# Lightning current and overvoltage protection device

## BETA Low-Voltage Circuit Protection Technology Primer


Answers for industry.

SIEMENS

## Preface

Be it protection, switching, monitoring or measurement – BETA Low-Voltage Circuit Protection offers you a broad overall spectrum – for residential buildings just as much as for non-residential buildings or industrial applications. It puts your entire electrical circuit system under your control.

More than a million lightning strikes are registered in Germany each year. This is an enormous risk for buildings and plants since lightning current and line surges, left unchecked, can cause considerable damage. Many times, however, nobody realizes that damage, when it occurs, has been caused by lightning current or line surges.

Even so, the use of lightning and overvoltage protection devices does not receive the attention it deserves despite the indisputable necessity in electrical installations. This may be due to the costs involved, but is certainly also based on the highly specialized subject of overvoltage protection. The higher costs are easily justified, though, as soon as the very first overvoltage event occurs.

Under its BETA product line, Siemens offers a complete range of low-voltage circuit protection technology. This product guide is intended to explain lightning and surge protection issues more clearly and provide practical tips for installation of our high-quality products for lightning and surge protection.

The BETA Low-Voltage Circuit Protection Team

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# Product portfolio of Siemens lightning and surge arresters

## Lightning arresters Type 1

**5SD7 4**
- With plug-in protection moduls for TN-C, TN-S and TT networks
- Rated voltage 350 V AC for lightning currents from 50 to 100 kA
- All versions feature remote signaling contact
- For installation in main distribution boards, upstream or downstream of meter

## Combination Surge Arresters Type 1 and Type 2

**5SD7 4**
- With plug-in protection blocks for TN-C, TN-S and TT networks
- Rated voltage 350 V AC for lightning currents from 50 to 100 kA
- All versions with remote signaling contact
- For installation in main distribution boards, downstream of meter

## Surge arresters Type 2

**5SD7 4**
- With plug-in protection blocks for TN-C, TN-S and TT networks
- Rated voltage 350 V AC
- Nominal leakage current 20 kA
- Leakage current 40 kA
- For installation in sub-distribution boards

## Surge arresters Type 3


**5SD7 4**
- With plug-in protection blocks for 1-phase and 3-phase systems
- Rated voltage 1-phase 24 V AC/DC, 60 V, 120 V, 230 V and 3-phase 230/400 V AC
- For installation as close as possible upstream of the terminal equipment

## Overvoltage protection adapters


**5SD7 4**
- Plugs into SCHUKO socket outlets with status display and monitoring of protection circuit
- For line contactor, telecommunications devices, ISDN/RDSI, TV/radio and SAT sets

# 1 Basic information

## 1.1 Consequences of lightning strikes and overvoltage events

Overvoltage causes considerable damage to electrical and electronic equipment. In many cases, all it takes is a small voltage peak on the supply line. This is apparent from damage profiles of destroyed lines, circuit boards or switching devices. Such damage can be prevented by taking the proper measures to protect from overvoltage.

Roughly a third of all claims reimbursed by building insurers can be attributed to lightning strikes and overvoltage events. For homeowners insurance, that rate of claims is even higher at 45 percent. However, while claims from residential buildings usually "only" involve upmarket hi-fis or PCs, the damage befalling commercial or industrial property can quickly skyrocket. Aside from the severe and direct damage to electronic equipment, the consequential damage should not be underestimated. In industry, if there is a loss of power and/or the computer systems fail, then production comes to a halt, and the losses begin to mount.

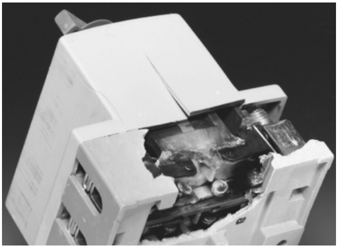


*Image 1: Overvoltage damage to an RCCB (residual current circuit breaker)*

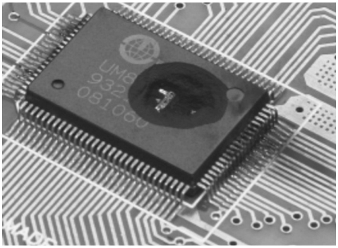


*Image 2: Overvoltage damage to printed board*

While insurance companies usually pay the claims of plant operators for electronic equipment, the added time and expense for acquiring replacements or making repairs is not reimbursed and should not be underestimated. Software damage, loss of data or plant downtime always entail a financial burden which is often not covered by any insurance policy. Therefore, lightning and overvoltage protection appropriate to the local conditions is an absolute must.

## 1.2 Causes for overvoltage

Overvoltage can occur due to a lightning electromagnetic pulse (LEMP), switching electromagnetic pulse (SEMP) or electrostatic discharge (ESD).

It only takes a split second. That is why they are also referred to as transient voltages or transients. They have very brief rise times of a few microseconds before they drop off relatively slowly over a time frame of up to several 100 microseconds.

## 1.3 Protection from lightning current and overvoltage events

Implement a comprehensive protection concept, consisting of line protection, personal and fire protection as well as lightning current and overvoltage protection requires a completely harmonized range of protective devices. BETA low-voltage protective devices are based on German and international standards and feature a maximum degree of safety and protection. The uniform lightning current and surge protection it provides ranges from lightning arresters and surge arresters to special protective devices for sensitive electronics – for all network systems in installation technology (TNC, TNS and TT systems).

The surge protection devices are often referred to simply as SPDs.

## 1.4 Risk analysis

The risk management described in the IEC 62305-2 standard is based on a preceding risk analysis to specify the necessity for lightning protection and determine the most technically effective and economical protective measures described in IEC 62305-3 and DIN EN 62305-4. This analysis divides the property to be protected into one or more lightning protection zones (LPZ). Each LPZ is defined according to geometrical limits, relevant characteristic data, the lightning hazard data and the types of damage to expect. Based on an unprotected condition of the property, the assumed risk is minimized through (further) protective measures until an acceptable level of residual risk is reached. The standard includes protective measures for buildings and the people in it, for electrical and electronic equipment and for supply lines.

The described procedures can be used both to determine the protection class of a lightning protection system and to define a complex protection system to protect from lightning electromagnetic pulse.

The following table shows the lightning current parameters of the first impulse current within the various lightning protection classes.

| Lightning protection class | I | II | III+IV |
|---|---|---|---|
| I [kA] | 200 | 150 | 100 |
| $T_1$ [μs] | 10 | 10 | 10 |
| $T_2$ [μs] | 350 | 350 | 350 |
| $Q_s$ [As] | 100 | 75 | 50 |
| W/R [MJ/Ω] | 10 | 5.6 | 2.5 |

*Table 1: Lightning current parameters of the first impulse current within the various lightning protection classes*

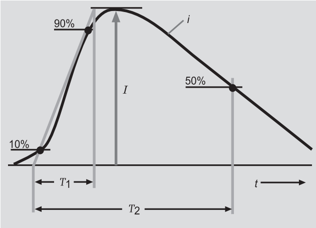



*Figure 1: Impulse form of an impulse current*

**Key to table and figure:**

I [kA] = peak current (*1)

$T_1$ [μs] = front time (*2)

$T_2$ [μs] = half life on wave tail (*3)

$Q_s$ [As] = charge

W/R [MJ/Ω] = specific energy

Lightning currents are shown with an impulse current of waveform 10/350 μs.

(*1) = Maximum value of impulse current

(*2) = Rise time of impulse current from 10 % to 90 % of peak current

(*3) = 50 % of peak current in the fall time, measured from the point of 10 % of peak current

## 1.5 Distribution of lightning current when lightning strikes a building

When lightning strikes a building, the IEC 62305 standard states that approx. 50 % of the lightning current is conducted via the outside lightning protection system (lightning arrester) into ground. Up to 50 % of the remaining lightning current flows into the building via electrically conducting systems such as the main equipotential bonding conductor. Therefore, it is always necessary to install an inside lightning protection system in addition to the outside protection system.

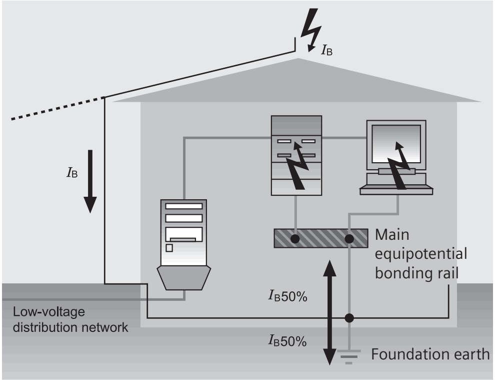



*Figure 2: Distribution of lightning current upon lightning discharge on a building*

The lightning protection classes specified in the standard define the maximum expected total lightning current inside the building.

| Total lightning current (10/350 μs) | Lightning protection class |
|---|---|
| 100 kA | I |
| 75 kA | II |
| 50 kA | III + IV |

*Table 2: Categories of lightning protection classes*

It can be assumed that the total lightning current is distributed evenly among the conductors of the power supply system. Therefore, the lightning currents on the individual conductors are much smaller than the total lightning current.

| Number of "active" conductors | Max. expected lightning current per conductor (10/350 μs) | Lightning protection class |
| --- | --- | --- |
| 4 | 25.0 kA | I |
| | 18.7 kA | II |
| | 12.5 kA | III + IV |
| 3 | 33.3 kA | I |
| | 25.0 kA | II |
| | 16.6 kA | III + IV |

*Table 3: Maximal expected lightning current per conductor*

## 1.6 Lightning protection zone concept

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

Siemens employs the lightning protection zone concept described in IEC 62305. This concept combines devices or areas into groups with the same risk potential which can be switched with arresters of the same type.

Depending on the requirement, lightning current or overvoltage protection devices are used at the transitions between lightning protection zones and installed in an appropriate location such as the main or sub-distribution system.

The protection zones are defined as follows:

**Zone 0 (LPZ 0):**

Outside the building/exposed to direct lightning strikes:

– No shielding against lightning strikes (LEMP)
– Lightning protection zone 0A: strike hazard
– Lightning protection zone 0B: strike protected

**Zone 1 (LPZ 1):**

Inside the building/energetic transients by:

– Switching actions (SEMP)
– Lightning currents

**Zone 2 (LPZ 2):**

Inside the building/weaker transients by:

– Switching actions (SEMP)
– Electrostatic discharges (ESD)

**Zone 3 (LPZ 3):**

Inside the building:

– No transient currents or voltages generated above the limit
– Shielding and separate laying of electric circuits which may influence one another

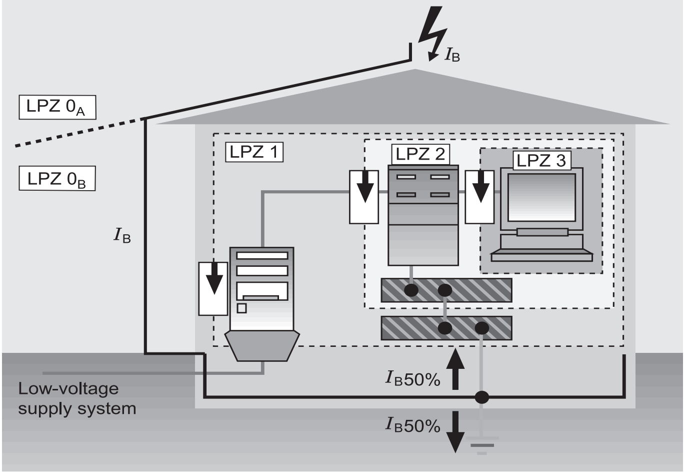



*Figure 3: Protection zones outside and inside a building*

## 1.7 Overvoltage categories and rated impulse voltage

All equipment in an electrical plant is assigned to an overvoltage category depending on its use and location. This categorization serves as a basis for determining the required rated impulse voltage (dielectric strength).

Based on this, it is possible to derive the necessary power parameters for the overvoltage protection devices to be used.

| Rated voltage of the power supply system (line) in compliance with IEC 60038 [V] | | Voltage conductor discharged to neutral conductor from the rated AC or DC voltage up to and including [V] | Rated impulse voltage [V] | | | |
|---|---|---|---|---|---|---|
| | | | Overvoltage category | | | |
| 3-phase | 1-phase | | I | II | III | IV |
| | 120–240 | 50 | 330 | 500 | 800 | 1,500 |
| | | 100 | 500 | 800 | 1,500 | 2,500 |
| | | 150 | 800 | 1,500 | 2,500 | 4,000 |
| 230/400 277/480 | | 300 | 1,500 | 2,500 | 4,000 | 6,000 |
| 400/690 | | 600 | 2,500 | 4,000 | 6,000 | 8,000 |
| 1,000 | | 1,000 | 4,000 | 6,000 | 8,000 | 12,000 |

*Table 4: Overvoltage categories and rated impulse voltages*

**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 other household appliances and similar devices.
**Overvoltage category I:** equipment connected to electrical circuits in which measures have been taken to limit transient voltages to an acceptably low level.
Example: equipment with electronic switching devices and a correspondingly low protection level.

## 1.8 Insulation coordination in compliance with DIN EN 60664-1 and IEC 60364-4-44

Insulation coordination describes the dielectric strength (proof voltage) of the insulation of a piece of equipment.

Factors to consider here are:
– The expected overvoltages and the characteristics of the overvoltage protection devices used
– The expected ambient conditions and the protective measures against contamination of the equipment

The proof voltage of the insulation for all electrotechnical equipment in various plant areas is:

– 6 kV in the main power supply network
– 4 kV in the electrical circuits (sub-distribution)
– 2.5 kV at the terminal equipment
– 1.5 kV at special terminal equipment

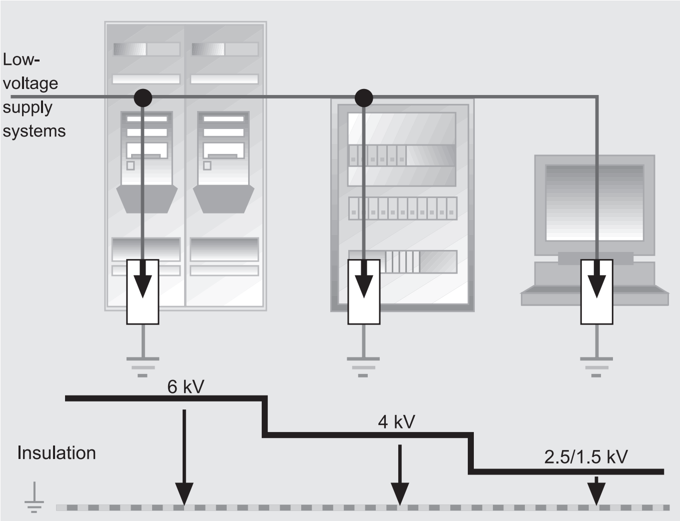



*Figure 4: Insulation coordination in compliance with DIN EN 60664-1*

## 2 Design and functioning of overvoltage protection devices

To prevent overvoltages from destroying sensitive electric plants, the conductors where such high voltages occur must be short-circuited in a flash with the equipotential bonding conductor. Various devices are available to handle this job. These devices are used individually in surge protection devices or in complex protection circuits to make simultaneous use of the different advantages.

Spark gaps, gas-filled surge arresters, varistors and suppressor diodes are used depending on the scenario. This equipment basically differs in the following:

– Discharge capacity (ampacity)
– Response behavior (response time in the event of overvoltage)
– Quench behavior (transition from low-impedance discharge state to high-impedance idle state after a discharge event)
– Voltage limitation (residual voltage/protection level for the device to be protected)

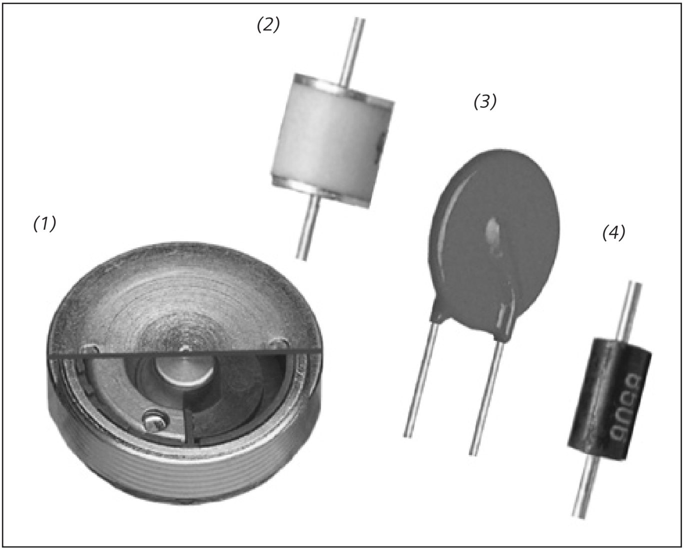



*Image 3: Equipment for SPDs: encapsulated spark gaps (1), gas-filled surge arresters (2), varistors (3) and suppressor diodes (4)*

## 2.1 Lightning arrester Type 1

Lightning arresters represent the first and most effective category of protection for the power supply. From a technical perspective, the most favorable location for installation is directly downstream of the service panel. Depending on the system of power supply (TN-C, TN-S or TT system), the appropriate lightning arrester is installed in a separate housing on the main line upstream of the meter. In this case, the responsible power utility must be consulted and/or approval obtained. Lightning arresters consisting merely of spark gaps can be installed upstream of the meter. If installation upstream of the meter is not possible, then the lightning arrester is installed in the main distribution downstream of the meter.

### Total surge current and N-PE spark gaps

A so-called 3+1 circuit is set up in power supply systems with separate N and PE conductors, for example for three-phase feeds. In this configuration, one protective device is placed between each outer conductor and the neutral conductor. The gap between the neutral conductor and ground is connected with a summation current spark gap or an N-PE spark gap. The total sum of all partial surge currents resulting from the overvoltage interference in the active lines, i. e. in the outer and neutral conductors, must now be completely mitigated by the summation current spark gap. This type of layout is free from residual current against ground. However, it requires the use of a powerful summation current spark gap. These kinds of protective devices usually feature a discharge capacity of 100 kA (10/350 μs) which, in turn, fulfills the requirements of lightning protection class I.

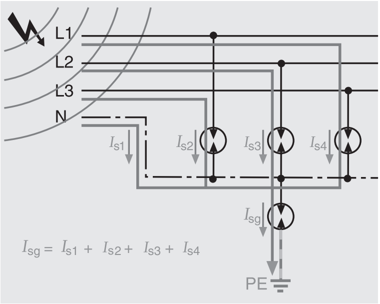



*Figure 5: Partial surge currents and summation surge current in a 3+1 circuit*

$I_{s1}$, $I_{s2}$, $I_{s3}$, $I_{s4}$ = *partial surge currents*

$I_{sg}$ = *summation surge current via N-PE spark gap*

## 2.2 Surge arrester Type 2

The Type 2 surge arrester is the second protection stage in the power supply. It reduces the residual voltage below the proof voltage of the equipment and lines in the area of the fixed installation between the electrical circuit distribution and current connection for terminal equipment. In plants with an operational voltage of e.g. 230 V, that means 2.5 kV. In general, protective devices are designed for this operational voltage, even affording a protection level of just 1.5 kV. The protection circuit consists of temperature-monitored varistors with a high discharge capacity, up to 40 kA (8/20 μs)[1].

In the case of a temperature-monitored varistor, the internal resistance of the varistor drops with the voltage-incurred overload and the leakage current in the varistor rises. There is then a corresponding rise in temperature that triggers an isolating arrester. Once a defined 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 protective device. Many protective devices also feature a remote indication contact. This contact can be used to send a signal to a central signal receiver or controller. That way, it is possible to monitor the operating state of the protective device permanently.

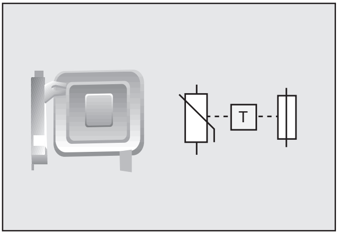



*Figure 6: Temperature-monitored varistor*

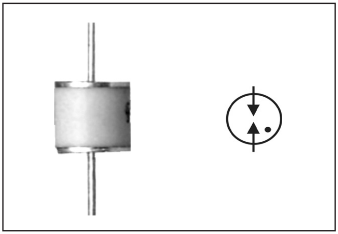


*Figure 7: Gas-filled surge arresters as N-PE spark gap*

Another version involves the N-PE spark gaps as Type 2 surge arresters. They possess a gas-filled surge arrester with an especially high discharge capacity. They are connected in so-called 3+1 circuits as a summation current spark gap between the neutral and protective earth conductor.

[1] *Surge current with waveform 8/20 μs. The energy content of this impulse is much smaller than that of a lightning impulse current (waveform 10/350 μs).*

*Image 4*

*Image 5*

Surge arrester Type 2

There are various models of Type 2 surge arresters with different designs with the following differing features:

- modular 1-pole or compact multi-pole
- plug-in or one-piece
- mounting width/pole 17.5 mm (standard) or 12 mm (space-saving)

The 1-pole protective devices have the advantage that they can be modularly configured as needed. However, this does involve a certain amount of installation work. Compact, multi-pole protective devices which already have all the required poles are available for conventional power supply systems. That makes selection and installation very easy.

Two-piece model designs where the device is placed in the connector and the basic element contains the connection contacts are very useful. With this version, the protective connector can be replaced if the device is overloaded without disturbing the installation.

## 2.3 Lightning / surge arrester combination Type 1+2

Type 1+2 arrester combinations meet the requirements for the first and second protection stage (cf. Chapter 3). Arrester combinations functioning according to the AEC principle1 have proven very effective.

From a technical perspective, the most favorable location for installation is at the building infeed. Depending on the system of power supply (TN-C, TN-S or TT networks), the proper arrester combination is installed in the main distribution system directly downstream of the current meter. Arrester combinations with varistors possess a minimal operational current (residual current) of a few mA during normal operation. 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.

[1] *AEC stands for Active Energy Control, i.e. the active energy control between Type 1 arresters and Type 2 arresters. This involves an appropriate load distribution of the surge current so that the low protection level of the Type 2 arresters and the high discharge capacity of the Type 1 arrester can be used.*

## 2.4 Surge arrester Type 3 (device protection)

The Type 3 surge arrester is the third protection stage in the power supply and reduces the residual voltage below the proof voltage of the terminal equipment. For devices with an operational voltage of e. g. 230 V, that is ≤ 1.5 kV.

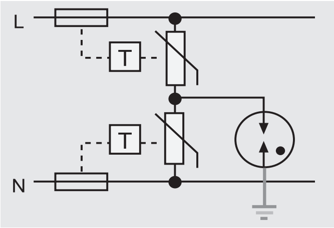



*Figure 8: Typical protection circuit of a Type 3 surge arrester*

The protection circuit generally consists of a series connection of two varistors lying between the outer and neutral conductor. A gas arrester extends to the connection point between the varistors with one connection pin and to ground with the other. This results in a series connection free from residual current of varistor and gas arrester between L-ground and N-ground. These varistors are also temperature-monitored. The heat generated by a varistor overload here triggers an isolating arrester which mechanically separates the varistor from the network before dangerous temperatures are reached.

## 2.5 Important features of the product range

- Integrated plug-in arresters with mechanical encoding
  --> Targeted and low-cost exchange of individual arresters
  --> Service work (e. g. isolation measurements) possible without interfering with the installation
- Mechanical function display requiring no power consumption
  --> Type 1 lightning arrester also for use upstream of the meter
- Powerful spark gap with increased follow current quenching capacity (Type 1)
  --> Back-up fuses are not needed and/or can be scaled down in most cases
- Remote signaling without additional space requirements in the distributor
- The rated arrester voltage is standard 350 V
  --> TOVs (temporary overvoltages) in the network cause no device interference

# 3 Protection stage concept

## 3.1 Effective protection circuit

The term “effective protection circuit” represents a gapless measure for protecting from overvoltages. The first step for developing this kind of protection concept 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, measuring and control equipment, data processing and telecommunications (transmitters/receivers).

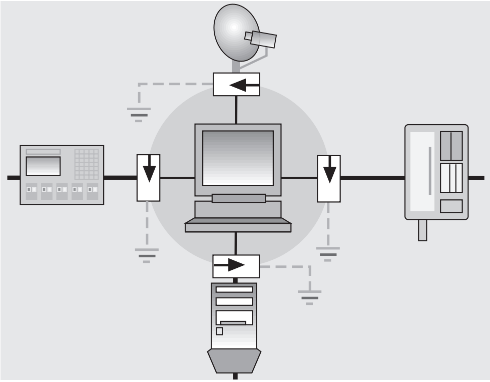


*Figure 9: Effective protection circuit*

It is best to envision the plant or equipment to be protected inside a protective room. SPDs (surge protection devices) corresponding to the rated data of the respective electrical current and/or the interface of the equipment to be protected must be installed at all “line-protection circuit” interfaces. That way, the area is secured within the protection circuit so that line-bound overvoltage interference is no longer possible.

The first step in an efficient and comprehensive overvoltage protection concept is to examine the power supply. The energetic overvoltages and surge currents occurring here cause arcing to ground through creepage and clearances and through the insulation of voltage-carrying parts and lines. All electrical equipment is affected, from the main building feed to the electrical consumers.

The measures required to protect the power supply of plants and devices depend on the results of the risk analysis. Two or three protection stages are defined. The SPDs for the individual categories basically differ in their degree of discharge capacity and their protection level according to the protection level categorization.

## 3.2 Three-level protection for power supply – Protection stages 1 and 2 installed separately

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

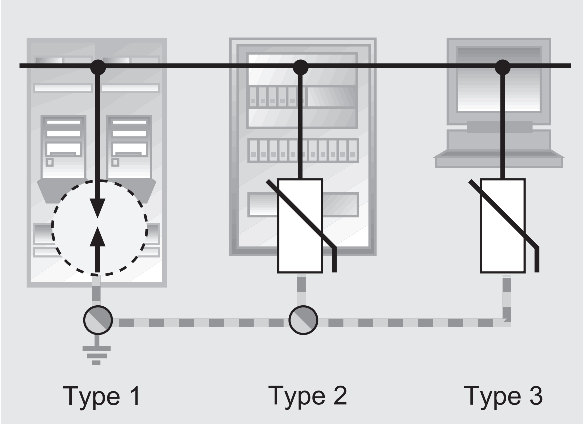



*Figure 10: Three protection stages with different installation locations in the power supply*

| Protection stage | Designation | SPD Type | Protection level | Usual installation location |
|---|---|---|---|---|
| 1 | Lightning arrester | 1 | ≤ 4 kV | Main distributor |
| 2 | Surge arrester | 2 | ≤ 2.5 kV | Sub-distributor |
| 3 | Device protection | 3 | ≤ 1.5 kV | Upstream of terminal equipment |

## 3.3 Three-level protection for power supply – Protection stages 1 and 2 combined

A three-level concept where the first and second protection stages are combined into one device is set up as follows:

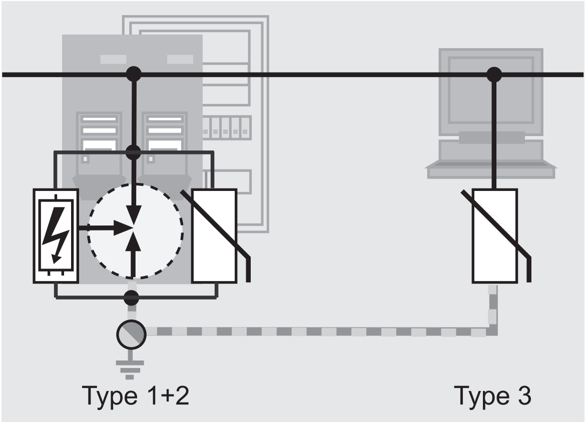



*Figure 11: Three-level protection for the power supply, protection stages 1 and 2 coordinated according to the AEC principle*

| Protection stage | Designation | SPD Type | Protection level | Usual installation location |
|---|---|---|---|---|
| 1+2 | Arrester combination | 1+2 | ≤ 2.5 kV | Main distributor |
| 3 | Device protection | 3 | ≤ 1.5 kV | Upstream of terminal equipment |

## 3.4 Two-level protection for power supply for lower risk potential

The risk potential for lightning discharges is relatively low for buildings located in the midst of residential areas and where nor 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 lightning arrester.

This resulting two-level protection with a limited discharge capacity is set up as follows:

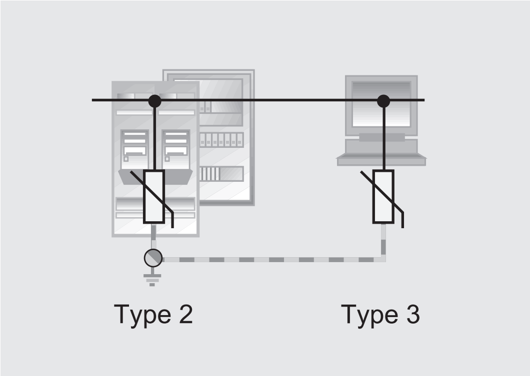



*Figure 12: Two-level protection for power supply without lightning arrester*

| Protec-tion stage | Designation | SPD Type | Protection level | Usual installation location |
|---|---|---|---|---|
| 2 | Surge arrester | 2 | ≤ 2.5 kV | Main distributor or sub-distributor |
| 3 | Device protection | 3 | ≤ 1.5 kV | Upstream of terminal equipment |

## 4 Network systems

The network system of the power supply determines which protective devices are required to provide effective protection.

The network systems basically differ in whether or not the neutral point of the supply transformer is grounded and the PE conductor is separated from or connected with the N conductor as a PEN conductor. Other differences arise from the number of phases, type of voltage and current, frequency and voltage rating.

Power distribution systems according to DIN VDE 0100-300:

- TN-S system
- TN-C system
- TT system
- IT system

### 4.1 The TN-S system

In this network system, the neutral conductor (N) and protective earth conductor (PE) are each equipped in separate conductors. Therefore, a three-phase power supply consists of five lines: L1, L2, L3, N and PE.

Systems where N and PE are separated are considered less sensitive to electromagnetic interference than systems using PEN conductors.

Systems with 1 to 3 phases are set up depending on the consumer requirements.

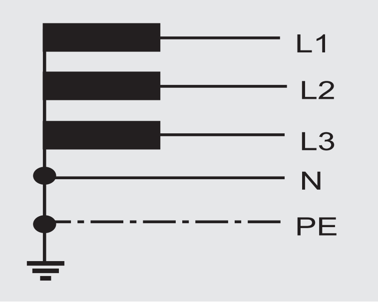



*Figure 13: TN-S system three-phase*

Applications in the TN-S system

Lightning and surge arresters are placed between the outer conductors and the neutral conductor in this case. Furthermore, a so-called "summation current spark gap" is connected between the neutral conductor and the protective earth conductor.

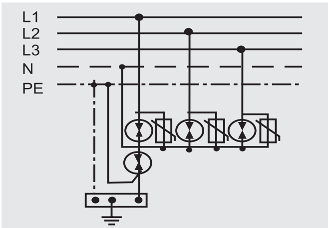


*Figure 14: Circuit diagram of a Type 1+2 arrester combination in a 3-phase TN-S system*

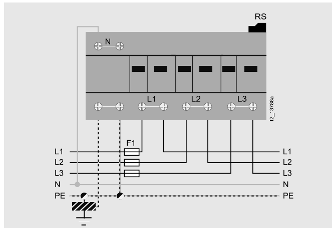


*Figure 15: Connection diagram of a Type 1+2 arrester combination in a 3-phase TN-S system*

The 1-phase device protection as a third protection stage features corresponding circuits integrated into the application-specific housing, such as outlets, outlet adapters or even modular installation devices for standard mounting rails.

## 4.2 The TN-C system

In this network system, neutral conductors (N) and protective earth conductors (PE) are combined into one conductor (PEN). Therefore, a 3-phase power supply consists of the four lines: L1, L2, L3 and PEN.

This system is considered more sensitive to electromagnetic interference than systems where N and PE are separate, as is the case in the TN-S system.

To use a conductor for protective purposes and for returning current, i. e. as a PEN conductor, the cross-section of the conductor must be at least 10 mm$^2$ Cu or 16 mm$^2$ Al. Set-up of a TN-C system is limited to applications with high electrical connected loads, such as high-powered machines or the central power supply of plants and buildings.

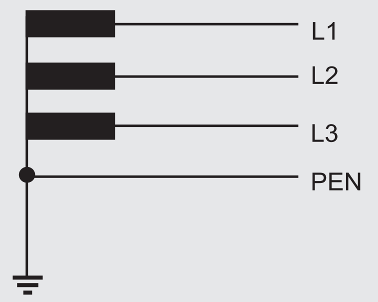



*Figure 16: TN-C system 3-phase*

Applications in the TN-C system

The lightning and surge arresters are placed here between the outer conductor and the PEN conductor.

One-phase device protection is hardly feasible for this system since the conditions for normal load circuits with connected loads of just a few kW are not present.

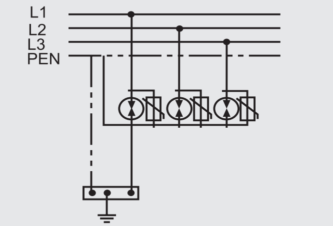



*Figure 17: Circuit diagram of a Type 1+2 arrester combination in the 3-phase TN-C system*

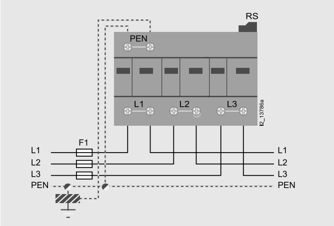



*Figure 18: Connection diagram of a Type 1+2 arrester combination in the 3-phase TN-C system*

## 4.3 The TT system

In this network system, one point is directly grounded (system ground), generally the neutral point of the transformer. The grounded point is usually connected to the plant through an N conductor. The bodies of the electrical plant are connected with ground point separated from system ground. That means a local ground is set up directly on the plant or on a building. This ground serves as the main equipotential bonding.

Neutral conductors (N) and protective earth conductors (PE) are each connected through separate conductors in this system. Therefore, a 3-phase power supply consists of the five lines: L1, L2, L3, N and the PE from the local ground.

Depending on the load requirements, the systems are set up as 1 to 3 phases.

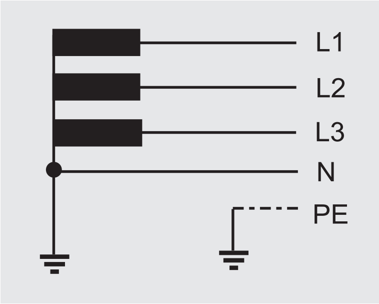



*Figure 19: TT system 3-phase*

Applications in the TT system

As is the case in the TN-S system, the lightning and surge arresters here are placed between the phases and the neutral conductors. In addition, a so-called “summation current spark gap” is set up between the neutral and protective earth conductor.

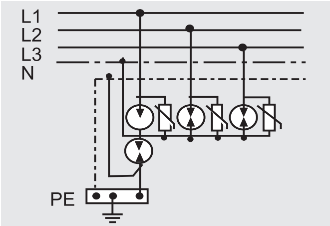



*Figure 20: Circuit diagram of a Type 1+2 arrester combination in the 3-phase TT system*

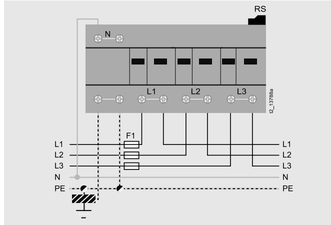



*Figure 21: Connection diagram of a Type 1+2 arrester combination in the 3-phase TT system*

One-phase device protection as the third protection stage features corresponding connections integrated into application-specific housings such as socket outlets, socket adapters or even modular installation devices for standard mounting rails.

## 4.4 Converting network systems within a plant

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).

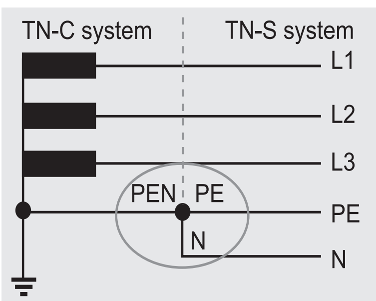



*Figure 22: Conversion of a 3-phase TN-C system into a TN-S system*

# 5 Installation notes

## 5.1 Installation notes for Type 1 lightning arresters

The typical installation location for Type 1 lightning arresters in the first stage is the central power supply of buildings or plants (see Figure 22).

The conductor cross-section in compliance with DIN EN 62305-1 is a minimum of 16 mm².

The protective devices must be protected in coordination with the given connected loads of the manufacturer. Protection levels of a max. of 250 A gG to 315 A gG are typical for these SPDs. If the plant back-up fuses have a higher rating, then the SPDs must be connected upstream of smaller fuses tuned selectively to the plant fuse system.

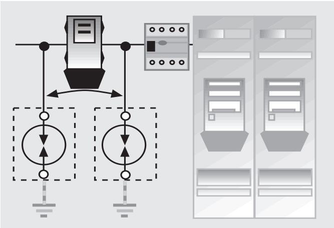


*Figure 23: Installation environment for Type 1 arresters*

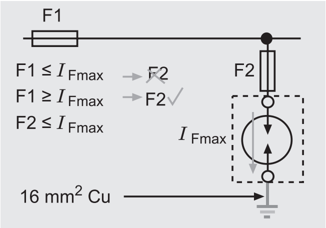



*Figure 24: Conductor cross-section and protection of Type 1 arresters*

## 5.2 Installation notes for Type 2 surge arresters

The typical installation location for Type 2 surge arresters in the second protection stage is the electrical circuit distribution/sub-distribution or the feed of control cabinets and controllers to machines.

The protective devices must be installed upstream of the residual current protective devices (RCDs). That way, the contacts of the residual current circuit breaker (RCCB) are not impaired by the leakage currents, avoiding unnecessary tripping of the sensitive summation current transformer.

The conductor cross-section in compliance with DIN EN 62305-1 is a minimum of 6 mm².

The protective devices must be protected in coordination with the given connected loads of the manufacturer. Protection levels of a max. of 125 A gG are typical for these SPDs. If the plant back-up fuses have a higher rating, then the SPDs must be connected upstream of smaller fuses tuned selectively to the plant fuse system.

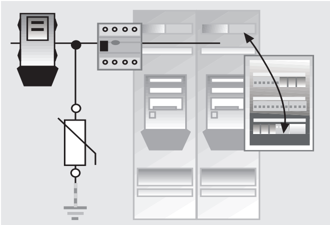


*Figure 25: Type 2 arresters are installed in the main or sub-distribution system depending on the planned protection concept*

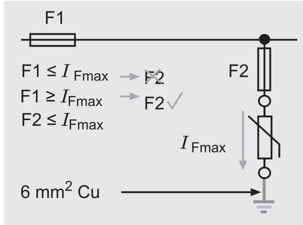



*Figure 26: Conductor cross-section and protection of Type 2 arresters*

## 5.3 Installation notes for Type 3 surge arresters (device protection)

Type 3 surge arresters are installed directly upstream of the device to be protected. This prevents overvoltages from discharging back into the already protected line. Therefore, care should be taken to ensure that loose connecting cables already protected on the device are not connected in parallel with unprotected lines.

The rated current of the installed overvoltage protection device should also be taken into consideration when protecting an electrical circuit. In general, the rated current of the protective devices is geared to practical use cases so that conventional circuit fuses such as 16 A can be used.

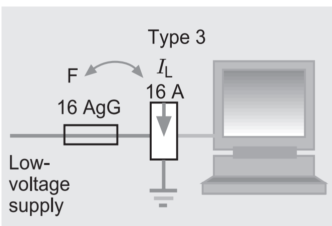
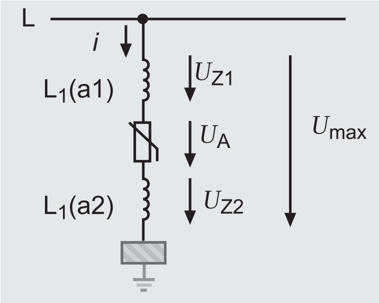



*Figure 27: The circuit fuse F must correspond to the rated current $I_L$ of the Type 3 arrester*

## 5.4 Cable lengths and additional voltage

Additional voltages 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 part of the lines does have an influence. The great fluctuations in current over just a short time cause voltages up to a few kV in the inductive part of a line. In an objective risk evaluation of the plant section involved, the additional voltages must be determined and added to the limiting voltage of the protective device.




$U_A$ = residual voltage

$U_{Z1}$ and $U_{Z2}$ = inductive additional voltages

$U_{max}$ = maximum overvoltage between current-carrying conductors and equipotential bonding rail

*$i$ = partial lightning current*

*Figure 28: Voltages on the connecting cables of the SPD. Depiction of additional voltage.*

## 5.5 Protecting overvoltage protection devices

The protective devices must be protected in coordination with the given connected loads of the manufacturer. If the plant back-up fuses have a higher rating, then the SPDs must be connected upstream of smaller fuses tuned selectively to the plant fuse system.

*Manufacturers of electrical equipment for connecting to the main power distribution system must provide a maximum permissible back-up fuse system. Type 1 and Type 2 SPDs are considered equipment in this sense, even if they do not carry any operational plant current.*

## 5.6 Branch wiring and V-type connection, T/V wiring

A distinction is drawn between a branch wiring and V-type connection particularly for Type 1 lightning arresters.
With a branch wiring, the arrester is connected to the main power distribution system over one line. The connection geometry is T-shaped. 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 F2 arrester. Accordingly, the arrester is also protected separately in the line spur.
If the back-up fuse F2 is tripped, the respective protection path and in turn the protective effect is separated from the main network. Therefore, tripping of F2 should be monitored so that errors can be quickly detected and corrected. The operating capability of the SPD should also be monitored simultaneously.

With V-type layouts, the in-and-out lines are each connected directly to a terminal on the protective device. This limits possible additional voltages $U_z$ to a minimum. In this case, the plant fuse system must not exceed the maximum fuse rating of the arrester (see data sheet).

These connection options can be used for Type 1+2 arrester combinations and for Type 2 surge arresters.

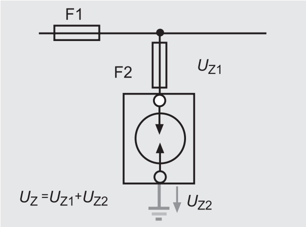



*Figure 29: Branch wiring connection (T-shaped layout)*

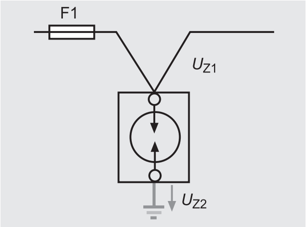



*Figure 30: V-type connection*

## 5.7 Remote signaling

Many protective devices also feature remote signaling. Many protective devices also feature a remote indication contact. This contact can be used to send a signal to a central signal receiver or controller. That way, it is possible to monitor the operating state of the protective device permanently.

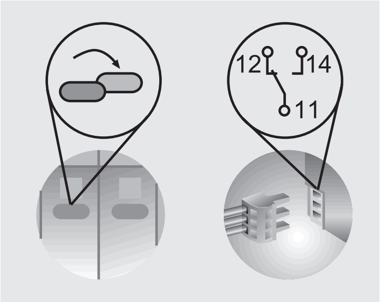



*Figure 31: Optical status display and pluggable remote signaling connection on the SPD*

## 5.8 Equipotential bonding

Possibilities for effective overvoltage protection:
- complete insulation against ground
- complete equipotential bonding (after risk analysis):
  - outside lightning protection (lightning arrester) plus inside lightning protection (lightning and surge arresters)
  - inside lightning protection (lightning and surge arresters)
  - inside overvoltage protection (surge arrester)

Complete insulation against ground is not possible for many practical applications. Therefore, a complete equipotential bonding system is usually put in place.

With complete equipotential bonding, all electrical conductors (with the exception of parts carrying operational voltage) are directly connected with the equipotential bonding lines. The electrically active parts (with supply voltage, measuring and control equipment signals, data signals, ...) are connected to the equipotential bonding system with the aid of overvoltage protection devices. In the normal operating mode, the overvoltage protection devices are high-resistance. If transients occur, the protective devices convert to low-resistance, i. e. conductive. This puts all electrically conductive and electrically active parts at nearly the same potential, effectively preventing damage from overvoltage.

A low-resistance and/or low-impedance equipotential bonding system forms the basis for effective equipotential bonding between all electrically conductive and electrically active parts of a plant.

Equipotential bonding systems come in the following forms:
- linear
- star
- meshed

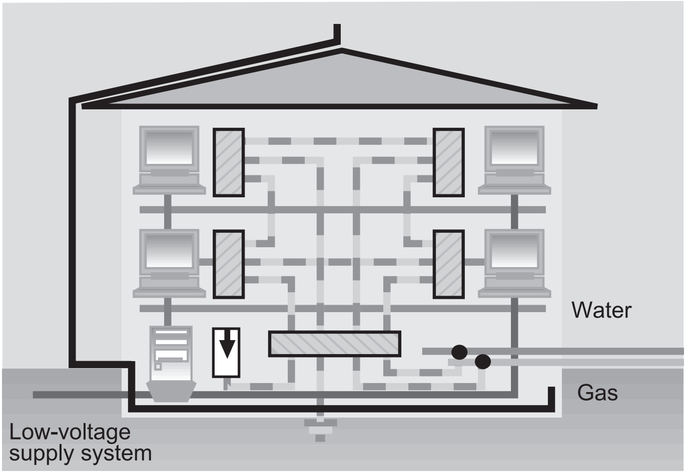



*Figure 32: Complete equipotential bonding*

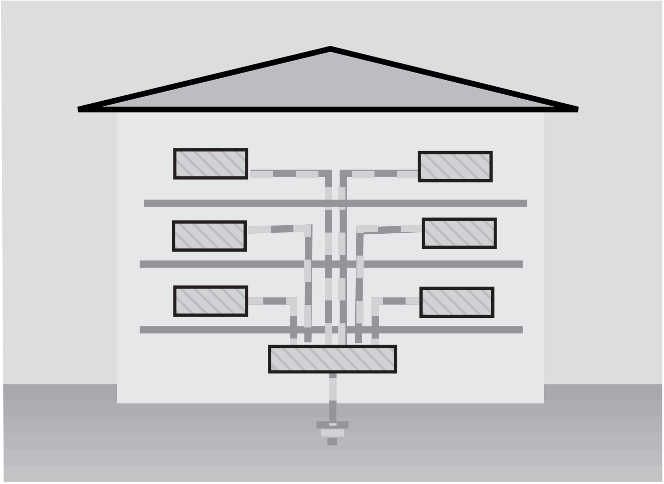


*Figure 33: Star-shaped equipotential bonding*

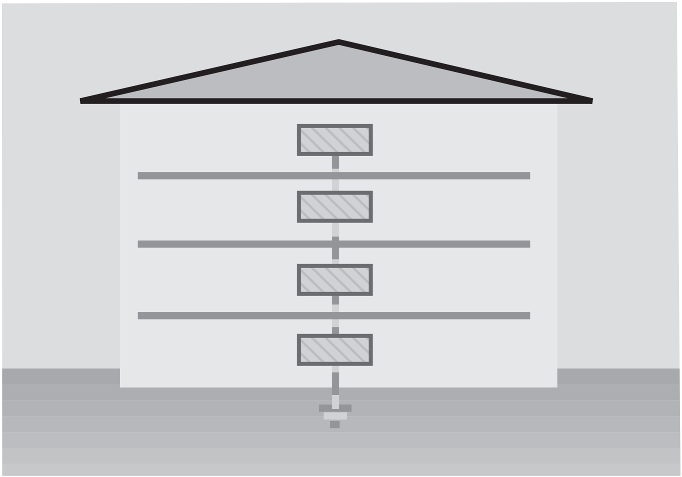


*Figure 34: Linear-shaped equipotential bonding*

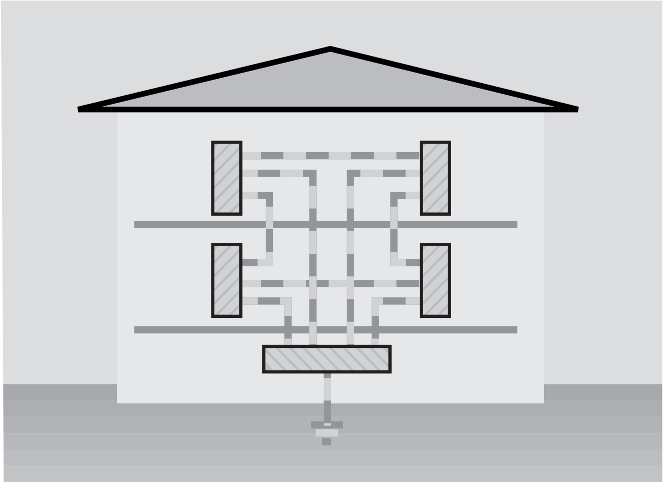
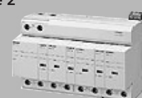


*Figure 35: Meshed equipotential bonding*

| **Situation**<br>What type of building do you want to protect? In general, all devices are suitable for residential, office, industrial and commercial structures. | **Systems** | **Basic protection**<br>for installation upstream of meter in main distribution or in combined main/sub-distribution |
|---|---|---|
| **Low-risk buildings**<br><br>– no outside lightning protection<br>– power supply via ground wire | **TN-S and TT system** | **Surge arrester Type 2**<br>Thin design<br>5SD7 424-0, 5SD7 424-1<br>Standard design<br>5SD7 464-0, 5SD7 464-1<br>With or without remote signaling<br>  |
| | **TN-C system** | **Surge arrester Type 2**<br>Thin design<br>5SD7 423-0, 5SD7 423-1<br>Standard design<br>5SD7 463-0, 5SD7 463-1<br>With or without remote signaling<br>  |
| **High-risk buildings**<br><br>– outside lightning protection system | **TN-S and TT system** | **Lightning arrester Type 1**<br>5SD7 414-1<br><br>With remote signaling<br> |
| | **TN-C system** | **Lightning arrester Type 2**<br>5SD7 413-1<br><br>With remote signaling<br> |
| <br>– power supply via overhead lines | **TN-S and TT system** | **Arrester combination Type 1 and Type 2**<br>5SD7 444-1<br><br>With remote signaling<br> |
| <br>– Grounded antenna structures | **TN-C system** | **Arrester combination Type 1 and Type 2**<br>5SD7 443-1<br><br>With remote signaling<br> |
| | **IT networks without corresponding N conductor** | IT networks are typically only used in special sections of a building. TN-C, TN-S or TT networks are usually present in the area of the main distributor. The protective devices listed above should be used in this case. |
| | **IT networks with corresponding N conductor** | |

**Equipment protection**
for installation upstream of meter in the main distribution system or in combined main/sub-distribution

**Surge arrester Type 2**
Thin design
5SD7 424-0, 5SD7 424-1
Standard design
5SD7 464-0, 5SD7 464-1
With or without remote signaling
Only necessary if the distance between the main and sub-distribution system is > 10 m

**Surge arrester Type 2**
Thin design
5SD7 423-0, 5SD7 423-1
Standard design
5SD7 463-0, 5SD7 463-1
With or without remote signaling
Only necessary if the distance between the main and sub-distribution system is > 10 m

**Surge arrester Type 2**
Thin design
5SD7 424-0, 5SD7 424-1
Standard design
5SD7 464-0, 5SD7 464-1
With or without remote signaling

**Surge arrester Type 2**
Thin design
5SD7 423-0, 5SD7 423-1
Standard design
5SD7 463-0, 5SD7 463-1
With or without remote signaling

**Surge arrester Type 2**
Thin design
5SD7 424-0, 5SD7 424-1
Standard design
5SD7 464-0, 5SD7 464-1
With or without remote signaling
Only necessary if the distance between the main and sub-distribution system is > 10 m

**Surge arrester Type 2**
Thin design
5SD7 423-0, 5SD7 423-1
Standard design
5SD7 463-0, 5SD7 463-1
With or without remote signaling
Only necessary if the distance between the main and sub-distribution system is > 10 m

**Surge arrester Type 2**
5SD7 473-0, 5SD7 473-1
3-pole (3+0 circuit)
Uc = 580 V AC
With or without remote signaling

**Surge arrester Type 2**
5SD7 485-0, 5SD7 485-1
4-pole (4+0 circuit)
Uc = 440 V AC
With or without remote signaling

**Low-voltage protection**
for installation directly upstream of the terminal equipment

**Surge arrester Type 3**
for installation in sub-distribution systems or control cabinets
5SD7 432-x and
5SD7 434-1
With remote signaling

**Overvoltage protection adapter Type 3**
for line contactor
5SD7 435-0

**Overvoltage protection adapter Type 3**
for telecommunications devices/TAE
5SD7 435-2

**Overvoltage protection adapter Type 3**
for ISDN/RDSI
5SD7 435-3

**Overvoltage protection adapter Type 3**
**for telecommunications devices/RJ12**
**5SD7 435-6**

**Overvoltage protection adapter Type 3**
for TV/radio
5SD7 435-5

**for TV/SAT sets**
5SD7 435-7

# Glossary

## Response time $t_A$

Response times mainly characterize the response behavior of individual protective elements used in arresters. Depending on the rate of rise du/dt of the surge voltage or di/dt of the surge current, the response times may vary within certain limits.

## Versions designed for Austria

The standard ÖVE/ÖNORM E 8001-1 with its corresponding supplements has been accepted for general use in Austria. The main difference for use of Type 2 surge arresters is that these devices must have a higher rated voltage (335 V AC, 440 V AC).

## Breaking capacity, follow current discharge capacity $I_{fi}$

The breaking capacity is the uninfluenced (prospective) effective value of the follow current which can be canceled from the overvoltage protection device when connecting $U_c$.

## Operating temperature range

The operating temperature range indicates the range in which the devices can be used. For non-self-heating devices, this is the same as the ambient temperature range. The rise in temperature for self-heating devices must not exceed the maximum value indicated.

## Lightning impulse current $I_{imp}$

Lightning impulse current is a standardized surge current curve with a waveform 10/350 μs. It renders the load caused by natural lightning currents with its parameters (peak value, charge, specific energy). Lightning arresters and arrester combinations must be able to discharge these kinds of lightning currents several times over without destructing.

**Frequency range**

The frequency range represents the transmission range and/or conducting range of an arrester depending on the described damping characteristics.

**Limit frequency $f_G$**

The limit frequency describes the frequency-dependent behavior of an arrestor. The imit frequency is equivalent to the frequency which induces an insertion loss ($a_E$) of 3 dB under certain test conditions (see EN 61643-21:2000). Unless otherwise indicated, this value refers to a 50 ohm system.

**Rated arrester voltage $U_c$**

The maximum continuous voltage (maximum permissible operating voltage) is the effective value of the maximum voltage which may be connected to the corresponding connection terminals of the overvoltage protection device for operation. This is the maximum voltage on the arrester in the defined, non-conducting state and that which reverts the arrester back to this state after it has tripped and discharged. The value of $U_c$ depends on the rated voltage of the system being protected as well as the installer's specifications.

**Categories in compliance with IEC 61643-21:2000**

**(DIN VDE 0845-3-1)**

A number of surge voltage impulses and surge current impulses are described in IEC 61643-21:2000 (DIN 0845-3-1) for testing the current-carrying capacity and voltage limitation of impulse interference. Table 3 of this standard lists these in categories and specifies preferred values. Siemens overvoltage protection devices surpass the values in the specified categories. Therefore, the explicit value for surge current-carrying capacity is indicated by the given rated discharge current (8/20 μs) and lightning impulse current (10/350 μs).

### Combined surge $U_{oc}$

The combined surge is produced by a hybrid generator (1.2/50 μs, 8/20 μs) with a fictitious impedance of 2 ohm. The idle voltage of this generator is referred to as $U_{oc}$. $U_{oc}$ is a preferred indicator for Type 3 surge arresters.

### Short-circuit strength

The value of the prospective short-circuit current which is mitigated by the overvoltage protection device when the corresponding back-up fuse is connected upstream.

### Maximum discharge surge current $I_{max}$

The maximum peak value of the surge current with the waveform 8/20 μs which the device can safely discharge.

### Rated discharge surge current $I_n$

The rated discharge current is the peak value of a surge current with the waveform 8/20 μs for which the overvoltage protection device is rated in a certain test program.

### Rated load current (rated current) $I_L$

The rated load current is the maximum permissible operating current which may be carried permanently through the corresponding terminals.

### Rated voltage $U_n$

This stands for the rated voltage of the system to be protected. The value of the rated voltage often serves as the type designation for protective devices used in data systems plants. It is indicated as an effective value for AC systems.

### Supply-side overcurrent protection/arrester back-up fuse

An overcurrent protection system (e. g. fuse or circuit breaker) located outside of the arrester on the infeed side is tasked with interrupting the line-frequency follow current if the breaking capacity of the overvoltage protection device is exceeded.

### N-PE arresters

Protective devices exclusively designed for installation between the N and PE conductors.

### Return loss

In high-frequency applications, return loss refers to how many parts of the “leading” wave are reflected at the protective device (“surge point“). This is a direct measure of how well a protective device is attuned to the surge impedance of the system.

### Degree of protection

The IP degree of protection corresponds to the protection categories described in DIN EN 60529 (VDE 0470-1).

### Protective earth current $I_{PE}$

The current which flows through the PE connection when the overvoltage protection device is connected to the maximum permanent voltage UC according to installation instructions and without load-side loads.

## Protection level $U_p$

The protection level of a overvoltage protection device is the maximum instantaneous value of the voltage at the terminals of a overvoltage protection device, consisting of the standardized individual tests:

- response lightning impulse voltage 1.2/50 μs (100 %)
- response voltage with a rate of rise 1 kV/s
- residual voltage with rated discharge voltage $U_{res}$

The protection level characterizes the capacity of a overvoltage protection device to limit overvoltages to a residual level. The protection level determines the installation location with regard to the overvoltage category for power networks.

For overvoltage protection devices to be used in data networks, the protection level must be adapted to the interference immunity level of the equipment to be protected.

## Protection circuit

Protection circuits are multi-stage, cascaded protective devices. The individual protection stages may consist of discharge paths, varistors, and/or semiconductor devices. Energetic coordination of the individual protection stages is implemented using decoupling devices.

## Thermal isolating arresters

Overvoltage protection devices for power networks equipped with voltage-controlled resistors (varistors) must possess an integrated isolating arrester that separates the overvoltage protection device from the network upon overload and indicates this operational state. The isolating arrester responds to the “current heat” generated by an overloaded varistor and separates the overvoltage protection device from the network if a certain temperature is exceeded. The intent is to have the isolating arrester separate the overloaded overvoltage protection device from the network in time to prevent a fire. The isolating arrester is not intended to ensure “protection from indirect contact“. The function of this thermal isolating arrester is tested by means of a simulated overload/deterioration of the arrester.

**Surge Protective Devices (SPDs)**

Overvoltage protection devices are devices consisting mainly of varistors, suppressor diodes and/or spark gaps. SPDs are used to protect other electrical equipment and electrical plants from impermissibly high overvoltage and to ensure equipotential bonding.

SPDs are categorized according to their application and protective function:

a) SPDs for use in low-voltage plants up to 1,000 V rated voltage. Selection and installation must be in compliance with national construction regulations for low-voltage systems, such as IEC 60634-5-53-534 and/or VDE 0100-534. Product standard is the EN(IEC) 61643-11.
According to these standards, the devices are divided into 3 arrester categories:

Type 1: lightning arrester for interference resulting from direct or near strikes to protect the installation and equipment at interfaces between lightning protection zones LPZ 0 and 1 (building infeed). Type 1 arresters are definitely recommended for buildings with an outside lightning protection system.

Type 2: surge arrester for interference resulting from remote strikes, inductive or capacitive interferences as well as switching surge to protect the installation, equipment and terminal devices at the interfaces between lightning zones LPZ 1 and 2 (main distribution and sub-distribution).

Type 3: additional surge arresters to protect especially sensitive terminal equipment and to further reduce the voltage level in lightning zones 1 or 2. These may include devices for fixed installations in the distribution systems or non-stationary protective devices in the area of socket outlets directly upstream of the terminal equipment to be protected.

General information is available in the Application Guide IEC 61643-12. Basic information on lightning protection, the lightning protection zone concept and risk analysis is available in the four-part EN (IEC) 62305-... / VDE 0185-305-... .

b) SPDs for use in AC power networks at up to and over 200 kV rated voltage.
Product standard is EN (IEC) 60099 from Parts 1 to 4.
Mainly for applications in medium-voltage and high-voltage systems.
Part 5 describes the general rules for selecting products.

c) SPDs for use in telecommunications and signal-processing networks to protect from direct and indirect interference from lightning strikes and other transient overvoltages.
This also includes low-voltage data systems, electrical measuring and control circuits and voice transmission networks with rated voltages of up to 1,000 V AC and 1,500 V DC.

Product standard is EN 61643-21 VDE 0845-3-1.
This standard divides the products into the categories A1, A2, B1, B2, B3, C1, C2, C3 and D1, D2 to define testing requirements and performance classes.
One protective device can be labeled and tested multiple categories and performance classes.

General information is available in the Application Guide IEC (TS) 61643-22. Further information can be found in the parts VDE 0800... and VDE 0845... .

## Further information – standards

**IEC 60364-4-41: 2005**
**DIN VDE 0100-410: 2007**

Setting up electrical power installations with rated voltages of up to 1,000 V, Part 4:
Protective measures, Chapter 41: Protection from electrical shock

**IEC 60364-5-54: 2002**
**DIN VDE 0100-540: 2007**

Setting up electrical power installations with rated voltages of up to 1,000 V, Part 540:
Selecting and setting up electrical equipment, grounding, PE conductors, equipotential bonding conductors

**IEC 60364-4-44: 2007**
**DIN VDE 0100-443: 2007**

Setting up low-voltage systems Part 4: Protective measures, Chapter 44: Protection from overvoltages, Main Section 443:
Protection from overvoltages of atmospheric origin or due to switching

**IEC 60364-5-53: 2002**
**DIN IEC 6036-5-53/A2**
**VDE 0100-534: 2009**

Electrical plants in buildings, Part 534: Selection and installation of equipment, overvoltage protection devices

**IEC 60664-1: 2007**
**EN 60664-1: 2007**

Insulation coordination for electrical equipment in low-voltage systems, Part 1: Basics, requirements and tests

**IEC 62305-1: 2006**
**EN 62305-1: 2006**
**VDE 0185-305-1**

Lightning protection, Part 1: General principles

**IEC 62305-2: 2006**
**EN 62305-2: 2006**
**VDE 0185-305-2**

Lightning protection, Part 2: Risk management: Assessment of risk for structures

**IEC 62305-3: 2006**
**EN 62305-3: 2006**
**VDE 0185-305-3**

Lightning protection, Part 3: Physical damage to structures and life hazard

**IEC 62305-4: 2006**
**EN 62305-4: 2006**
**VDE 0185-305-4**

Lightning protection, Part 4: Electrical and electronic systems within structures

**IEC 60099-1: 1991 + A1: 1999**
**EN 60099-1: 1994 + A1: 1999**
**VDE 0675-1: 2000-08**

Surge arresters, Part 1: Non-linear type gapped surge resistor arresters for AC systemse.

**IEC 60099-4: 2004 + A1: 2006**
**EN 60099-4: 2004 + A1: 2006**
**VDE 0675-4: 2007**

Part 4: Metal-oxide surge arresters without spark gaps for AC systems

**IEC 60099-5: 1996**

Part 5: Selection and application recommendations

**IEC 61643-1: 2005**
**EN 61643-11: 2002 + A11**
**VDE 0675-6-11: 2007**

Low-voltage surge protective devices, Part 11:
Surge protective devices connected to low-voltage power systems, requirements and tests

**DIN VDE 0800-1: 1989-05**

Telecommunications; general concepts, requirements and tests for the safety of plants and equipment

**DIN VDE 0800-2: 1985-07**

Telecommunications; grounding and equipotential bonding

**EN 50114: 2008**
**DIN EN 50514: 2009**
**VDE 0805-514**

Information technology equipment; routine electrical safety testing in production

**DIN VDE 0845-1: 1987-10**

Protection for telecommunications equipment from lightning, static charges and overvoltages from power systems, measures against overvoltages

**IEC 61643-21: 2000**
**EN 61643-21: 2001**
**VDE 0845-3-1: 2002**

Low-voltage surge protective devices, Part 21:
Surge protective devices connected to telecommunications and signaling networks, performance requirements and testing methods

**IEC 61643-12: 2008**

Part 12: Surge protective devices connected to low-voltage power systems – selection and application principles

**IEC 61643-22: 2004**

Part 22: Surge protective devices connected to telecommunications and signaling networks – selection and application principles

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