ensure that individual protective devices are selectively effective, i.e. each protection stage only takes on the amount of interference energy which it is designed for. The synchronisation between the protective stages is generally termed coordination and is explained more detailed in IEC 62305-4 (EN 62305-4) Chapter 7. In order to achieve the described selectivity as the protective device operates, the parameters of the individual arrester stages must be coordinated in such a way that, if one protection stage is faced with the threat of an energy overload, the upstream more powerful arrester "responds" and thus takes over the discharge of the interference energy. When designing the coordination, one must be aware that the

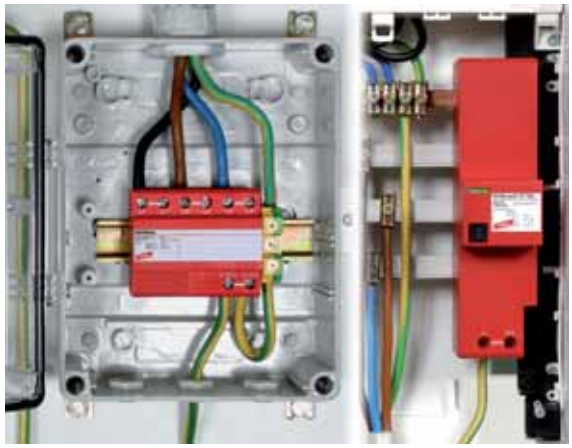


Fig. 7.8.1.1 DEHNbloc 3-pole – Lightning current arrester and DEHNventil ZP – Combined arrester



Fig. 7.8.1.2 DEHNguard TT H LI – Multi-pole surge arrester with service life indication

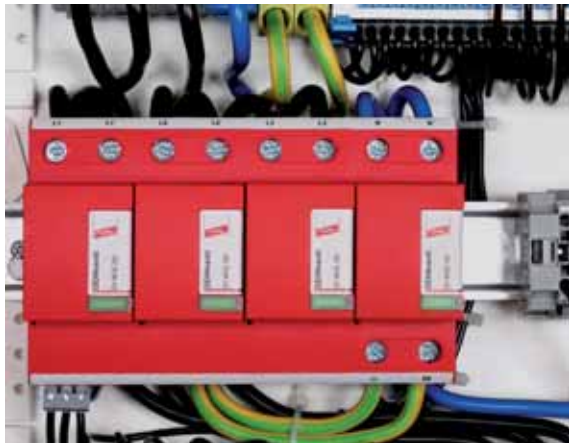


Fig. 7.8.1.3 DEHNventil M TNS – Modular combined arrester

pulse waveform with the greatest pulse length must be assumed to be a threat for the complete arrester chain. Even though surge protective devices, by definition, are only tested with pulse waveforms of 8/20 µs, for the coordination between surge arrester and lightning current arrester, and also for the surge protective device, it is imperative to determine the ability of the device to carry an impulse current of the partial lightning currents with the waveform 10/350 µs. The Red/Line family of energy-coordinated products, was created to avert the dangers arising from defective coordination and the resulting overloading of low-energy protective stages . These surge protective devices, which are coordinated both with each other and also with the device to be protected, provide the user with high safety. By designing them as lightning current arresters, surge arresters and combined lightning current and surge arresters, they are ideally matched to the requirements of the corresponding LPZ boundaries (**Figures 7.8.1.1 – 7.8.1.3**).

7.8.2 IT installations

When implementing measures to protect against disturbance variables from nearby, distant and direct lightning strikes within buildings, it is recommended to apply a concept of protective devices with several protective stages. This reduces the high energy interference (partial lightning current) in stages because an initial energy absorbing stage prevents the main part of the interference from reaching the downstream system. The subsequent stages serve to reduce the interference to values which the system can cope with. Depending on the conditions of the installation, several protective stages can also be integrated into one surge protective device using a combined protective circuit.

The relevant interfaces where the protective devices are employed as part of a cascade are, for example, the zone boundaries (LPZ) of a lightning protection zone concept which conforms to IEC 62305-4 (EN 62305-4).

A cascading of the surge protective devices must be carried out with due regard to the coordination criteria.

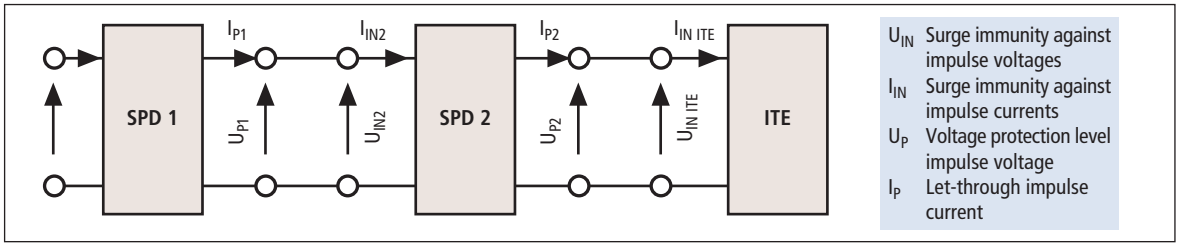


Fig. 7.8.2.1 Coordination according to let-through method of 2 SPDs and one terminal device (according to IEC 61643-21)

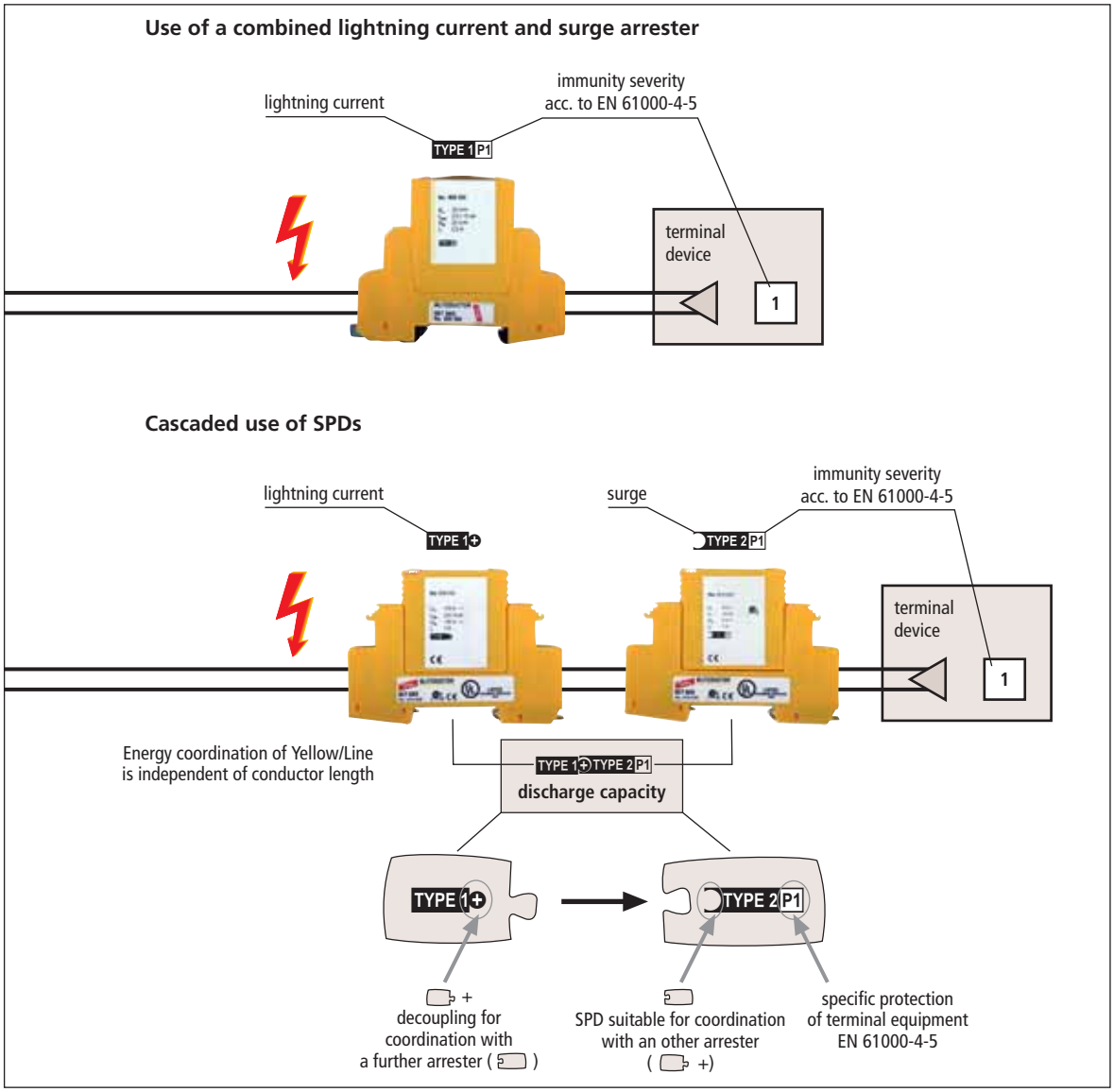


Fig. 7.8.2.2 Examples for the energy coordinated use of arresters according to the Yellow/Line TYPE of arresters and structure of the Yellow/Line-TYPE of arresters symbol

Characteristic	Symbol	Legend
Discharge capacity of an SPD (acc. to categories of IEC 61643-21)	TYPE 1	Impulse D1 (10/350 µs), lightning impulse current ≥ 2.5 kA / line or ≥ 5 kA / total • exceeds the discharge capacity of TYPE 2 – TYPE 4
	TYPE 2	Impulse C2 (8/20 µs), increased impulse load ≥ 2.5 kA / line or ≥ 5 kA / total • exceeds the discharge capacity of TYPE 3 – TYPE 4
	TYPE 3	Impulse C1 (8/20 µs), impulse load ≥ 0.25 kA / line or ≥ 0.5 kA / total • exceeds the discharge capacity of TYPE 4
	TYPE 4	Load < TYPE 3
Protective effect of an SPD (limitation below the test levels acc. to EN 61000-4-5)	P1	Test level required for the terminal device: 1 or higher
	P2	Test level required for the terminal device: 2 or higher
	P3	Test level required for the terminal device: 3 or higher
	P4	Test level required for the terminal device: 4
Energy coordination (with another Yellow/Line arrester)	⊕	SPD has a decoupling impedance and is suitable for coordination with an arrester labeled ❒
	❒	SPD suitable for coordination with an arrester having a decoupling impedance ⊕

Table 7.8.2.1 Symbol of the SPD class

Cabling	SPD	Exemplified assignment of SPD classes to LPZ boundaries		
		to LPZ 1	to LPZ 2	to LPZ 3
From LPZ 0_A	Combined SPD	TYPE 1 P1		
	Cascading	TYPE 1 ⊕	❒ TYPE 2 P1	
		TYPE 1 ❒	⊕ TYPE 3 P1	
From LPZ 0_B	Same solution as from LPZ 0_A	s. a.		
	Surge arrester	TYPE 2 P1 or ❒ TYPE 2 P1		
	Cascading	TYPE 2 ❒	⊕ TYPE 3	
From LPZ 1	Combined arrester	–	TYPE 1 P1	
	Surge arrester	–	TYPE 2 P1 or ❒ TYPE 2 P1	
From LPZ 2	Same solution as from LPZ 1	–	s. a.	
	Surge arrester	–	–	TYPE 2 P1
		–	–	TYPE 3 P1
		–	–	TYPE 4 P1

Table 7.8.2.2 Assignment of the Yellow/Line class of the SPDs at the LPZ boundaries

To determine the coordination conditions acc. to IEC 61643-22, various methods are available (IEC 60364-5-53/A2 (IEC 64/1168/CDV: 2001)), some of which require certain knowledge about the structure of the protective devices. A "black box" method is the so-called "Let-Through-Energy Method", which is based on standard pulse parameters and hence can be understood from both a mathematical and a practical point of view.

All parts of the cascade are considered to be coordinated if the residual values I_p for a short-circuited output, and U_p for an open-circuit output, are smaller than the input values I_{in}/U_{in}.

These methods are, however, difficult for the user to carry out because they are very time-consuming. In order to save time and work, the standard permits the use of information supplied by the manufacturers for the coordination (**Figure 7.8.2.1**).

Lightning current arresters at LPZ 0/1 or higher are, as a rule, specified with a discharge capacity of waveform 10/350 µs. Surge arresters, by contrast, are only specified with a waveform of 8/20 µs. This originates from the fact that surge arresters were developed primarily for interferences of inductive and capacitive inputs. If, however, a line passing out of the building is connected to a cascade comprising lightning current arrester and surge arrester, it follows from the coordination conditions that

⇒ the most sensitive element responds first – the surge arrester

⇒ the surge arrester must also be able to carry part of the partial lightning current with the waveform 10/350 µs, albeit a small one

⇒ before the surge arrester is overloaded, the lightning current arrester must trip and take over the discharge process.

The surge protective devices of the Yellow/Line family are coordinated sequentially and safely with each other and with the terminal devices. Therefore they provide markings indicating the symbol of their SPD class (**Figure 7.8.2.2, Tables 7.8.2.1** and **7.8.2.2**).

7.9 Inspection and maintenance of the LEMP protection

The fundamentals and pre-conditions governing the inspection and maintenance of the LEMP protection are the same as those governing the inspection and maintenance of lightning protection systems, as previously described in Chapter 3.4.
The inspections carried out during the construction phase are particularly important for the inspection of the LEMP protection, since many components of the LEMP protection are no longer accessible when the building work has been completed. The necessary measures (e.g. connecting the reinforcement) must be documented photographically and included with the inspection report.

Inspections shall be carried out:

⇒ during the installation of the LEMP protection,

⇒ after the installation of the LEMP protection,

⇒ periodically,

⇒ after each modification to components which are relevant for the LEMP protection,

⇒ after a lightning strike to the building or structure, if necessary.

After completion of the inspection, all defects found must be corrected forthwith. The technical documentation must be updated as and where necessary.
A comprehensive inspection of the LEMP protection should be carried out at least every four years as part of the inspection of the electrical installation in accordance with workplace regulations.