Surge protection:
what should be considered?

Effective surge protection is not just simply installed. It has to be individually coordinated based on the system that is to be protected and the ambient conditions that are prevalent on site. For this reason, the design and concept must be consistent. This means that many details must be taken into account, for everything from standards and stipulations to creating a lightning protection zone concept.

1 How surge protection works

Surge protection should ensure that surge voltages do not cause damage to installations, equipment or end devices.

As such, surge protective devices (SPDs) chiefly fulfill two tasks:

- Limit the surge voltage in terms of amplitude so that the dielectric strength of the devices is not exceeded.
- Discharge the surge currents associated with surge voltages to a distant ground.

The way in which the surge protection works can be easily explained by means of the equipment's power supply diagram (Fig. 7).

As described in Section 1.4, a surge voltage can arise either between the active conductors as normal-mode voltage (Fig. 8) or between active conductors and the protective conductor or ground potential as common-mode voltage (Fig. 9).

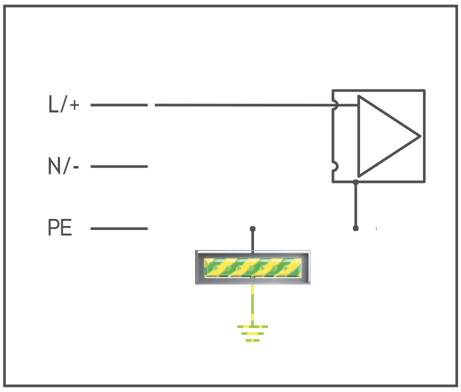

Fig. 7: Schematic power supply of a piece of equipment

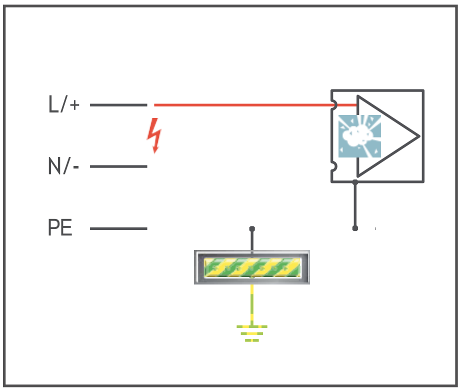

Fig. 8: Effects of a surge voltage as normal-mode voltage

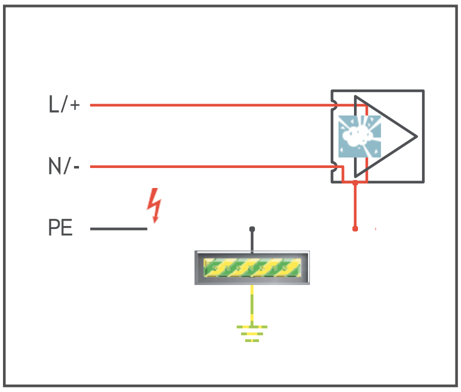

Fig. 9: Effects of a surge voltage as common-mode voltage

With this in mind, surge protective devices are installed either in parallel to the equipment, between the active conductors themselves (Fig. 10) or between the active conductors and the protective conductor (Fig. 11).
A surge protective device functions in the same way as a switch that turns off for the brief time of the surge voltage. By doing so, a sort of short circuit occurs; surge currents can flow to ground or to the supply network. This limits the difference in voltage (Fig. 12 and 13). This short circuit of sorts only lasts for the duration of the surge voltage event, typically a few microseconds. As such, the equipment to be protected is safeguarded and continues to work unaffected.

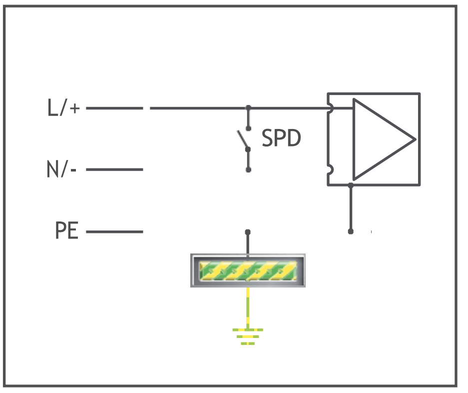

Fig. 10: SPD between the active conductors

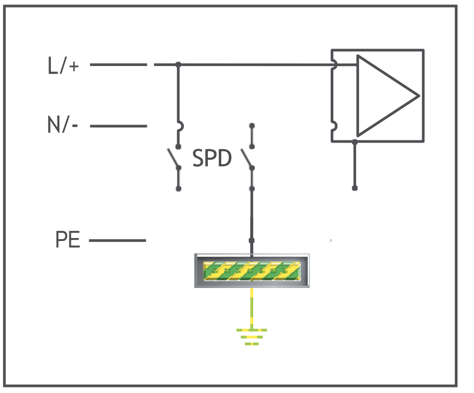

Fig. 11: SPD between active conductors and the protective conductor

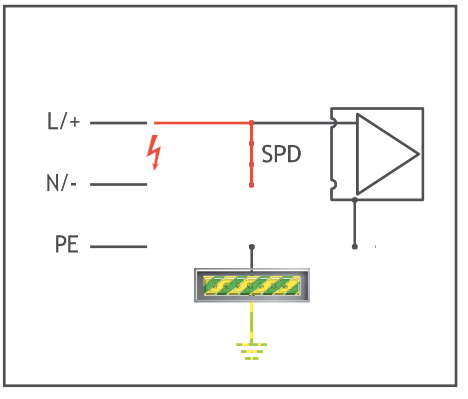

Fig. 12: SPD between the active conductors in the case of normal-mode voltage

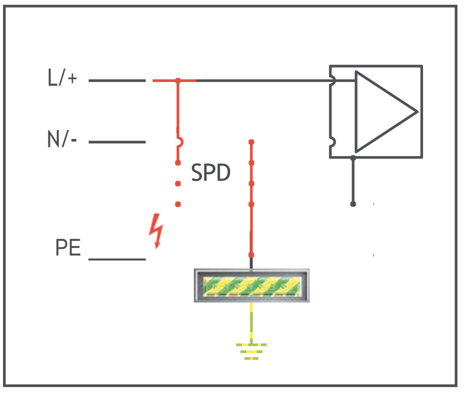

Fig. 13: SPD between active conductors and the protective conductor in the case of common-mode voltage

2 Lightning and surge protection standards

National and international standards provide a guide to establishing a lightning and surge protection concept as well as the design of the individual protective devices. A distinction is made between the following protective measures:

- Protective measures against lightning strike events: stipulated in lightning protection standard IEC 62305 [1] [2] [3] [4]. A key component of this is an extensive risk assessment regarding the necessity, scope, and cost-effectiveness of a protection concept.
- Protective measures against atmospheric influences or switching operations: stipulated in IEC 60364-4-44 [5]. In comparison with IEC 62305, it is based on a shortened risk analysis and uses this as the basis for deriving corresponding measures.

In addition to the standards mentioned, it may be necessary to observe other legal and country-specific stipulations, which often make the use of surge protection a compulsory requirement. The following sections do not address the individual particularities of standards in various countries. Normative references are made, to the extent possible, based on the international IEC documents.

2.1 Lightning protection in accordance with IEC 62305

Part 1: Characteristics of lightning strikes

In Part 1 of this standard [1], the characteristic properties of lightning strikes, the likelihood of occurrence, and the potential for hazard are taken into account.

Part 2: Risk analysis

The risk analysis according to Part 2 of this standard [2] describes a process with which, first of all, the need for lightning protection for a physical structure is analyzed. Various sources of damage, e.g., a direct lightning strike in the building, come into focus, as do the types of damage resulting from this:

- Impact on health or loss of life
- Loss of technical services for the public
- Loss of irreplaceable objects of cultural significance
- Financial losses

The financial benefits are determined as follows: how does the total annual cost for a lightning protection system compare to the costs of potential damage without a protection system? The cost evaluation is based on the expenditures for the planning, assembly, and maintenance of the lightning protection system.

Parts 3 and 4: Planning aids and specifications

If the risk assessment determines that lightning protection is required and cost-effective, then the type and scope of the specific measures for protection can be planned based on Parts 3 [3] and 4 [4] of this standard. The lightning protection level determined by risk management is decisive for determining the type and scope of the measures.

For physical structures that require an extremely high level of safety, almost all strikes must be captured and conducted away safely. For systems where a higher residual risk is acceptable, strikes with lower amplitudes are not captured. Fig. 14 shows the lowest current amplitudes of lightning strikes that can still be captured safely as well as the highest current amplitudes of lightning strikes that can be conducted away safely depending on the lightning protection level. This is described by means of lightning protection classes I to IV.

Furthermore, these describe the probability of capturing lightning strikes relative to the overall occurrences of lightning strikes. The highest class, lightning protection class I, corresponds to a 99% probability of capturing a strike.

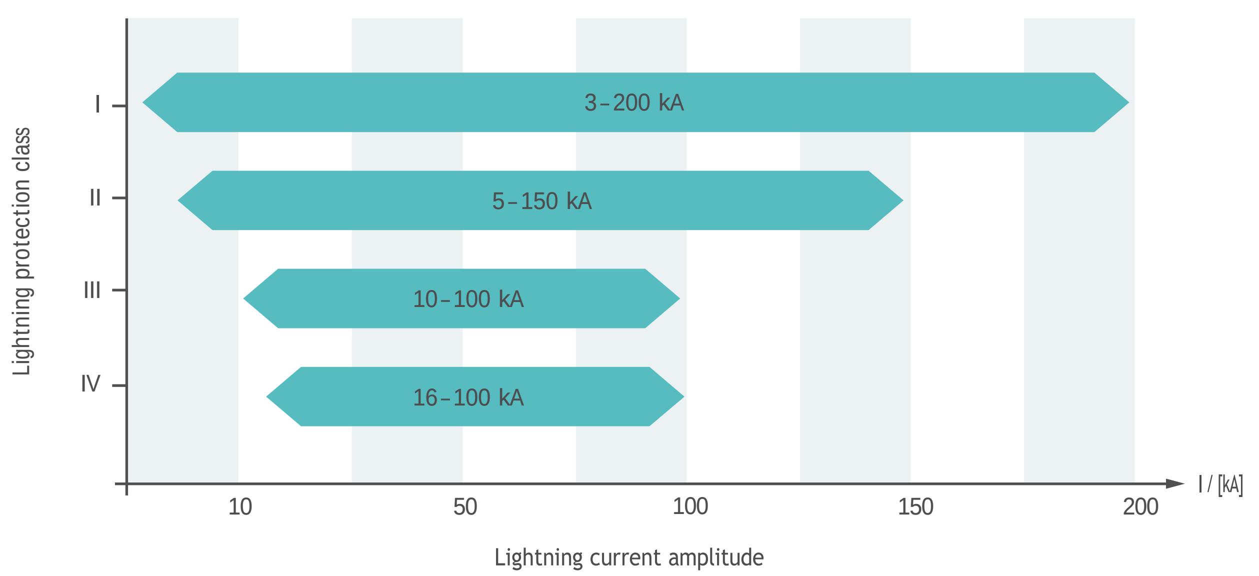

Fig. 14: Lightning protection classes in accordance with IEC 62305-1 [1] with corresponding minimum and maximum values of lightning current amplitude

2.2 Surge protection in accordance with IEC 60364-4-44

IEC 60364-4-44 [5] includes a description of the requirements for protecting the electrical installation against transient overvoltages caused by atmospheric influences.

The standard's area of application includes transient overvoltages that are transmitted by the power supply system. In addition to surge voltages (such as those arising from switching operations), this includes a direct lightning strike on the supply line. However, direct lightning strikes on or near a physical structure are not taken into consideration; in these cases, refer to IEC 62305 [1-4].

Likewise, the standard does not apply to installations if the consequences from surge voltages affect:

- Physical structures with a risk of explosion
- Physical structures that, if damaged, could impact the environment (such as chemical systems or nuclear power plants).

Surge protective devices must be used in accordance with IEC 60364-4-44 if transient overvoltages could have an impact on the following:

- Human life; for example, systems for safety purposes, medical areas
- Public and cultural institutions; for example, failure of public services, telecommunications centers, museums
- Industrial or trade activities; for example, hotels, banks, industrial firms, trade markets, agricultural enterprises

In all other cases, a risk assessment must be carried out in line with the international standard.

However, there are country-specific deviations in which the use of surge protection is generally obligatory, making a risk assessment unnecessary.

3 Basic protective measures and equipment

In order to ensure the total protection of a physical structure from the effects of lightning strikes and surge voltages, various protective measures or equipment that are tailored to one another are required. A broad classification is shown below:

- External lightning protection
- Internal lightning protection
- Grounding and equipotential bonding
- Coordinated SPD system

3.1 External lightning protection

External lightning protection (Fig. 15) aims to divert strikes which come near to the object to be protected and to transmit the lightning current from the point where it hits to ground. Dangerous spark formation must be prevented. Damage due to thermal, magnetic or electrical effects must be prevented as well through proper design and dimensioning. External lightning protection is a system that consists of the air terminal, the arresters, and the grounding system.

Part 3 of standard IEC 62305 [3] is essential for planning and erecting external lightning protection systems. Identifying and determining the lightning protection class is the basis for this. This is derived from the risk analysis. If there are no regulations or specifications for external lightning protection, a lightning protection class of at least class III is recommended.

The location of the air terminals on the building must also be determined. There are three methods of doing so:

- Rolling sphere method
- Protective angle method
- Mesh method

To insulate the external lightning protection system, a minimum distance between electrical lines and metal installations must be kept, referred to as the separation distance.

Fig. 15 External lightning protection, here on a private residence, for example

3.2 Internal lightning protection

The internal lightning protection system should prevent dangerous spark formation inside the system. Sparks can be caused by lightning-induced surge voltages in the external lightning protection system or in other conductive parts of the physical structure.

The internal lightning protection system consists of the equipotential bonding system and electrical insulation due to sufficient distances or suitable materials from the external lightning protection system.

The lightning protection equipotential bonding is intended to prevent dangerous potential differences. For this purpose, the lightning protection system is primarily connected to metal installations, internal systems, as well as electrical and electronic systems within the system. This occurs by means of equipotential bonding lines, surge protective devices or isolating spark gaps.

3.3 Grounding and equipotential bonding

The grounding system aims to distribute and discharge the captured lightning current to ground. For this process, the geometry of the grounding system is crucial for effectively deriving lightning current (not the grounding resistance value). Effective equipotential bonding is also important. Equipotential bonding connects all electrically conductive parts with each other via cables. Active conductors are integrated into the equipotential bonding via surge protective devices.

3.3.1 Coordinated SPD system

A coordinated SPD system is understood to be a multi-level system of surge protective devices that are coordinated with each other.

The following points are recommended in order to achieve a high-performance SPD system:

- Divide the physical structure into lightning protection zones
- Incorporate all cables that cross between different zones into the local equipotential bonding using suitable SPDs
- Coordinate different types of SPDs: The devices must operate with each other in a coordinated manner to prevent individual SPDs from overloading
- Use short supply lines for connecting SPDs between active conductors and the equipotential bonding
- Lay protected and unprotected cables separately
- For surge protection of signal transmission circuits, it is recommended to ground equipment only via the respective SPD

4 Lightning protection zones

The installation locations of surge protective devices within a physical structure are determined using the lightning protection zone concept from part 4 of lightning protection standard IEC 62305 [4].

It divides a physical structure into lightning protection zones (LPZ), and does so from outside to inside with decreasing lightning protection levels. In external zones only resistant equipment can be used. However, in internal zones, sensitive equipment can also be used.

The individual zones are characterized and named as follows:

LPZ 0_A
Unprotected zone outside of a building where direct lightning strikes are possible. The direct coupling of lightning currents in cables and the undamped magnetic field of the lightning strike can lead to danger and damage.

LPZ 0_B
Zone outside the building that is protected from direct lightning strikes, for example, by an air terminal. The undamped magnetic field of the lightning strike and induced surge currents can cause hazards and damage.

LPZ 1
Zone inside the building where high-energy surge voltages or surge currents and strong electromagnetic fields are still to be expected.

LPZ 2
Zone inside a building where surge voltages or surge currents and electromagnetic fields that have already been significantly weakened are to be expected.

LPZ 3

Zone inside the building where surge voltages or surge currents are expected to be only extremely low or entirely absent and electromagnetic fields are expected to be only very weak or non-existent.

All cables that cross between zones must use coordinated surge protective devices (Fig. 16). Their discharge capacities are based on the lightning protection class to be achieved, which has been determined according to legal requirements and requirements from government agencies and insurance companies, or by a risk analysis. When it comes to selecting surge protective devices, use the standard as a basis, assuming that 50% of the lightning current will be discharged to ground. The other 50% of the lightning current is directed to the electrical installation via the main equipotential bonding and from there must be conducted away from the SPD system.

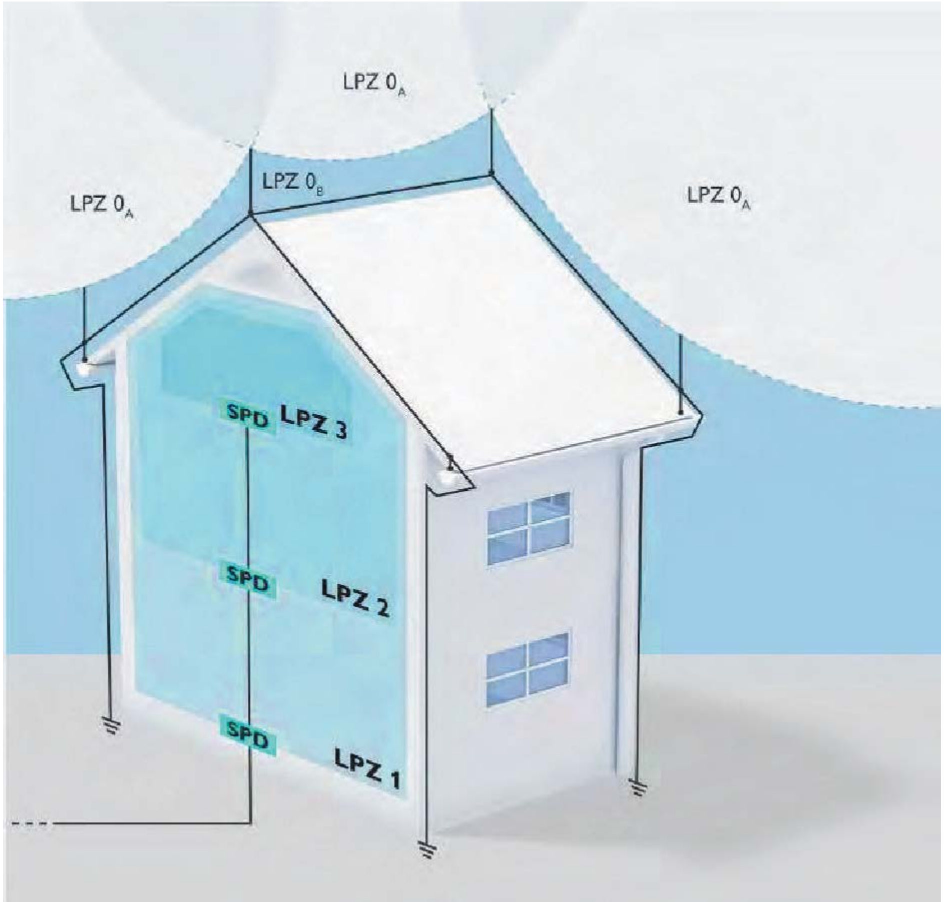

Fig. 16: Lightning protection zone concept with coordinated SPDs at the respective zone transition points

5 The protective circle principle

A clear depiction of the lightning protection zone concept is shown by the protective circle (Fig. 17). An imaginary circle should be drawn around the object to be protected. Surge protective devices should be installed at all points where cables intersect this circle. This secures the area inside the protective circle. Couplings of line-bound surge voltages are moderated to achieve effective protection.

The protective circle must include all electrical and electronic transmission lines in the following areas:

- Power supply
- Measurement and control technology
- Information technology
- Transceiver systems

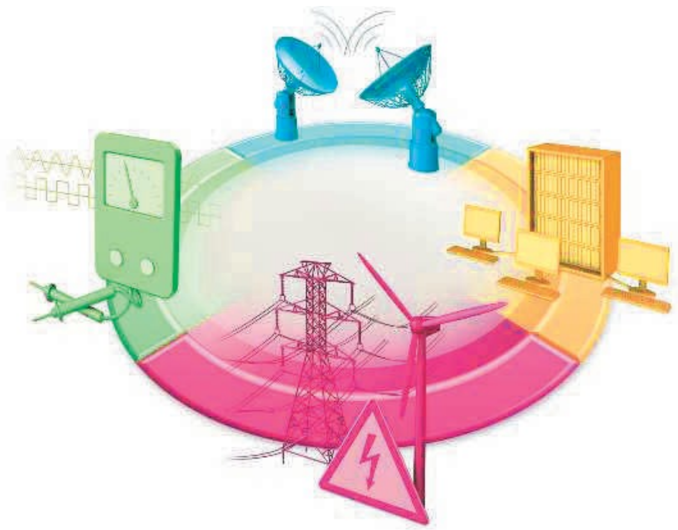

Fig. 17: Protective circle