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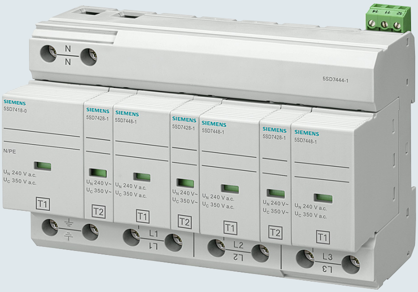


SENTRON

Overvoltage protection devices

Technology primer

Edition 06/2018

www.siemens.com/overvoltage-protection

More than a million lightning strikes are registered in Germany each year. This is an enormous risk for buildings and plants, since lightning currents and line surges, left unchecked, can cause considerable damage. In the event of damage, however, it is often not recognized that the damage was caused by lightning currents or overvoltages.

Despite the undisputed need in electrical installations, the use of lightning and overvoltage protection devices has so far played only a subordinate role. But this has changed in the meantime. Since October 2016, the more stringent installation standards DIN VDE 0100-443 and DIN VDE 0100-534 have applied to overvoltage protection in Germany. The result of these new installation regulations is that, from October 2018, the installation of overvoltage protection will also be mandatory in every newly constructed residential building in Germany.
By now there are also regulations for the installation of overvoltage protection devices in Austria, Great Britain and Norway.

This technology primer is intended to make lightning and overvoltage protection more understandable and to provide practical tips for installing our high-quality lightning and overvoltage protection products.

Contents

1. Product portfolio

Lightning arresters, type 1

5SD7414-1
- Max. continuous voltage: 350 V AC
- Versions for TN-C, TN-S and TT networks
- Lightning impulse current: up to 100 kA

Combination surge arresters type 1 + type 2

5SD7444-1
- Max. continuous voltage: 350 V AC
- Versions for TN-C, TN-S and TT networks
- Lightning impulse current: up to 100 kA
- Rated discharge current: up to 100 kA

Combination arresters, type 1/type 2

5SD7414-3
- Max. continuous voltage: 335 V AC
- Versions for TN-C, TN-S and TT networks
- Lightning currents: up to 50 kA
- Max. leakage current: up to 50 kA

Surge arresters Type 2

5SD7464-1
- Standard width (1MW per pole)
- Max. continuous voltage: 350 V AC
- Versions for TN-C, TN-S and TT networks
- Rated discharge current: up to 20 kA
- Max. leakage current: up to 40 kA

Surge arresters Type 2

5SD7424-3
- Narrow width
- Max. continuous voltage: 350 V AC
- Versions for TN-S and TT systems
- Rated discharge current: up to 40 kA
- Max. leakage current: up to 80 kA

Surge arresters Type 3

5SD7432-1
- Versions for 1- and 3-phase networks
- Rated voltages: 24 V, 120 V and 230 V AC
- Installation: as close as possible upstream from the unit to be protected

Adapter plug

5SD7581-3
- Versions for Ethernet interfaces up to 10 Gbits

2. Basics

2.1 Consequences of lightning strike and overvoltages

Overvoltage endangers a considerable number of electrical and electronic installations. Even small voltage peaks on the supply line or between the electrical lines and other conductive parts (e.g. earthed metal parts, the ground etc.) are sufficient. The damage profiles generally cover destroyed cables, printed circuit-boards and switching devices. Such damage can be prevented by suitable overvoltage protection measures.

A large proportion of all property damage that residential building insurers have to pay for is due to lightning strikes and overvoltages caused by switching operations. But while in residential buildings “only” a high-quality hi-fi system or a PC has to be replaced, damage in trade and industry is much higher. This is because consequential damage often outweighs direct damage to the electronics. A prime example here is the production stoppage in the industry due to the failure of the power supply and/or the EDP.

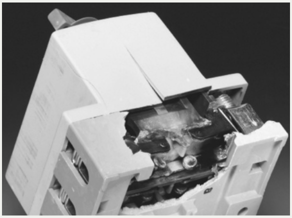


Fig. 1: Overvoltage damage to an RCCB

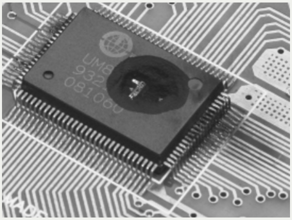


Fig. 2: Overvoltage damage on a printed circuit board

While the operator is usually reimbursed by his insurance company for damage to electronic equipment, the cost of replacement or repair that has not been reimbursed should not be underestimated. Software damage, data loss or the failure of a system are always associated with financial burdens that are often not covered by insurance. Lightning and overvoltage protection adapted to local conditions protects against these losses.

2.2 Causes of transient overvoltages

Transient overvoltages are caused by lightning discharges (LEMP – Lightning ElectroMagnetic Pulse), switching activity (SEMP – Switching ElectroMagnetic Pulse) and electrostatic discharges (ESD – ElectroStatic Discharge).
They occur only for a fraction of a second and have very short rise times of a few microseconds before they fall off again relatively slowly.

Lightning discharges (LEMP) have the greatest destructive potential. The high-energy surge current and surge voltage pulses (waveform 10/350 µs) can spread over long distances. Lightning strikes at greater distances can also lead to overvoltages of several kilovolts and surge currents of several kiloamperes.

During **switching operations (SEMP)** and especially when switching off inductive loads, very high voltage and current peaks (waveform 8/20 µs) can occur.
The amplitude of the voltage peaks can reach several times the operational voltage. These voltage and current peaks propagate in the supply network and can interfere with or damage connected devices.

Electrostatic discharge (ESD) occurs when bodies with different electrostatic potential approach each other and charge exchange occurs. The sudden charge exchange leads to a short-term surge voltage and a short-term surge current, posing a particular threat to sensitive electronic components.

2.3 Protection against lightning current and overvoltages

Suitable protective measures must be taken to prevent malfunctions, damage or even destruction of electrical systems and devices caused by overvoltages or overcurrents. If direct lightning strikes are to be expected in a building, the installation of an external lightning protection system is necessary – consisting of air terminals, down conductors and grounding system. However, an external lightning protection system is not capable of protecting electrical installations within a building. This requires additional measures for "internal lightning protection". An important prerequisite for the effectiveness of external and internal lightning protection is a professionally designed equipotential bonding system.
An essential component of internal lightning protection is the installation of a multi-level system of overvoltage protection devices.
The abbreviation "SPD" (Surge Protective Device) is used in German and in relevant standards for the term overvoltage protection device.

SPDs should ensure that transient overvoltages and currents do not cause damage to installations, equipment or terminals.
They must therefore fulfill two main tasks:

1. Limit the magnitude of the overvoltage so that the insulation strength of the units to be protected is not exceeded.
2. Safely discharge the surge currents connected to the overvoltage.

SPDs are installed in parallel to the equipment between the active conductors themselves and between the active conductors and the protective conductor or equipotential bonding conductor (see Fig. 3).

An SPD functions similarly to a switch that closes for the short period in which an overvoltage is present. This results in a "short circuit" and the potential difference can be compensated. Surge currents are diverted by this "short circuit" in such a way that there are as few restrictions as possible when operating electrical systems. The "short circuit" only exists for the short duration of the overvoltage.

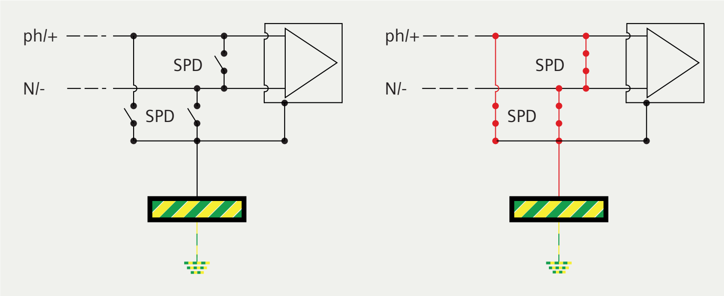


Fig. 3: Arrangement of SPDs

The implementation of comprehensive protection, consisting of line, electric-shock and fire protection as well as lightning current and overvoltage protection, requires a completely coordinated range of suitable measures and protective devices.
The SPDs from Siemens comply with national and international standards and offer state-of-the-art safety and protection at the highest level.

2.4 Test pulses

The transient currents and voltages to which SPDs are exposed in reality can be very diverse. Various typical transient current and voltage pulses are used to develop and professionally test powerful SPDs. These pulses are used in the laboratory to simulate the transient currents and voltages that occur in real electrical systems. Depending on the required discharge capacity, SPDs are tested with many different transients.
Some of these pulses are presented below to simulate lightning events and switching operations.

Lightning current pulse (10/350 µs)
The lightning current pulse (10/350 µs) is used for testing Type 1 SPDs (lightning arresters). This current pulse emulates the essential properties of lightning occurring in nature.
Depending on the lightning probability and the risk to be controlled, the standards require different levels of lightning current discharge capacity. Type 1 SPDs are divided into lightning protection classes I to IV, depending on the respective discharge capacity (see Fig. 4).

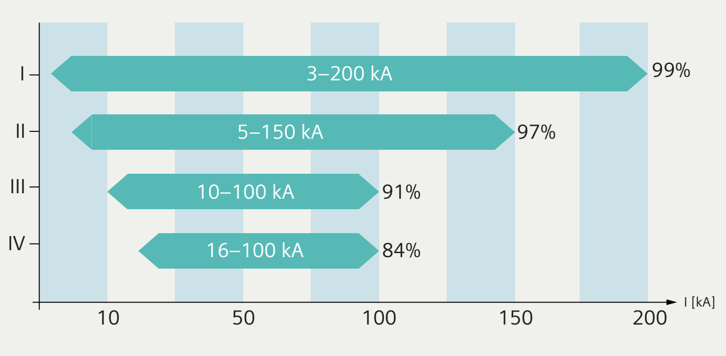


Fig. 4: Lightning protection classes

Products of lightning protection class I cover the lightning current range from 3 to 200 kA. This range covers 99% of all flashes.

The rise time of the lightning current pulse is 10 µs; the virtual time to half-value on tail is 350 µs. The area below the curve of a lightning current pulse is equivalent to the charge of the respective current impulse and is explicitly indicated in data sheets. The peak value of the lightning impulse current (10/350 µs) is designated as I_{imp}.
For the performance capacity of a Type 1 SPD, not only the waveform and the peak value of the lightning current are important, but also the charge and the specific energy. Above all, the charge that is led through the Type 1 SPD is decisive.
A Type 1 SPD with a discharge capacity of 100 kA (10/350 µs) fulfills the requirements of lightning protection class I (according to EN 62305) and must be able to discharge a charge of 50 As.
A Type 1 SPD with a discharge capacity of 50 kA must be able to discharge a charge of 25 As.

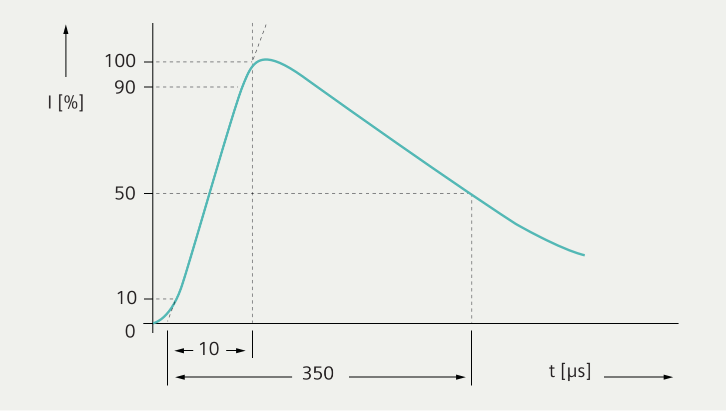


Fig. 5: Course of a (10/350 µs) lightning current pulse

Surge current impulse (8/20 µs)

The surge current impulse (8/20 µs) is used for testing Type 2 SPDs. The rise time of the surge current impulse is 8 µs; the virtual time to half-value on tail is 20 µs. This pulse is used to simulate transient currents with a lower energy content, such as lightning-induced currents at a greater distance from the location of a lightning strike and surge currents resulting from switching operations.
The peak value of the surge current for this waveform, with which a Type 1 SPD or a Type 2 SPD is tested, is designated as I_n.

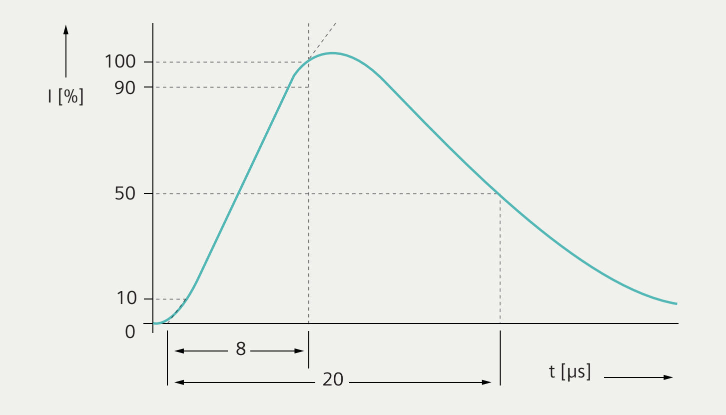


Fig. 6: Course of a (8/20 µs) lightning current pulse

2.5 Hazard analysis

The risk management described in the standard EN 62305-2 is preceded by a risk analysis to first ascertain the need for lightning protection and then determine the technically and economically optimal protective measures described in IEC 62305-3 and EN 62305-4.

For this purpose, the property to be protected is divided into one or more lightning protection zones (LPZ; see section 2.6). For each lightning protection zone, the geometric limits, the relevant characteristics, the lightning hazard data and the types of damage to be taken into account are defined. Based on the unprotected condition of the property, the assumed risk is reduced by applying (additional) protective measures until only an acceptable residual risk remains. The standard takes into account both protective measures for building structures and the persons contained therein as well as electrical and electronic installations and those for supply lines.

The methods described can be used both to determine the protection class of a lightning protection system and also to define a complex protection system against lightning current pulses and the electric and magnetic fields caused by lightning.

2.6 Distribution of lightning current during lightning discharge into a building

According to the IEC 62305 standard, it can be assumed in the event of a lightning strike that approx. 50% of the lightning current will be discharged through the external lightning protection system (lightning arrester) into the ground. Up to 50 % of the remaining lightning current will flow through electrically conductive systems, such as the main grounding bar, into the building and towards the power supply lines.

If an external lightning protection system is available, it is therefore always imperative to install an internal lightning protection system.

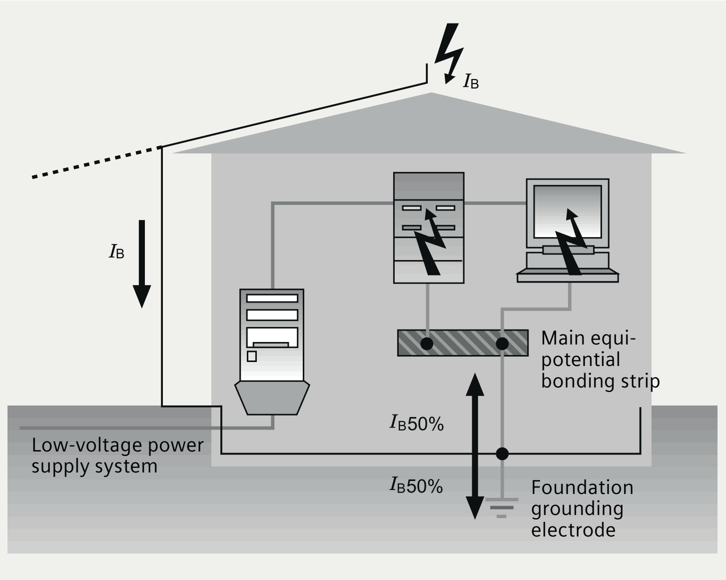


Fig. 7: Distribution of lightning current during lightning discharge into a building

To simplify matters, it can be assumed that the lightning current is evenly distributed among the conductors of the power supply system. Therefore, the lightning currents on the individual conductors are significantly lower than the total lightning current.

Number of conductors	Max. expected lightning currents per conductor (10/350 μs) [kA]	Lightning protection class
4	25.0	I
	18.7	II
	12.5	III + IV
3	33.3	I
	25.0	II
	16.6	III + IV

Table 1: Maximum expected lightning currents per conductor

2.7 Lightning protection zones (LPZs)

Each building requires a harmonized lightning protection concept. Tiered protection is an important factor here. Sufficient protection is only achieved when a tiered concept is firmly in place.

To this end, the lightning protection zone (LPZ) concept described in DIN EN 62305-1 is used. This concept combines devices or areas with the same risk potential into lightning protection zones. Depending on the requirement, SPDs are used at the transitions between lightning protection zones and installed in an appropriate location – such as the main or sub-distribution system.

LPZ 0_A

Zone endangered by direct lightning strikes and the full electromagnetic field of the lightning. The internal systems can be exposed to full or partial lightning impulse currents.

LPZ 0_B

Zone protected against direct lightning strikes, but endangered by the full electromagnetic field of the lightning. The internal systems can be exposed to partial lightning impulse currents.

LPZ 1
Zone in which the surge currents are limited by current sharing and by insulating interfaces and/or SPDs at the zone boundary. The electromagnetic field of the flash can be attenuated by spatial shielding.

LPZ 2, ..., n
Zone in which the surge currents are further limited by current sharing and by insulating interfaces and/or additional SPDs at the zone boundary. Additional spatial shielding can be used to further attenuate the electromagnetic field of the lightning.

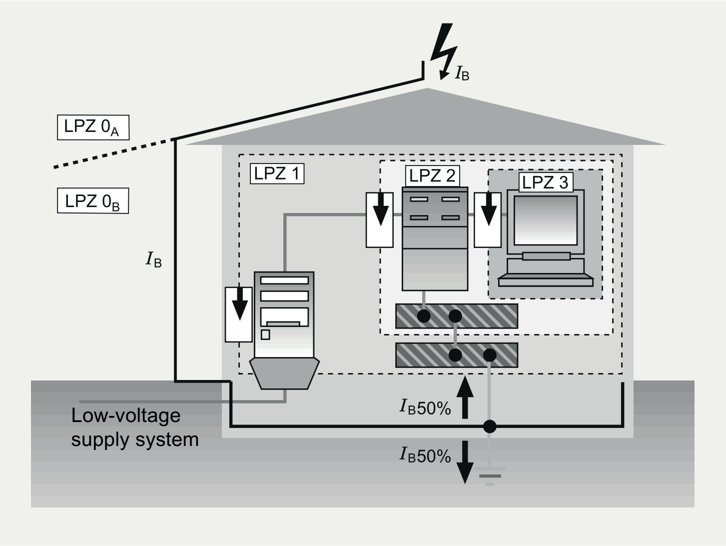


Fig. 8: Lightning protection zones outside and inside a building

2.8 Overvoltage categories, impulse withstand levels and protection levels

All equipment in an electrical plant is assigned to an overvoltage category depending on its use and location (see EN 60664-1). This categorization serves as a basis for determining the required rated impulse voltage U_W (dielectric strength). The 1.2/50 µs surge voltage impulse is used to test the surge strength.
The installation of SPDs is intended to ensure a voltage limitation in accordance with the rated surge strength required for the respective installation location of a device in order to avoid dangerous spark formation, short circuits and any resulting fires.

Rated voltage of the electrical installation	Required rated impulse voltage [kV] of the equipment in the various overvoltage categories			
	IV	III	II	I
120/280 V AC 120/240 V AC	4	2.5	1.5	0.8
230/440 V AC 277/480 V AC	6	4	2.5	1.5
400/690 V AC	8	6	4	2.5
1,000 V AC	12	8	6	4
1,500 V DC	15	10	8	6

Table 2: Rated impulse voltage (1.2/50 µs) in the various overvoltage categories

Overvoltage category IV
Equipment for use at the connection point of the installation.
Example: Equipment such as electricity meter and primary overcurrent protection modules.

Overvoltage category III
Equipment in fixed installations and for cases where special requirements for equipment reliability and availability are present.
Example: Equipment such as switches in fixed installations and equipment for industrial use with permanent connection to the fixed installation.

Overvoltage category II
Power consumers fed by the fixed installation.
Example: Equipment such as domestic appliances, portable tools and similar devices.

Overvoltage category I
Equipment for connection to electrical circuits in which measures have been taken to limit transient overvoltages to an acceptably low level.
Example: Sensitive equipment for special applications.
The SPD protection level U_p between active conductors and protective conductor must under no circumstances exceed the rated impulse voltage U_w of the equipment to be protected.

Recommendation
The protection level U_p should not exceed 80% of the rated impulse voltage U_w.
For example, the rated impulse voltage U_w according to overvoltage category II for 230/400V TN or TT systems is 2.5 kV and thus the recommended protection level U_p of the SPD to be used is a maximum of 2.0 kV.

2.9 Insulation coordination

The insulation coordination according to EN 60664-1 and IEC 60364-4-44 describes the minimum surge strength of a device to ground at the respective installation location.

Factors to consider here are:

- the expected overvoltages and the characteristics of the SPDs used, and
- the expected ambient conditions and the protective measures against contamination of the equipment.

The minimum surge strength to ground of equipment in 230/400 V AC networks is:

- 6 kV in the main power supply network (main distribution board)
- 4 kV in the area of electrical circuit distribution (sub-distribution) and in the area of permanent installation
- 2.5 kV at commercially available terminals
- 1.5 kV at particularly sensitive terminal equipment

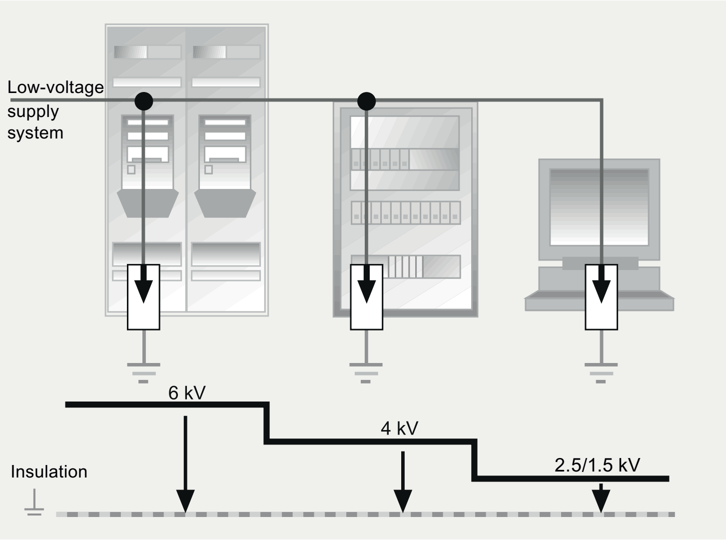


Fig. 9: Insulation coordination according to EN 60664-1

3. Relevant standards

National and international standards provide orientation when it comes to the design of lightning and overvoltage protection systems as well as the design, selection, classification and installation of the individual SPDs. In addition, there may be national or locally applicable rules and regulations which contain application notes or specifications for the design, installation and maintenance of lightning and overvoltage protection systems.
The most important standards for the design of lightning and overvoltage protection systems as well as for the classification of SPDs are briefly described below.

3.1 Design of a lightning and overvoltage protection system

3.1.1 Lightning protection standard series IEC 62305 [1] [2] [3] [4]

This series of standards deals with protection against direct lightning strikes. Central components are the description of general principles, a detailed risk analysis and extensive specifications for external lightning protection and internal lightning protection (overvoltage protection).

3.1.2 IEC 60364-4-44 [5]

Compared to IEC 62305, this standard is based on a simplified risk analysis and derives appropriate measures from it.
The range of application is limited to overvoltage and surge current impulses transmitted via the power supply network. Direct lightning strikes into a building are not taken into account here, only strikes in supply lines or in the vicinity of supply lines.
The standard describes the conditions under which SPDs are to be used in low-voltage systems to protect the electrical installation from overvoltages.

3.1.3 Installation regulations DIN VDE 0100-443 and DIN VDE 0100-534

DIN VDE 0100-443:2016-10 specifies the applications in which overvoltage protection must be installed.
DIN VDE 0100-534:2016-10 specifies how SPDs must be selected for the respective application and installed according to standards.
The standards DIN VDE 0100-443 and DIN VDE 0100-534 in force since October 2016 contain stricter regulations for the selection and installation of SPDs. After the end of the transition period for the application of previous editions of these standards (applicable until 14 December 2018), the stricter provisions in force since October 2016 must be applied to the selection and installation of SPDs. This tightening of the installation regulations means that overvoltage protection is mandatory even in a single-family house.

3.2 Product standard IEC 61643 for the classification, testing and application of SPDs

The surge protection devices (SPDs) are classified according to their performance requirements (depending on type class and location) in the IEC 61643-x product standard series. There you will find definitions of terms, general requirements and test methods for surge protection devices.

The most important parts of this series of standards are:

IEC 61643-11
Surge protective devices connected to low-voltage power systems – Requirements and tests

IEC 61634-12
Surge protective devices connected to low-voltage power systems – Selection and application principles

IEC 61643-21
Surge protective devices connected to telecommunication and signal-processing systems – Performance requirements and testing methods

IEC 61643-22
Surge protective devices connected to telecommunications and signaling networks – Selection and application principles

A list of all relevant standards can be found in the chapter “Overview of the standards” on page 65..

4. Design and method of operation of overvoltage protection devices

SPDs have high impedance during normal operation of an electrical system. Only during the occurrence of an overvoltage (through lightning or switching action) do SPDs briefly become low-impedance, and then return to the high-impedance state autonomously.
By changing from the high-impedance to the low-impedance state, SPDs are able to limit the voltages occurring during overvoltage and lightning events in such a way that electrical equipment is effectively protected against damage. With professional planning and the installation of equipotential bonding as well as lightning and overvoltage protection, SPDs are also able to "divert" surge currents and lightning currents in such a way that the operation of electrical systems is affected as little as possible.
In order to meet the diverse requirements with regard to the required protective effect, various components are used in SPDs. Overvoltage protection components are used in SPDs both as individual components and in the form of complex protection circuits.

Depending on the application, the following components are used in SPDs:
- Spark gaps
- Gas-filled surge arresters (GFSAs)
- Varistors
- Suppressor diodes

These components chiefly differ in the following respects:
- Discharge capacity (ampacity)
- Response behavior (response time in the event of overvoltage)
- Voltage limitation (residual voltage/protection level for the device to be protected)
- Voltage curve during the discharge of overvoltage and surge current pulses
- Follow current discharge capacity (transition from low-impedance discharge state to high-impedance idle state after a discharge event)

4.1 Type 1 SPD (lightning arrester)

Type 1 SPDs are the most effective surge protection devices. Therefore, they are used as the first protection level for the protection of power supply systems. From a technical perspective, the preferred location for installation location is at the feeding point of the electrical system – as close as possible to the main grounding bar. Depending on local conditions, it may therefore make sense to install these SPDs directly downstream of the incoming main feeder box or in the immediate vicinity of the main distribution board or within the main distribution board. When selecting suitable SPDs, the type of power supply system (TN-C, TN-C-S, TN-S, TT or IT system) must also be considered.
Leakage-current-free SPDs (e.g. with spark gaps) can also be installed upstream of the meter. This also protects the electricity meter against overvoltages. If SPDs are to be installed upstream of the meter, this must be approved by the responsible supply network operator.

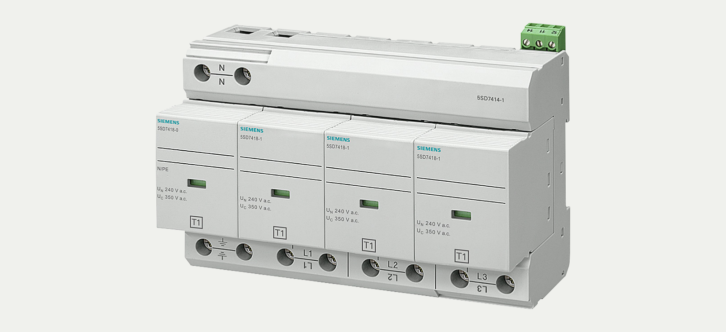


Fig. 10: Type 1 SPD 1 5SD7414-1

4.2 Type 2 SPD

As a rule, a Type 1 SPD at the feeding point of the electrical system is not capable of effectively protecting all electrical equipment of the subsequent installation. Therefore, lightning protection standards and application standards require the installation of overvoltage protection systems with more than one protection level. Type 2 SPDs are generally used as the second protection level of the internal lightning protection system. The second protection level – closer to the sensitive terminal equipment – allows the voltage to which the terminal devices are exposed to be better limited than would be possible with just one protection level. A Type 2 SPD lowers the residual voltage transmitted by an upstream Type 1 SPD below the dielectric strength of the equipment and lines in the area of the permanent installation between circuit distribution and power connection.

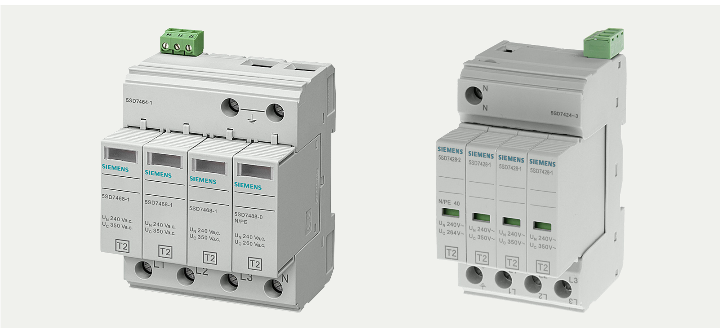


Fig. 11: Type 2 SPDs (SSD7464-1, 5SD7424-3)

The protection circuit in a Type 2 SPD consists of temperature-monitored varistors with high discharge capacity for surge currents, e.g. with amplitudes up to 80 kA (8/20 µs).

In the event of an overload of the varistor due to impermissibly high temporary overvoltages or due to aging of the varistor, the internal resistance decreases, which increases the leakage current in the varistor. There is then a corresponding rise in temperature, which triggers an isolating arrester. Once a defined temperature limit is reached, the varistor is mechanically separated from the network before a dangerous temperature is reached. The separation is usually signaled directly on the SPD (window appears red).

4.3 Type 1 + Type 2 SPD (surge arrester combination)

Improved protection is achieved by combining spark gaps and varistors in one SPD. Type 1 spark gaps offer the most effective protection against high-energy and long-duration lightning currents, whereas type 2 varistors offer the best protection against short-duration switching overvoltages. A combination of Type 1 spark gaps and Type 2 varistors is the best choice for installation locations where both lightning currents and switching overvoltages must be expected.

From a technical perspective, the most favorable location for installation of Type 1 + Type 2 SPDs is at the building infeed.

Depending on the system of power supply (TN-C, TN-C-S, TN-S, TT or IT), the proper arrester combination is installed in the main distribution system directly downstream of the electricity meter. Arrester combinations with varistors carry a low operational current (leakage current) of a few µA in undisturbed operation at rated voltage. Therefore, such devices should generally not be installed upstream of the meter. The connection and installation conditions for these protective devices are the same as those for Type 1 lightning arresters.

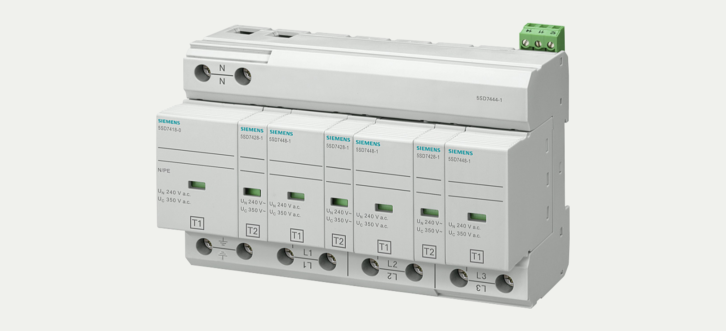


Fig. 12: Type 1 + Type 2 combination surge arrester 5SD7444-1

4.4 Type 1 / Type 2 SPD (combination arrester)

Due to the further development in the field of varistors, inexpensive Type 1 SPDs with powerful varistors are also available.
In general, the SPD components between L and N conductor or L and PEN conductor consist of a varistor, while the SPD components between N and PE contain a spark gap (total spark gap). The SPD meets the requirements for both Type 1 SPDs and Type 2 SPDs. This is why such SPDs are also referred to as "combination arresters".
Type 1 SPDs with varistors are usually not as powerful as Type 1 SPDs with spark gaps. Combination arresters are therefore primarily used in systems in which only requirements of lightning protection classes III or IV must be met.

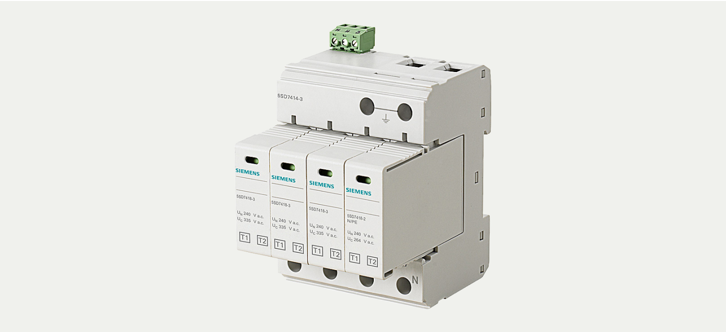


Fig. 13: Type 1 / Type 2 SPD 5SD7414-3

4.5 Type 3 SPD

The Type 3 SPD is the third protection level in the power supply. It reduces the transient voltage pulses caused by lightning events or switching operations to a voltage level that is lower than the proof voltage of the terminal equipment. For devices with an operational voltage of e.g. 230 V, that is max. 2.5 kV.

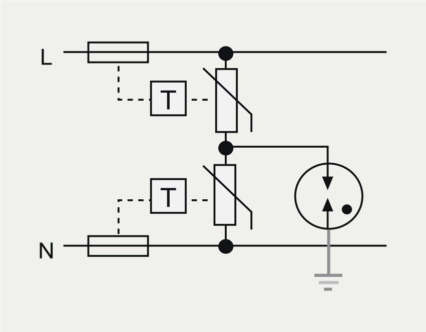


Fig. 14: Typical protection circuit of a Type 3 surge arrester

Fig. 15: Type 3 SPD 5SD7432-1

The protection circuit generally consists of a series connection of two varistors lying between the phase and neutral conductor. A gas-filled SPD (GFSA) connected in the middle between the varistors and joins this point to the protective conductor. This results in a leakage-current-free series connection between L-PE and N-PE respectively, consisting of varistor and gas-filled SPD (GFSA). The varistors of Type 3 SPDs are also temperature-monitored, which mechanically disconnects the varistor from the mains before dangerous temperatures are reached.

4.6 Important features of the product range

All Siemens surge protection devices are constructed in two parts from a basic element and a plug. The basic element contains the terminal contacts and the remote signaling, while the plug contains the protective element. In order to prevent incorrect assembly, the basic element and plug are provided with a mechanical coding.
All protective plugs are equipped with a mechanical status display. This display indicates when a plug is no longer functional and must be replaced.
Many SPDs also have a remote signaling contact. This contact can be used to send a signal to a central signal receiver or controller. The operating state of an SPD can thus be permanently monitored.

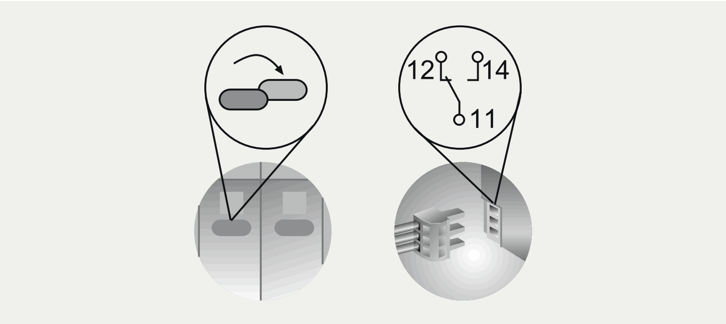


Fig. 16: Optical status display and plug-in remote signaling connection on the SPD

When testing the insulation strength, it is not necessary to disassemble the entire SPD; only the protective plug has to be removed.
Multi-pole versions for all types of power supply guarantee easy installation of the SPDs.

5. Multi-level overvoltage protection

5.1 Effective Protection Circuit

The term "effective protection circuit" represents a seamless measure for protecting against overvoltages. The first step in developing the measures required for lightning and overvoltage protection is to identify all equipment and plant areas in need of protection. Then, the required protection level for the identified equipment is evaluated. Basically, the various types of electrical circuits are divided up into the following areas:

- Power Supply
- Measurement and control equipment
- Data processing and telecommunications (transmitters/receivers)

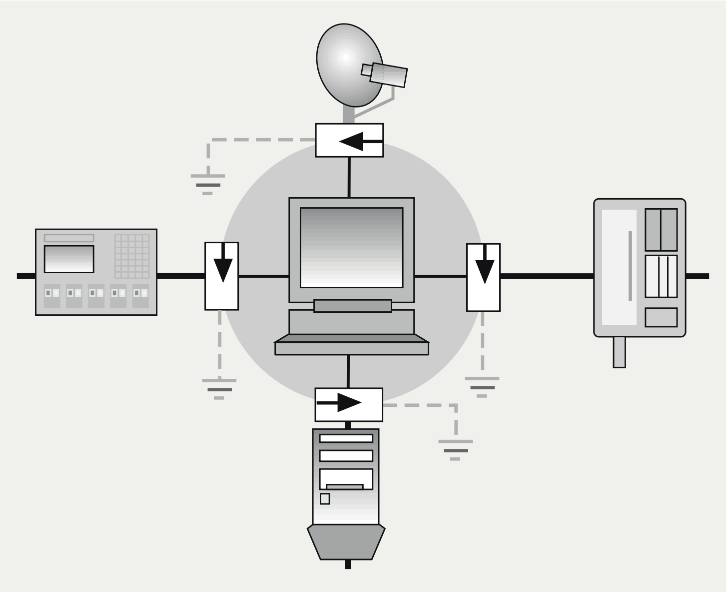


Fig. 17: Effective protection circuit

The system or device to be protected is located within a “protected room” – a protective zone. SPDs which match the nominal data of the respective circuit or the interface of the device to be protected are installed at all points of “cable – protective zone” intersection. This safeguards the area within the protective zone in such a way that devices located within the protective zone are effectively protected.

The first step in an efficient and comprehensive overvoltage protection concept is to examine the power supply. The high-energy overvoltages and surge currents occurring in this area can cause flashovers over air and creepage distances and through the insulation of live parts and cables to earth. All electrical equipment is affected, from the main building infeed to the electrical loads.

The measures required to protect the power supply of systems and devices depend on the results of the hazard analysis and on the stipulations made in application standards for the selection and installation of SPDs. The application standards generally require multi-stage protection with two or three protection levels. The SPDs for the individual protection levels differ in the type classification (Type 1, Type 2, Type 3), the degree of discharge capacity, the protection level, and the course of the residual voltage.

5.2 Three-level protection for the power supply – protection levels 1 and 2 installed separately

A three-level concept where all SPDs are installed at different locations is set up as follows:

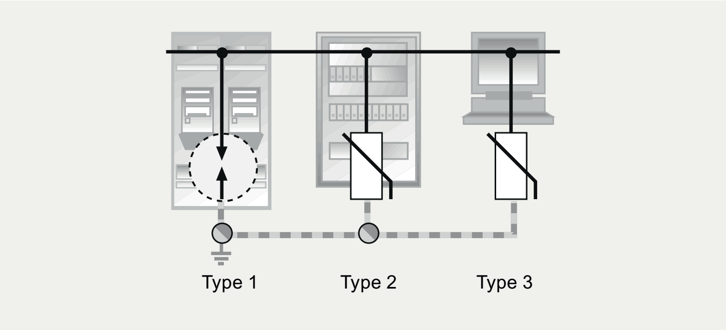


Fig. 18: Three protection levels with different installation locations in the power supply

5.3 Three-level protection for the power supply – protection levels 1 and 2 combined

A three-level concept for which Type 1 SPDs and Type 2 SPDs are combined in one device is set up as follows:

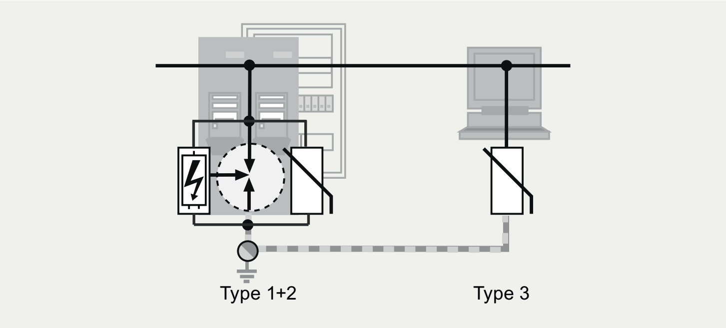


Fig. 19: Three-level protection for the power supply, protection levels 1 and 2 coordinated in one product

5.4 Two-level protection for the power supply with low risk potential

The risk potential for lightning discharges is relatively small for low buildings located in the midst of residential areas and where no lightning protection system or other grounded metal constructions are installed on the roof. A direct lightning strike here is unlikely from a statistical standpoint.
If the property meets these conditions after careful examination and assessment of the risk potential, then the installation can do without a Type 1 SPD.

Set-up for two-level protection with a limited discharge capacity

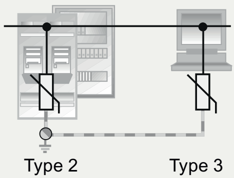


Fig. 20: Two-level protection for the power supply without lightning arrester

6. Network systems

The selection of SPDs also depends on the type of power supply system. SPDs must be adapted to the respective network system to ensure effective protection. Network systems differ primarily in whether and how one or more conductors of the network system are directly or indirectly earthed or whether the PE conductor is separated or carried along with the N conductor as the PEN conductor. Further differences result from the number of phases, the type of voltage and current as well as the frequency and the voltage level.

According to IEC 60364, a distinction is made between the following network systems:
- TN-S system
- TN-C system
- TT system
- IT system

6.1 The TN-S system

In a TN-S system, the neutral conductor (N) and protective conductor (PE) are each routed in a separate conductor. A three-phase power supply therefore consists of the five conductors L1, L2, L3, N and PE.
From the point of view of electromagnetic compatibility (EMC), systems in which N and PE are laid separately are considered more EMC-friendly than systems in which PEN conductors are used.
Depending on the requirements of the loads, systems are designed with 1 to 3 phases.

Fig. 21: The TN-S system

6.2 The TN-C system

In a TN-C system, the neutral conductor (N) and protective conductor (PE) are routed in a combined protective and neutral conductor (PEN). A three-phase power supply therefore consists of the four conductors L1, L2, L3 and PEN.

Fig. 22: The TN-C system

6.3 The TT system

In a TT system, one point – generally the neutral point of the transformer – is directly earthed (system ground). The grounded point is usually routed to the plant through an N conductor. The exposed conductive parts of the electrical system are connected to ground electrodes which have no direct connection to the system ground electrodes of the transformer. In other words, a local ground is set up directly at an installation or in a building. This local ground is connected to the local equipotential bonding system and the protective conductor of the local ground (PE), but not to the N conductor.
In a TT system, the neutral conductor (N) and protective conductor (PE) are routed in separate lines. A three-phase power supply therefore consists of the five conductors L1, L2, L3, N and PE from the local ground.
Depending on the requirements of the loads, systems are designed with 1 to 3 phases.

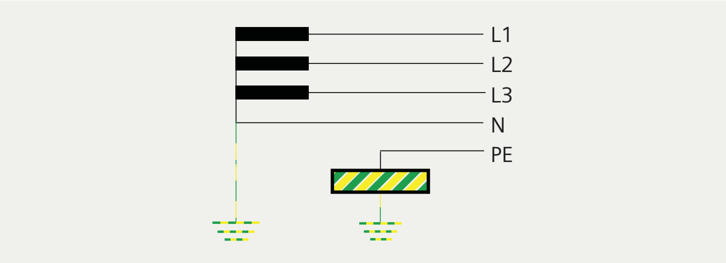


Fig. 23: The TT system

6.4 The IT system

In an IT system, the neutral point of the supplying transformer is not earthed or only earthed via a high impedance. If a neutral conductor is carried by the neutral point of the supplying transformer, it is led separately from the local protective conductor.
A 3-phase power supply consists of the 4 or 5 conductors L1, L2, L3, possibly N, and local PE.

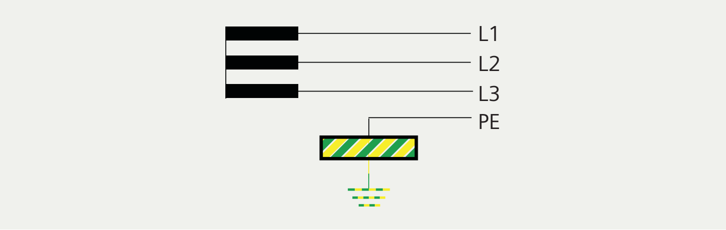


Fig. 24: The IT system

A special feature of the IT system is that an insulation fault against ground may occur for a limited period of time. The ground fault of a phase only has to be detected and reported by an insulation monitoring system so that it can be remedied promptly.

6.5 Converting network systems within an installation

In practice, network systems often change within a plant.

Example: Conversion of a TN-C system into a TN-S system

In this case, the PEN conductor is divided up into a separate PE conductor and an N conductor. Therefore, the 4-conductor TN-C system (L1, L2, L3, PEN) is transformed into a 5-conductor TN-S system (L1, L2, L3, N, PE).

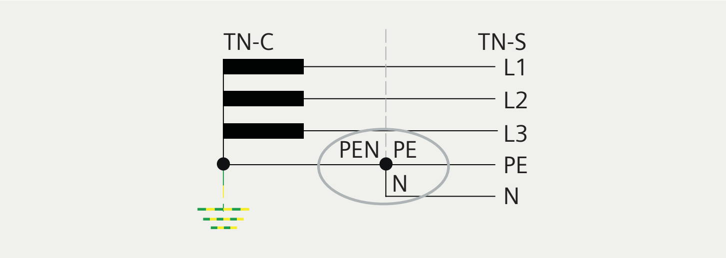


Fig. 25: Conversion of a 3-phase TN-C system into a 3-phase TN-S system

7. Installation notes

SPDs of the first protection level should be installed as close as possible to the feeding point of the electrical system – preferably in the immediate vicinity of the main grounding bar (HES), so that the downstream installation equipment is protected.
In systems fed from the public energy supply network, the feeding point of the electrical system is located near the main distribution board of the building.
In industrial plants with medium-voltage infeed, the SPDs must be installed in the low-voltage main distribution board.

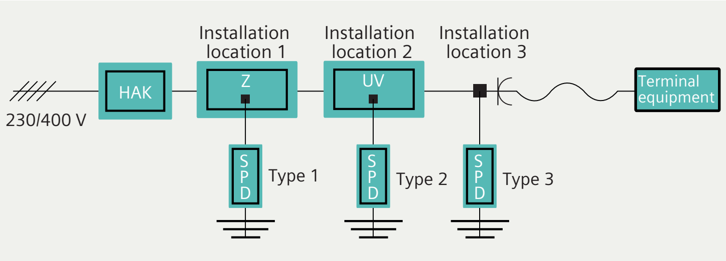


Fig. 26: Typical installation locations of SPDs

Fig. 26 shows the typical installation locations of SPDs.
The overvoltage protection devices today known as Type 1 SPD, Type 2 SPD and Type 3 SPD were often referred to in the past as SPDs for coarse, medium and fine protection.
The SPDs at installation locations 2 and 3 must not be used without an SPD at installation location 1. To prevent overloading of the SPDs at installation locations 2 and 3, the SPD at installation location 1 must be energy coordinated with the other SPDs (see Page 61).
To ensure the coordination of the SPDs, it is recommended that only SPDs from one manufacturer be used in an electrical system.

The effective protection range of an SPD is (in the energy flow direction) approx. 10 m of cable length. If this cable length is exceeded, an additional SPD should be installed as close as possible to the equipment to be protected. The necessary rated impulse voltage of the equipment to be protected must be observed.

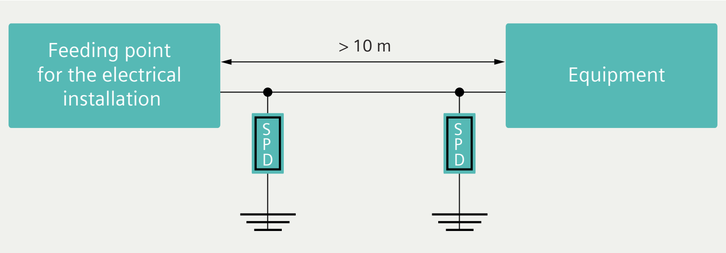


Fig. 27: Effective protection range of an SPD

7.1 Type 1 SPD (lightning arrester)

If structures are equipped with external lightning protection systems or protection against the effects of direct lightning strikes is otherwise required, Type 1 SPDs must be installed for the purpose of lightning equipotential bonding.
Lightning arresters have the task of discharging long-duration lightning currents with very high current amplitudes. The typical installation location for Type 1 SPDs as the first protection level is the central power supply of buildings or plants (installation location 1 in Fig. 26). In industrial plants with medium-voltage infeed, the SPDs must be installed in the low-voltage main distribution board.
Type 1 SPDs consisting exclusively of spark gaps may also be installed upstream of the meter.

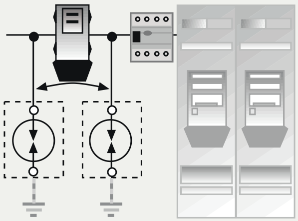


Fig. 28: Installation environment for Type 1 arresters

Practical tip

The lightning test current I_{imp} (10/350 µs) required for a Type 1 SPD depends among other things on the selected lightning protection class (see DIN VDE 0185-305). This can result in higher demands on the lightning test current I_{imp} than the requirements from the tables listed above.
Type 1 SPDs with the following lightning test currents I_{imp} (10/350 µs) have proven themselves on the market and in practice:
ph – N: 12.5 ... 50.0 kA
ph – PE: 12.5 ... 50.0 kA
N – PE: 50.0 ... 100.0 kA

For **industrial applications** with 3-phase power supply systems and 5 conductors, Type 1 SPDs with a ph-N discharge capacity of 25 kA (10/350 µs) and an N-PE discharge capacity of 100 kA (10/350 µs) are used in practice. Such a Type 1 SPD meets the requirements of all lightning protection classes (according to DIN VDE 0185-305).

If only the **requirements of lightning protection classes III and IV** have to be met, Type 1 SPDs with a ph-N discharge capacity of 12.5 kA (10/350 µs) and an N-PE discharge capacity of 50 kA (10/350 µs) can also be used for 3-phase power supply systems with 5 conductors.
Type 1 SPDs with a ph-N discharge capacity of 12.5 kA (10/350 µs) are currently composed of varistors. These SPDs have a considerably higher residual voltage curve than SPDs comprising spark gaps when transmitting long-duration lightning currents. For this reason, SPDs with spark gaps have a better protective effect for the downstream installation than Type 1 SPDs comprising varistors in the case of long-duration lightning currents. In order to achieve an optimized protective effect with long-duration lightning currents, a Type 1 SPD consisting of spark gaps should therefore preferably be used at installation location 1 (1st protection level).

7.2 Type 2 SPD

For protection against indirect lightning effects and switching overvoltages entering the system via the supply lines, at least Type 2 SPDs must be installed at or near the feed point (installation location 1).
These SPDs can discharge relatively high surge currents of the waveform (8/20 µs) and relieve the device protection at high-energy overvoltages that are too high. The typical installation location is the sub-distribution board (installation location 2).
The SPDs must be installed upstream of the residual current protective devices (RCDs). In this way, the contacts of the residual current protective device are not loaded by the high leakage currents and unnecessary disconnections are avoided.

7.3 Type 3 SPD

Type 3 SPDs are installed directly upstream of the device to be protected (installation location 3). This prevents overvoltages from discharging back into the already protected line, which would result in voltage increases due to reflection of voltage pulses at the end of lines. To avoid unwanted coupling of voltage pulses or current pulses, care should be taken to ensure that connecting cables already protected by SPDs are not routed in parallel with unprotected lines.

7.4 Stub connection and V-shaped connection

When connecting SPDs, a distinction is made between a stub connection and a V-shaped connection.
With the stub connection, the SPD terminals are connected to the (main) power supply system via a single line. This results in a T-shaped connection geometry (T wiring).
With this type of connection, the plant back-up fuse F1 can have a higher rating than the maximum permissible back-up fuse of the SPD, since the SPD in the line stub can be protected separately with a fuse F2.

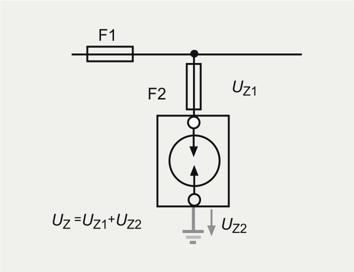


Fig. 29: Stub connection

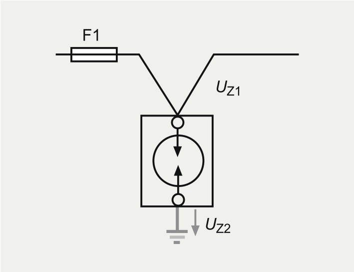


Fig. 30: V-shaped connection

With the V-shaped connection (V wiring), the incoming and outgoing lines are each connected directly to a terminal of the protective device. Possible additional voltages U_Z on the spur lines (see section 7.6.) are therefore limited to a minimum. In this case, the plant fuse F1 must not exceed the maximum SPD back-up fuse rating for V-shaped wiring specified in the data sheet.
The connection form mainly used in electrical systems for Type 1 SPDs and Type 2 SPDs is the stub connection.

7.5 Fuse protection for SPDs

A fuse connected upstream of the SPD primarily disconnects a faulty, short-circuited SPD from the mains.
SPDs with switching characteristics (spark gaps, GFSAs) must always be selected so that they are always capable of automatically extinguishing the prospective (uninfluenced) short-circuit current that may occur at the SPD's installation location. This means that the follow current discharge capacity I_{fi} specified for the corresponding SPD must be greater than the maximum short-circuit current to be expected at the SPD's installation location.

Notes on planning

The selected arrangement of fuses can be used to determine whether security of supply or protection against overvoltages is paramount.
If an additional fuse F2 is installed in the branch to the SPD, security of supply has priority. A fault in the overvoltage protection device does not cause the entire system section to shut down. The current discrimination with respect to F1 is given for fuses with gG/gL characteristics if the nominal fuse ratings are at least in the ratio F2:F1 = 1:1.6. The fuse F2 should always be sufficiently large to withstand the transient surge currents actually expected at the installation location of the fuse.

Note
The maximum permissible back-up fuse specified by the manufacturers always refers to the maximum surge current discharge capacity of an SPD in the protection path ph-N and the maximum permissible prospective short-circuit current at the SPD's installation location, according to IEC 61643-11 or DIN EN 61643-11.
At many locations where SPDs are installed, the actual surge currents to be expected in the protection path ph-N are significantly lower than the surge currents used for testing SPDs according to IEC 61643-11 or DIN EN 61643-11.

When selecting the back-up fuses, the planner of the overvoltage protection must make a practical consideration – taking into account the desired availability/supply reliability, limitation of short-circuit currents, selectivity and the surge currents in the protection path ph/N that can actually be expected at the installation location. In real systems, this deliberation process usually results in planners choosing fuses with a rated current value that is significantly lower than the rated current value of the maximum permissible back-up fuse for an SPD.

A high-energy transient surge current that is let through by the fuse F1 without melting the fuse can cause a smaller dimensioned fuse F2 to melt and thus disconnect the SPD from the mains. A possible melting of the fuse F2 can be detected, e.g. with the aid of a suitable fuse monitoring system.

If only one F1 fuse is installed, protection against overvoltages has priority. In this constellation, the entire plant section is switched off by triggering F1 if a fault occurs in the SPD or if the actual surge current exceeds the ampacity (surge current carrying capacity) of fuse F1. Sufficient dimensioning or an earth- and short-circuit-proof installation of the spur line must be ensured.

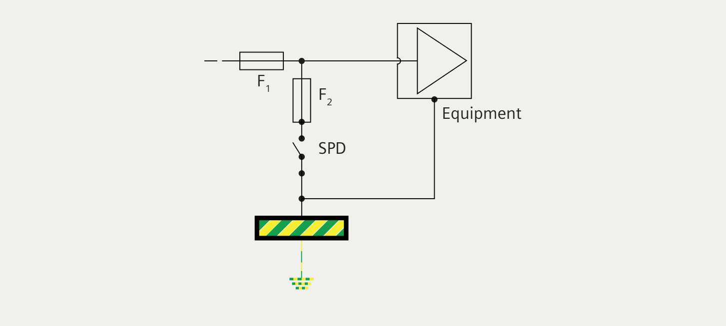
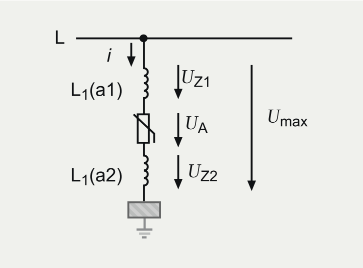


Fig. 31: Protection of SPDs with stub connection

If the fuse F1 is generally smaller than the maximum possible back-up fuse F2, no fuse needs to be installed upstream of the SPD.

7.6 Cable lengths and additional voltages

Additional voltages U_Z occur due to surge currents and/or partial lightning currents through the connecting cables of the protective devices. The ohmic resistance of a line plays only a minor role in overvoltage protection. However, the inductive component of the cables is particularly effective during the very short rise times of surge currents and lightning currents. These large current changes in a very short time can cause inductive additional voltages of up to several kV in cables. When objectively assessing the hazard of the relevant plant section, the additional voltages must be determined and added to the limiting voltage of the SPD.
For this reason, the connecting cables of the SPDs must always be kept as short as possible.



U_A	Residual voltage
U_{Z1}, U_{Z2}	Inductive additional voltages
U_{max}	Maximum overvoltage between current-carrying conductors and equipotential bonding rail
i	Partial lightning current

Fig. 32: Voltages on the connecting cables of the SPD: Depiction of additional voltage

Fig. 33 and Fig. 34 show the lines for the different connection options. According to the current standards (DIN VDE 0100-534), in both cases the sum of the cable lengths (a+b+c) must not exceed 0.5 m or suitable measures must be taken to ensure sufficient protection for the downstream installation.

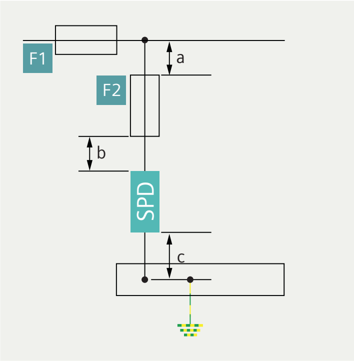


Fig. 33: Connection lengths for stub wiring

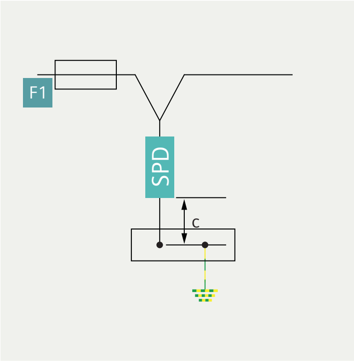


Fig. 34: Connection lengths for V wiring

If longer supply lines are used, the protective effect of the SPDs is reduced. If the total length of the connecting cables specified in the standards is exceeded, the following measures must be taken to ensure the protection of the downstream installation:

1. Use of an SPD with a sufficiently lower protection level U_P
2. Use of a second, energy coordinated SPD in the vicinity of the equipment to be protected in order to adapt the protection level U_P to the rated impulse voltage of the equipment to be protected
3. SPD connection by means of “V wiring”

7.7 Conductor cross-sections of the connecting cables

The minimum cross-sections for cables between active conductors and SPDs are:

- Type 1 SPDs: at least 6.0 mm^2 Cu or equivalent
- Type 2 SPDs: at least 2.5 mm^2 Cu or equivalent

The minimum cross-sections for cables between SPDs and the PE or PEN conductor are:

- Type 1 SPDs: at least 16.0 mm^2 Cu or equivalent
- Type 2 SPDs: at least 6.0 mm^2 Cu or equivalent

7.8 Connection diagrams and requirements

The connection diagrams for SPDs shown below depend on the respective network configuration:

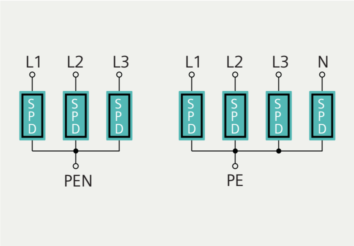


Fig. 35: Connection diagram 1 (e.g. 3+0 or 4+0 circuit)

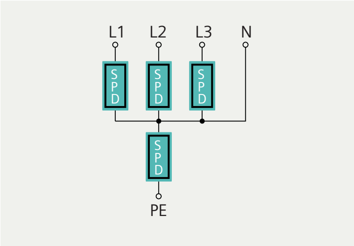


Fig. 36: Connection diagram 2 (e.g. 3+1 circuit)

Network configuration at the installation location of the SPD combination	Connection diagram 1	Connection diagram 2
TN system	X	X
TT system	Not permissible in Germany	X
IT system with incorporated neutral conductor	X	X
IT system without incorporated neutral conductor	X	N/A
X = applicable, N/A = not applicable		

Table 3: Connection diagrams

In connection diagram 1, one SPD is arranged between each of the phase conductors and the PE/PEN conductor.
In connection diagram 2, one SPD is connected between each phase conductor and the neutral conductor. The protection path between neutral conductor and earth is connected with a special SPD (N-PE total spark gap). The sum of all partial surge currents resulting from an overvoltage/surge current coupling into the active lines, i.e. into the phase and neutral conductors, must be completely controlled by the total current spark gap.

According to the new installation regulations DIN VDE 0100-443 and DIN VDE 0100-534, the following minimum values for the leakage currents are specified for these two connection diagrams.

Case 1: Buildings with external lightning protection system
For buildings with an external lightning protection system, a Type 1 SPD must be installed at location 1 and the required lightning test current I_{imp} of Type 1 SPDs must be selected as follows:

- If no risk analysis according to DIN VDE 0185-305-2 has been carried out, the lightning impulse current I_{imp} must at least correspond to the values in Table 4.
- If a risk analysis according to DIN VDE 0185-305-2 has been carried out, the lightning impulse current I_{imp} must be determined in accordance with the lightning protection standard VDE 0185-305.

Connection	I_{imp} [kA]			
	1-phase network system		3-phase network system	
	Connection diagram 1	Connection diagram 2	Connection diagram 1	Connection diagram 2
ph – N	–	12.5	–	12.5
ph – PE	12.5	–	12.5	–
N – PE	12.5	25	12.5	50

Table 4: Minimum values of the impulse leakage current I_{imp} (10/350 µs) – Case 1

Case 2: Building without external lightning protection system, but with overhead line infeed

Type 1 SPDs must be used at installation location 1 in buildings with overhead line infeed. This also applies if the supply cable between the last mast of the overhead line and the structure is designed as an underground cable.

These Type 1 SPDs must be designed at least for lightning impulse currents I_{imp} in accordance with Table 5.

The minimum values of lightning impulse current I_{imp} according to the tables for Type 1 SPDs are assigned to lightning protection class III and IV in conformity with the specifications of the lightning protection standard series VDE 0185-305.

Connection	I_{imp} [kA]			
	1-phase network system		3-phase network system	
	Connection diagram 1	Connection diagram 2	Connection diagram 1	Connection diagram 2
ph – N	–	5	–	5
ph – PE	5	–	5	–
N – PE	5	10	5	20

Table 5: Minimum values of the impulse leakage current I_{imp} (10/350 µs) – Case 2

Case 3: Building without external lightning protection system, but with underground cable infeed

In buildings with underground cable infeed, overvoltages may occur due to indirect lightning strikes. Type 2 SPDs (for increased safety requirements) must therefore be used at installation location 1. These must be designed at least for rated leakage currents of I_n (8/20 µs) according to Table 6.

Connection	I_n [kA]			
	1-phase network system		3-phase network system	
	Connection diagram 1	Connection diagram 2	Connection diagram 1	Connection diagram 2
ph – N	–	10	–	10
ph – PE	10	–	10	–
N – PE	10	20	10	40

Table 6: Minimum values of rated leakage currents I_n (8/20 µs) for Type 2 SPDs at installation location 1

The minimum values of rated leakage currents I_n (8/20 µs) for Type 2 SPDs at installation locations 2 and 3 are listed in Table 7.

Connection	I_n [kA]			
	1-phase network system		3-phase network system	
	Connection diagram 1	Connection diagram 2	Connection diagram 1	Connection diagram 2
ph – N	–	5	–	5
ph – PE	5	–	5	–
N – PE	5	10	5	20

Table 7: Minimum values of rated leakage currents I_n (8/20 µs) for Type 2 SPDs at installation locations 2 and 3

8. Quality characteristics – certifications

The quality and performance capacity of SPDs is difficult for a customer to assess. Correct function can only be tested in the appropriate laboratories. Besides the external appearance and haptics, only the technical data specified by the manufacturer can therefore provide orientation.
This makes it all the more important for the manufacturer to make a reliable statement on the performance capacity of the SPD and for the necessary tests in the respective product standard of the IEC 61643 series to have been passed.
An initial quality statement is given by the CE Declaration of Conformity. It proves the conformity of the product with the Low Voltage Directive 2014/35/EC of the European Union. For SPDs, compliance with the product standards of the EN 61643 series, which are based on the IEC 61643 series, is a prime prerequisite. However, the CE conformity assessment and declaration is carried out by the manufacturer himself. It is not a seal of approval from an independent institute. The CE mark on the product merely indicates that the manufacturer confirms compliance with the relevant regulations in relation to his product.

Product certifications from independent testing institutes are genuine proof of quality. They can also confirm compliance with the relevant product standard. In addition, they can document additional properties of the products.

Examples of independent testing institutes for this product range include

9. Glossary

Isolating arrester
Device required to disconnect an overvoltage protection device (SPD) or part of an overvoltage protection device from the mains.

Impulse sparkover voltage
Maximum voltage value before breakdown between the electrodes of the spark gap of an SPD.

Response time t
Response times largely characterize the response behavior of the individual protective elements used in arresters. Depending on the rate of rise du/dt of the surge voltage or the di/dt of the surge current, response times may change within specific limits.

Connection diagrams for SPDs
DIN VDE 0100-534 (2016) describes the three typical connection diagrams for SPDs in three-phase power supply systems. They are referred to as 3+0, 4+0 and 3+1 circuits. In Germany, the 4+0 circuit is only permissible in TT systems if the SPD is installed in the energy flow direction downstream of a residual current protective device (RCD).

Rated impulse voltage U_w
Value of an impulse withstand voltage specified by the manufacturer for a piece of equipment, or part of it, and which indicates the specified withstand capability of its associated insulation against transient overvoltages.

Lightning protection system
System consisting of air terminal rods, down conductors and grounding system (outside the building) as well as the equipotential bonding system and coordinated SPD system (inside the building) for protection against damage from overvoltages and surge currents from lightning discharges.

Lightning protection class
A normative classification of lightning protection systems into classes I to IV, which are related to a set of lightning current parameter values with regard to the probability that the corresponding maximum and minimum rated values will not be exceeded for naturally occurring lightning flashes and that the lightning can be safely dissipated. Lightning protection class I corresponds to the highest rated values and the highest capture probability. The values decrease accordingly up to lightning protection class IV.

Lightning protection zone
Zone in which the electromagnetic environment is defined with regard to the lightning hazard. All (supply) lines crossing the zone boundaries must be included in the lightning equipotential bonding via appropriate SPDs. The zone boundaries of a lightning protection zone are not necessarily physical boundaries (e.g. walls, floor or ceiling).

Lightning impulse current I_{imp}
Peak value of a leakage current by an overvoltage protection device (SPD) with a specific charge Q and a specific energy W/R in a fixed time. The pulse shape (10/350 µs) of a surge current is characteristic of the effects of a direct lightning strike. The value of the impulse leakage current is used for the special tests of an SPD to verify the load capacity with respect to high-energy lightning currents. Depending on the specified lightning protection class for a lightning protection system, the SPDs must meet corresponding minimum values with regard to this value.

EMC
EMC stands for electromagnetic compatibility: the ability of an apparatus, installation or system to operate satisfactorily in the electromagnetic environment without itself causing electromagnetic interference which would be unacceptable to the apparatus, installations or systems in that environment.

Energy coordination

The term energy coordination refers to the selective and coordinated response of the successive protection levels of an overvoltage protection system. This prevents overloading of individual components.
The relevant requirements and basic principles are described in detail in Appendix C of EN 62305-4.

Follow current discharge capacity I_{fi}

The follow current discharge capacity indicates the prospective rms value of the short-circuit current at the installation location of a voltage-switching SPD, up to which the SPD automatically returns to a high-impedance state when the maximum continuous voltage U_C is applied, after responding to a surge current and without triggering an upstream overcurrent protective device.

Maximum continuous voltage U_c

Maximum rms value of the voltage that may be continuously applied to the protection paths of the SPD (rated arrester voltage). The maximum continuous voltage must be at least 10% above the value of the rated voltage. In systems with large voltage supply deviations, SPDs with a larger difference between U_C and U_N must be used.

Insulation strength P_W

Strength exhibited by the insulation of electrical circuits of equipment against withstand and surge voltages with amplitudes above the maximum continuous voltage.

Open-circuit voltage U_{OC}

Open-circuit voltage of the hybrid generator at the connection points of the SPD. A hybrid generator generates a so-called combined surge, i.e. it delivers a voltage pulse of defined pulse shape in no-load operation, usually (1.2/50 μs), and in short circuit a current pulse of defined pulse shape, usually (8/20 μs). The combined surge is characteristic of the effects of induced overvoltages. Depending on the protection class specified for a lightning protection system, the SPDs must meet the corresponding minimum values with regard to this value.

Short-circuit strength I_{SCCR}
Highest prospective short-circuit current of the electrical network for which the SPD is designed in conjunction with the upstream overcurrent protective device. The short-circuit strength indicates the prospective short-circuit current up to which the SPD may be used at the installation location. The appropriate tests to determine this value are carried out in conjunction with the upstream overcurrent protective device.
In the case of special overvoltage protection devices for PV systems, the value I_{SCPV} corresponds to the maximum DC short-circuit current of a system up to which the SPD may be used.

Lightning protection zone, LPZ
Lightning protection zone

Rated discharge surge current I_n
Peak value of the current flowing through the SPD with the pulse shape (8/20 µs). The pulse shape (8/20 µs) of a surge current is characteristic of the effects of an indirect lightning strike or a switching operation.

Rated load current I_L
Maximum rms value of the rated current that can flow to an ohmic load connected to the protected output of the SPD. This maximum value is determined by the parts carrying operational current within the SPD: These must be able to withstand the continuous current load thermally.

Rated voltage U_N
Rated value of the voltage of the power or signal circuit, related to the intended use of the SPD. The rated voltage specified for an SPD corresponds to the system voltage of the typical location of the SPD, e.g. 230/400 V AC for a conventional three-phase system. Lower system voltages can also be protected by the SPD. For higher system voltages, it must be decided on a case-by-case basis whether the SPD can be used and whether restrictions must be observed.

OCPD
Overcurrent protective device

Protection path
Intended current path between the terminals containing one or more protective elements, e.g. between the conductors, conductors to ground, conductors to neutral, neutral to ground.

Protection level U_p
Maximum voltage that can occur at the terminals of the SPD during loading with a pulse of fixed rate of voltage rise and with a discharge current of given amplitude and waveform. This value characterizes the overvoltage protection effect of the SPD. In the event of an overvoltage phenomenon lying within the power parameters of the SPD, the voltage at the SPD's protected terminals is reliably limited to this value as a maximum.

Surge voltage
A pulse-shaped voltage characterized by a large voltage rise within a short period of time. A typical pulse shape is (1.2/50 μs), which is also used to check the response behavior of SPDs or the surge strength of equipment.

Surge current
A pulse-shaped current characterized by a large current rise within a short period of time. Typical pulse shapes are (8/20 μs) used to test the voltage limiting behavior of SPDs, and (10/350 μs), used to test the lightning current load capacity of SPDs.

Combination SPD
One or more surge protective devices (SPDs), each including all isolating arresters prescribed by the manufacturer of the surge protective device that are necessary for overvoltage protection of a specific system according to the type of ground connection.

Overvoltage protection device (SPD = surge protective device)
Protective device which contains at least one non-linear component and is intended to limit overvoltages and discharge pulse currents.

Overvoltage category
Classification of equipment into categories I to IV according to its surge strength. Overvoltage category I corresponds to the lowest value and includes particularly sensitive (terminal) devices. The values rise accordingly up to overvoltage category IV. The values for the individual categories also depend on the voltage level of the power supply system.

10. Overview of the standards

EN 50310
DIN EN 50310, VDE 0800-2-310
Telecommunications bonding networks for buildings and other structures

IEC 60099-1 + A1
EN 60099-1 + A1
DIN EN 60099-1, VDE 0675-1
Surge arresters
Part 1: Non-linear resistor type gapped surge arresters for a.c. systems

IEC 60099-4
EN 60099-4
DIN EN 60099-4, VDE 0675-4
Surge arresters
Part 4: Metal-oxide surge arresters without gaps for a.c. systems

IEC 60099-5
EN 60099-5
DIN EN 60099-5, VDE 0675-5
Surge arresters
Part 5: Selection and application recommendations

IEC 60364-1
HD 60364-1
DIN VDE 0100-100, VDE 0100-100
Low-voltage electrical installations
Part 1: Fundamental Principles, Assessment of General Characteristics, Definitions

IEC 60364-4-41
HD 60364-4-41
DIN VDE 0100-410 + A1
Low-voltage electrical installations
Part 4-41: Protection for safety - Protection against electric shock

IEC 60364-4-44 + A1
HD 60364-4-443
DIN VDE 0100-443, VDE 0100-443
Low-voltage electrical installations
Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances
Clause 443: Protection against transient overvoltages of atmospheric origin or due to switching

IEC 60364-5-53 Edition 3.2
HD 60364-5-53
DIN VDE 0100-534, VDE 0100-534
Low-voltage electrical installations
Part 5-53: Selection and erection of electrical equipment – Isolation, switching and control
Clause 534: Devices for protection against transient overvoltages (SPDs)

IEC 60364-5-54
HD 60364-5-54
DIN VDE 0100-540, VDE 0100-540
Low-voltage electrical installations
Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors

IEC 60364-7-717
HD 60364-7-712
DIN VDE 0100-717
Low-voltage electrical installations
Part 7-717: Requirements for special installations or locations – Mobile or transportable units

IEC 60664-1
EN 60664-1
DIN EN 60664-1, VDE 0110-1
Insulation coordination for equipment within low-voltage systems
Part 1: Principles, requirements and tests

IEC 61643-11
EN 61643-11
DIN EN 61643-11, VDE 0675-6-11
Low-voltage surge protective devices
Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods

IEC 61643-12
CLC/TS 61643-12
DIN CLC/TS 61643-12, VDE V 0675-6-12
Low-voltage surge protective devices
Part 12: Surge protective devices connected to low-voltage power distribution systems – Selection and application principles

IEC 61643-21
EN 61643-21
DIN EN 61643-21, VDE 0845-3-1
Low-voltage surge protective devices
Part 21: Surge protective devices connected to telecommunications and signalling networks – Performance requirements and testing methods

IEC 62305-1
EN 62305-1
VDE 0185-305-1
Protection against lightning
Part 1: General principles

IEC 62305-2
EN 62305-2
VDE 0185-305-2
Protection against lightning
Part 2: Risk management – Calculation assistance for assessment of risk for structures

IEC 62305-3
EN 62305-3
VDE 0185-305-3
Protection against lightning
Part 3: Physical damage to structures and life hazard

IEC 62305-4
EN 62305-4
DIN EN 62305-4, VDE 0185-305-4
Protection against lightning
Part 4: Electrical and electronic systems within structures

IEC 62911
EN 62911
DIN EN 62911, VDE 0868-911
Audio, video and information technology equipment – Routine electrical safety testing in production

11. List of figures and tables

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