Lightning and surge protection for hazardous areas

White Paper

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When producing, processing, storing and transporting flammable substances (e.g. fuel, alcohol, liquid gas, explosive dusts) in chemical and petrochemical industrial plants, potentially explosive atmospheres often come into being in which it is imperative to avoid all sources of ignition which may cause an explosion. The relevant safety regulations describe the risk for such plants posed by atmospheric discharges (lightning strikes). In this context, it is important to note that there is a risk of fire and explosion resulting from direct or indirect lightning discharge since in some cases these plants are widely distributed.
To ensure the required plant availability and safety, a conceptual procedure is required to protect parts of electrical and electronic installations of process plants from lightning currents and surges.

Protection concept

Intrinsically safe measuring circuits are frequently used in potentially explosive atmospheres. **Figure 1** shows the general design and lightning protection zones of such a system. Since maximum system availability is required and numerous safety requirements must be observed in hazardous areas, the following areas have been divided into lightning protection zone 1 (LPZ 1) and lightning protection zone 2 (LPZ 2):

- Controller unit in the control room (LPZ 2)
- Temperature transmitter on the tank (LPZ 1)
- Interior of the tank (LPZ 1)

According to the lightning protection zone concept as per IEC 62305-4 (EN 62305-4), adequate surge protective devices, which will be described below, must be provided for all lines at the boundaries of the lightning protection zones.

External lightning protection system

The external lightning protection system includes all those systems installed outside or inside the structure to be protected which intercept and discharge the lightning current to the earth-termination system.
A lightning protection system for potentially explosive atmospheres is typically designed according to class of LPS II. Another class of LPS can be chosen in justified individual cases, in case of special conditions (legal requirements) or as a result of a risk analysis. The requirements described below are based on class of LPS II.

Air-termination systems

In potentially explosive atmospheres, air-termination systems must be installed at least according to class of LPS II (**Table 1**). To determine the relevant points of strike, the recommendation is to use the rolling sphere method with a minimum radius according to class of LPS II. However, in case of a lightning strike to the air-termination system, sparking may occur at the point of strike. To prevent ignition sparks, the air-termination systems should be installed outside Ex zones (**Figure 2**). Natural components such as metallic roof structures, metal pipes

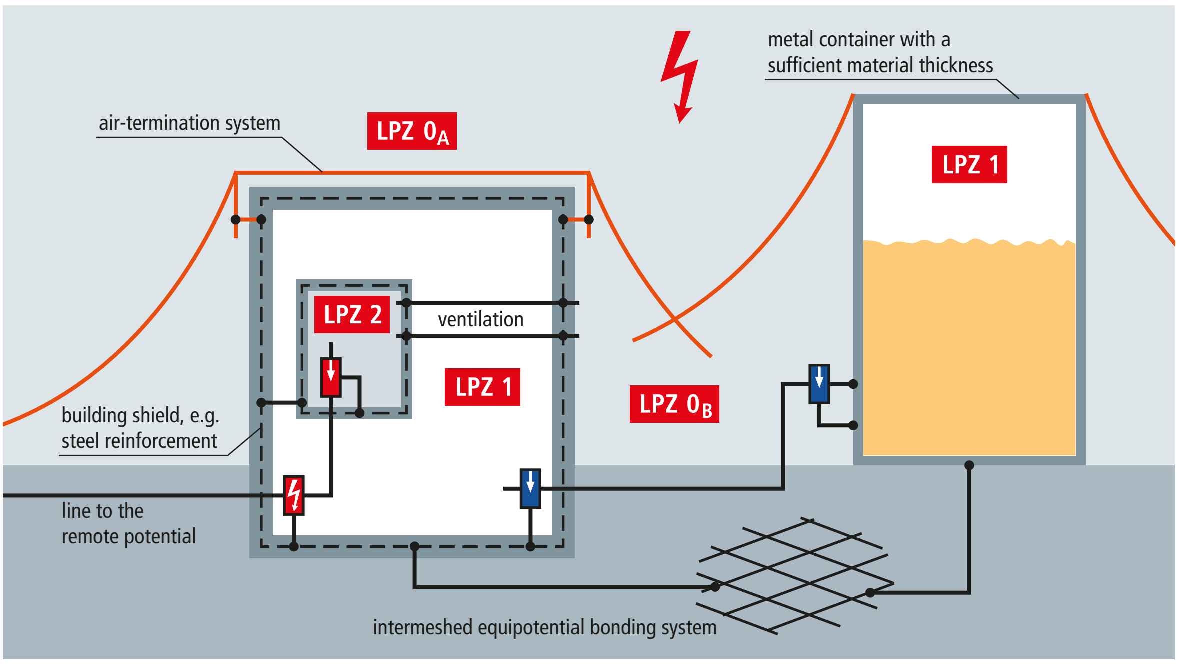


Figure 1 Basic division of an installation into lightning protection zones (LPZs)

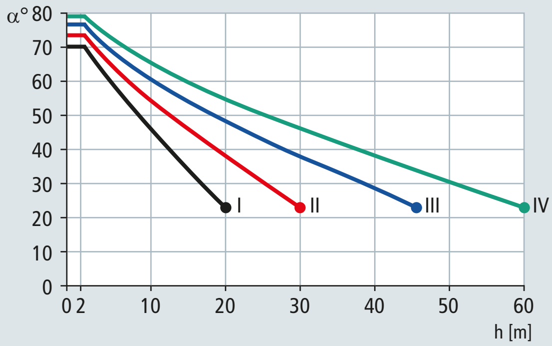
Class of LPS	Protection method			Typical down conductor spacing [m]
	Rolling sphere radius r [m]	Protective angle α	Mesh size w [m]	
I	20		5 x 5	10
II	30		10 x 10	10
III	45		15 x 15	15
IV	60		20 x 20	20

Table 1 Arrangement of air-termination systems according to the class of LPS

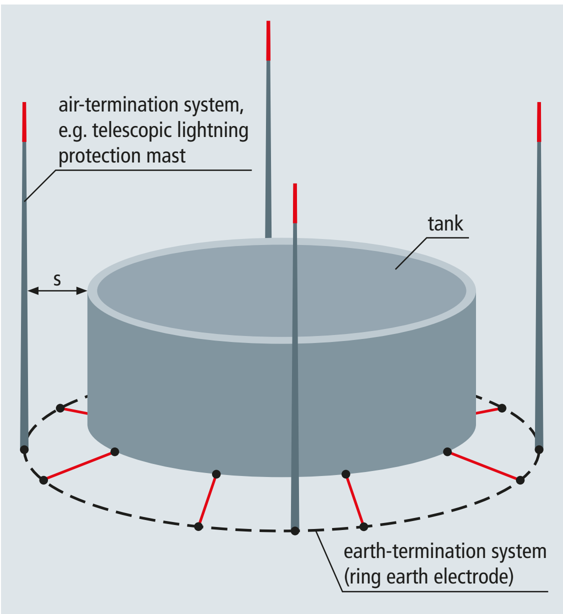


Figure 2 Air-termination system for a tank with air-termination rods and air-termination cables

and containers can also be used as air-termination systems if they have a minimum material thickness of 5 mm according to Annex D 5.5.2 of the IEC 62305-3 (EN 62305-3) standard and the temperature rise and reduction of material at the point of strike do not present additional risks (e.g. reduction of the wall thickness of pressure containers, high surface temperature at the point of strike) (**Figure 1**).

Down conductors

Down conductors are electrically conductive connections between the air-termination system and the earth-termination system. To prevent damage when conducting the lightning current to the earth-termination system, the down conductors must be arranged in such a way that from the point of strike to earth:

- there are several parallel current paths (systems in hazardous areas: one down conductor for every 10 m of the perimeter of the outer roof edges, however, at least two),
- the length of the current paths is as short as possible,
- connection to the equipotential bonding system is established wherever necessary.

An equipotential bonding system at ground level at intervals of 20 m has proven its worth.
The reinforcements of the concrete buildings may also be used as down conductors if they are permanently interconnected in such a way that they can carry lightning currents.

Separation distance

If there is insufficient separation distance s between the air-termination system or down conductor and metal and electrical installations inside the structure to be protected, dangerous proximities may occur between the parts of the external lightning protection system and metal as well as electrical installations inside the building.
Since in practice the lightning current splits between the individual down conductors depending on the impedances, the separation distance must be calculated separately for the relevant building / installation as per IEC 62305-3 (EN 62305-3).

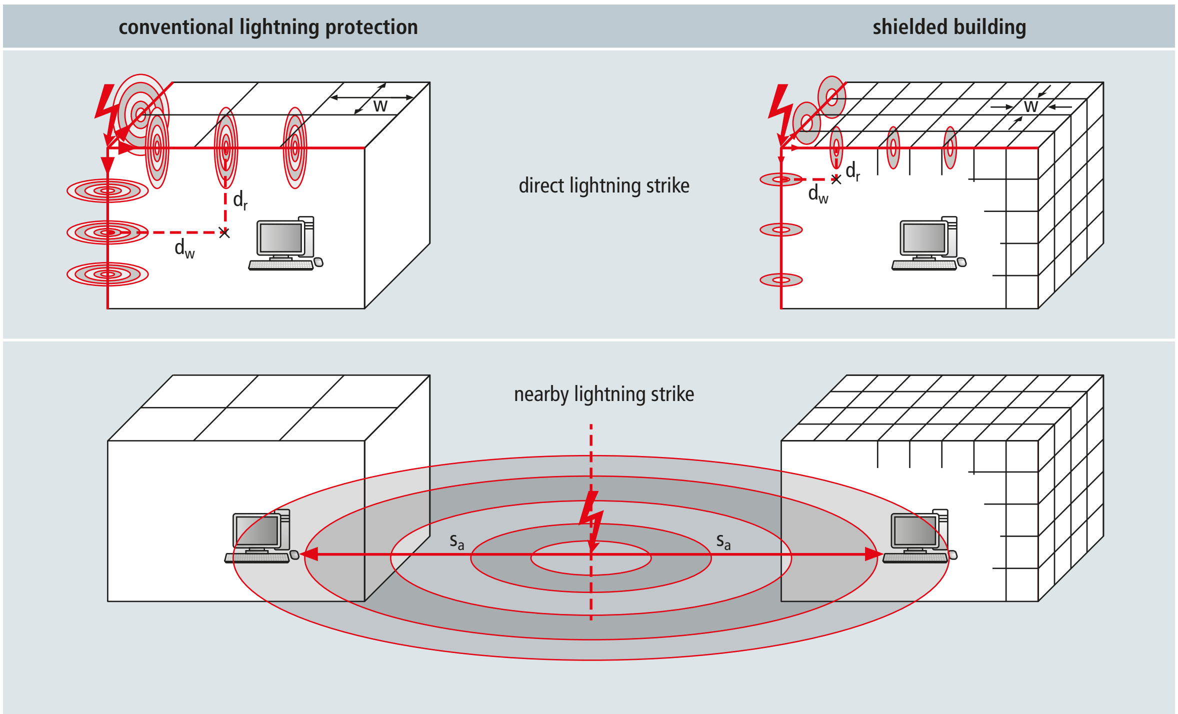


Figure 3 Shielding of structures by using natural components of the building

Shielding of buildings

Another measure of the lightning protection zone concept is to shield buildings. To this end, metal facades and reinforcements of walls, floors and ceilings on or in the building are, as far as practicable, combined to form shielding cages (**Figure 3**). Electrically interconnecting these natural metal components of the object to be protected to form closed shielding cages considerably reduces the magnetic field. Thus, the magnetic field can easily be decreased by a factor of 10 to 300 and an infrastructure for EMC protection established at low cost. When retrofitting existing installations, the room shielding must be adapted to the EMC requirements, for example, by means of reinforcement mats.

Surge protection in hazardous areas

The lightning protection and Ex zones are already harmonised at the design stage. This means that the requirements for the use of surge protective devices both in hazardous areas and at the boundaries of lightning protection zones must be fulfilled. Consequently, the place of installation of the surge arrester is exactly defined, i.e. the transition from LPZ 0_B to LPZ 1. This prevents dangerous surges from entering Ex zone 0 or 20 since the interference has already been discharged. The availability of the temperature transmitter, which is important for the process, is considerably increased. In addition, the requirements of IEC 60079-11 (EN 60079-11), IEC 60079-14 (EN 60079-14) and IEC 60079-25 (EN 60079-25) must be observed (**Figure 4**):

- Use of surge protective devices with a minimum discharge capacity of 10 impulses of 10 kA each without damaging the equipment or interfering with the surge protective effect.
- Installation of the surge protective device in a shielded metallic enclosure and earthing by means of a copper earthing conductor with a cross-section of at least 4 mm^2.
- Installation of the lines between the arrester and the equipment in a metal pipe earthed on both ends or use of shielded lines with a maximum length of 1 m.

According to the definition in the protection concept, the controller unit in the control room is defined as LPZ 2. A surge protective device is also provided at the transition from LPZ 0_B to LPZ 1 for the intrinsically safe measuring line from the temperature transmitter. This surge protective device at the other end of the field line which extends beyond the building must have the same discharge capacity as the surge

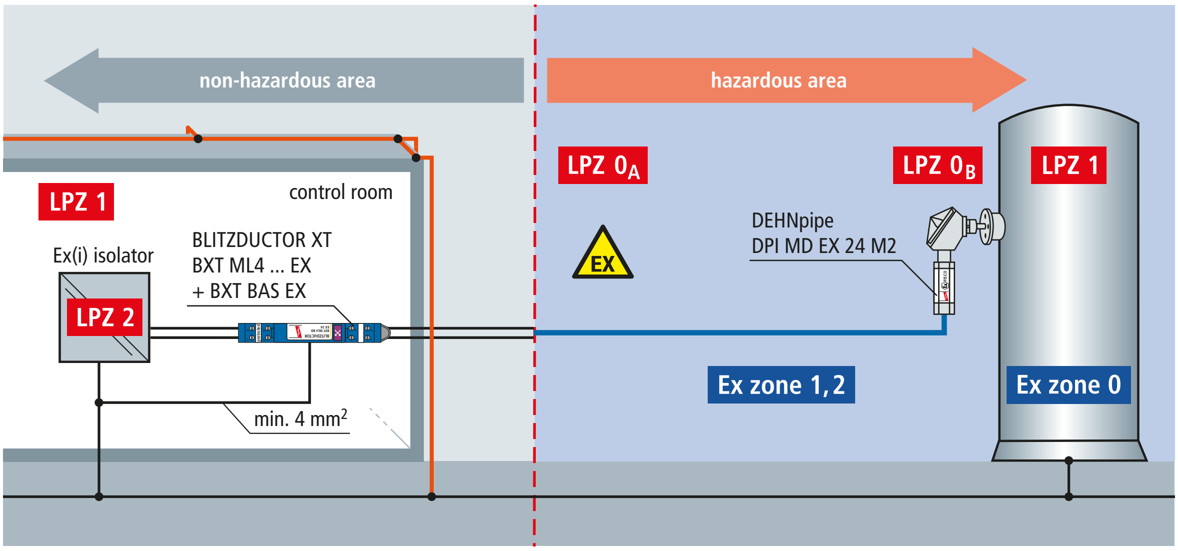


Figure 4 Surge protective devices in an intrinsically safe measuring circuit

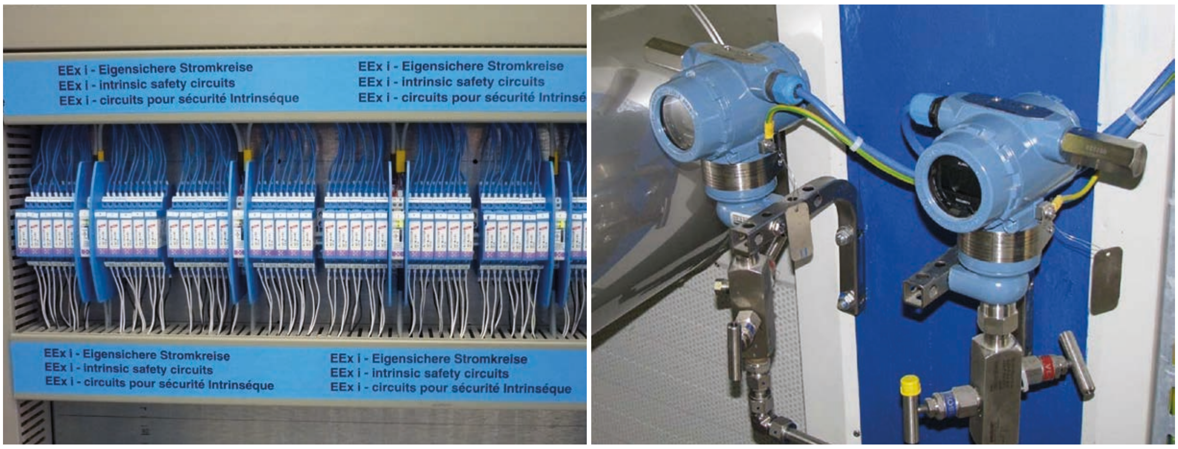


Figure 5 Surge protective devices for intrinsically safe measuring circuits

protective device installed on the tank. Downstream of the surge protective device, the intrinsically safe line is led via an isolating amplifier (**Figure 5**). From there, the shielded line to the controller unit is routed in LPZ 2. The cable shield is connected on both ends, therefore no surge protective device is required at the transition from LPZ 1 to LPZ 2 since the electromagnetic residual interference to be expected is significantly attenuated by the cable shield earthed on both ends (see also "Shield treatment in intrinsically safe measuring circuits").

Other selection criteria for surge protective devices in intrinsically safe measuring circuits

Insulation strength of equipment

To ensure that leakage currents do not influence the measured values, the sensor signals from the tank are usually galvanically isolated. The insulation strength of the transmitter between the intrinsically safe 4 … 20 mA current loop and the earthed temperature sensor is ≥ 500 V a.c. Thus, the equipment is unearthed. When using surge protective devices, this unearthed state must not be interfered with.

Technical data	Transmitter TH02	Surge protective device BXT ML4 BD Ex 24
Place of installation	zone 1	zone 1
Degree of protection	ib	ia
Voltage	U_i max. = 29.4 V DC	U_i = 30 V DC
Current	I_i max. = 130 mA	I_i = 500 mA
Frequency	f_{HART} = 2200 Hz, frequency modulated	f_G = 7.7 MHz
Immunity level	according to NE 21, e.g. 0.5 kV line / line	discharge capacity of 20 kA (8/20 µs), voltage protection level ≤ 52 V line / line
Tested to	ATEX, IECEx	ATEX; IEC 61643-21; IECEx; CSA, Hazloc; EACEx
Unearthed 500 V	yes	yes
Internal capacitance C_i	C_i =15 nF	negligibly small
Internal capacitance L_i	L_i = 220 µH	negligibly small

Table 2 Example of a temperature transmitter

If the transmitter has an insulation strength of < 500 V AC, the intrinsically safe measuring circuit is earthed. In this case, surge protective devices which in case of a nominal discharge current of 10 kA (8/20 µs wave form) have a voltage protection level below the insulation strength of the earthed transmitter must be used (e.g. U_p (line / PG) ≤ 35 V).

Type of protection – Category ia, ib or ic?

The transmitter and the surge protective device are installed in Ex zone 1 so that type of protection ib is sufficient for the 4 … 20 mA current loop. The surge protective devices used (ia) fulfil the most stringent requirements and are thus also suitable for ib and ic applications.

Permissible maximum values for L_0 and C_0

Before an intrinsically safe measuring circuit can be put into operation, it must be proven to be intrinsically safe. To this end, the power supply unit, the transmitter, the cables and the surge protective devices must fulfil the conditions of intrinsic safety. If required, energy buffers such as the inductances and capacitances of the surge protective devices should be taken into account. According to the ATEX / IECEx certificates, the internal capacitances and inductances of BXT ML4 BD EX 24 surge protective devices (**Figure 5**) are negligible and do not have to be taken into account for the conditions of intrinsic safety (**Table 2**).

Maximum values for voltage U_i and current I_i

According to its technical data, the intrinsically safe transmitter to be protected has a maximum supply voltage U_0 and a maximum short-circuit current I_0 when used in intrinsically safe applications (**Table 2**). The rated voltage U_c of the arrester or the maximum permissible input voltage U_i of the protective device must be at least as high as the maximum open-circuit voltage of the power supply unit. The nominal current of the arrester must also be at least as high as the short-circuit current I_0 of the transmitter to be expected in the event of a fault. If these marginal conditions are not observed when dimensioning the surge arresters, the surge protective device might be overloaded and fail or the intrinsic safety of the measuring circuit no longer be ensured due to an impermissible temperature rise on the surge protective device.

Coordination of surge protective devices with terminal equipment

NAMUR recommendation NE 21 defines general interference immunity requirements for process and laboratory equipment (e.g. transmitters). The signal inputs of such equipment must withstand voltages of 0.5 kV between the cable cores (transverse voltage) and 1.0 kV between the cable core and earth (longitudinal voltage). The measurement set-up and the wave form are described in the IEC 61000-4-5 (EN 61000-4-5) basic standard. Depending on the amplitude of the test impulse, a specific immunity level is assigned to terminal equipment. These immunity levels of terminal equipment are documented by test levels (1 – 4) whereby test level 1 is the lowest and test level 4 the highest immunity level. The test level can usually be found in the documentation of the device to be protected or requested from the manufacturer of the device. In case of a risk of lightning and surge effects, the conducted interference (voltage, current and energy) must be limited to a value within

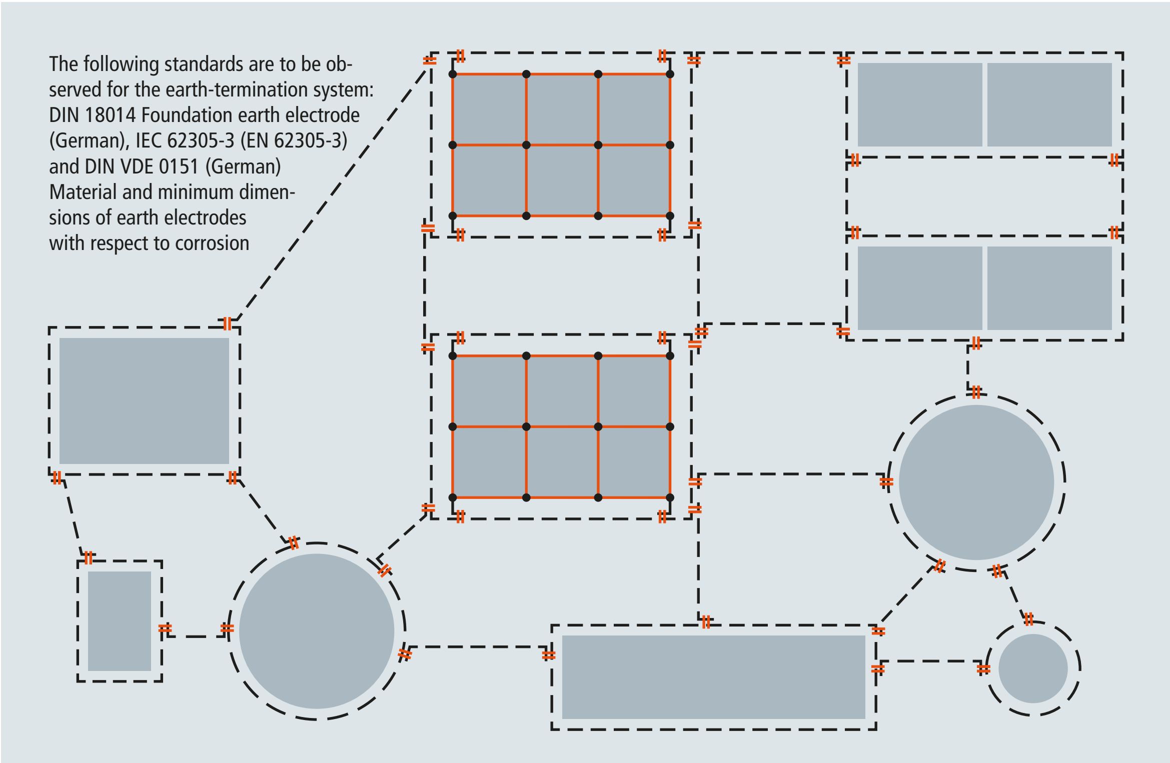


Figure 6 Example of an intermeshed earth-termination system

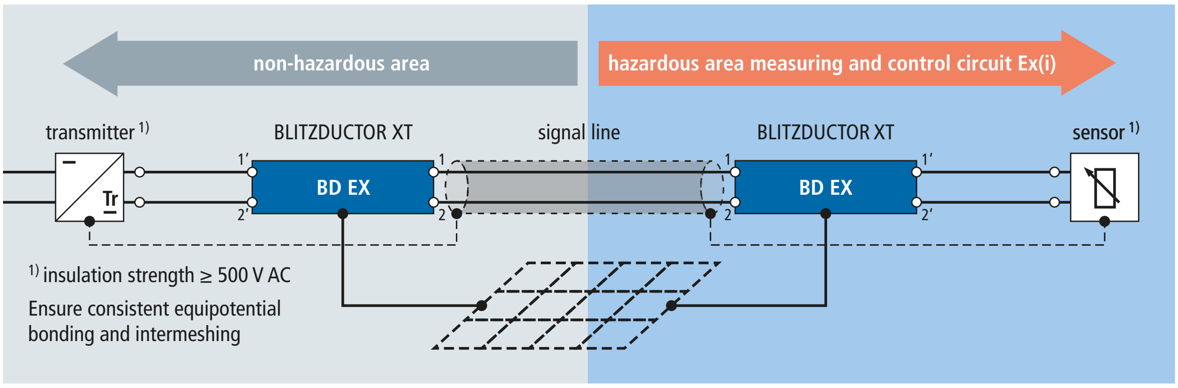


Figure 7 Example of the shield treatment of intrinsically safe cables

the immunity level of the terminal equipment. The test levels are documented on the surge protective devices (e.g. P1).

Intermeshed earth-termination system

In the past, separate earth-termination systems were often used, i.e., the lightning protection and protective earthing were separate from the functional earthing. This turned out to be extremely unfavourable and even dangerous. In case of a lightning strike, voltage differences up to some 100 kV can occur which may lead to the destruction of electronic components, personal injury and explosions in potentially explosive atmospheres due to sparking.
Therefore, it is advisable to install a separate earth-termination system for every single building or part of an installation and

to intermesh them. This intermeshing (**Figure 6**) reduces potential differences between the buildings / parts of the installation and thus conducted partial lightning currents. The closer the mesh of the earth-termination system, the lower the potential differences between the buildings / parts of the installation in case of a lightning strike. Mesh sizes of 20 x 20 m (mesh sizes of 10 x 10 m are recommended in potentially explosive atmospheres and when using electronic systems) have proven to be economically feasible. When selecting the earthing material, it must be ensured that the buried pipes do not corrode.

Equipotential bonding

Consistent equipotential bonding must be established in all potentially explosive atmospheres to prevent potential differences between different and extraneous conductive parts. Building columns and structural parts, pipes, containers, etc. must be integrated in the equipotential bonding system so that a voltage difference is not to be expected even under fault conditions. The connections of the equipotential bonding conductors must be secured so they cannot work loose. According to IEC 60079-14 (EN 60079-14), supplementary equipotential bonding is required. It must be properly established, installed and tested in line with the IEC 60364-4-41 (HD 60364-4-41) and IEC 60364-5-54 (HD 60364-5-54) standard. When using surge protective devices, the cross-section of the copper earthing conductor for equipotential bonding must be at least 4 mm^2.

Lightning equipotential bonding outside the hazardous area

The use of surge protective devices in low-voltage installations and measuring and control systems outside the hazardous area (e.g. control room) does not differ from other applications. In this context, it must be pointed out that surge protective devices for lines from LPZ 0_A to LPZ 1 must have a lightning current discharge capacity which is described by the 10/350 μs test wave form. Surge protective devices of different requirement classes must be coordinated with one another. This is ensured by creating a protective chain of DEHN surge arresters.

Shield treatment in intrinsically safe measuring circuits

The treatment of the cable shield is an important measure to prevent electromagnetic interference. In this context, the effects of electromagnetic fields must be reduced to an acceptable level to prevent ignition. This is only possible if the shield is earthed on both cable ends (**Figure 7**). Earthing the shield on both ends is only permitted in hazardous areas if absolutely no potential differences are to be expected between the earthing points (intermeshed earth-termination system, mesh size of 10 x 10 m) and an insulated earthing conductor with a cross-section of at least 4 mm^2 (better 16 mm^2) is installed in parallel to the intrinsically safe cable, is connected to the cable shield at any point and is insulated again. This parallel cable must be connected at the same equipotential bonding bar as the shield of the intrinsically safe cable.
Moreover, permanently and continuously connected reinforcing bars can be used as equipotential bonding conductor. These are connected to the equipotential bonding bar on both ends.

Summary

The risk posed to chemical and petrochemical plants due to a lightning discharge and the resulting electromagnetic interference is described in the relevant standards. When using the lightning protection zone concept for designing and installing such plants, the risks of sparking in case of a direct lightning strike or discharge of conducted interference energies must be safely minimised at an economically acceptable cost. The surge arresters used must fulfil explosion protection requirements, ensure coordination with terminal equipment and meet the requirements resulting from the operating parameters of the measuring and control circuits.

Surge Protection
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