



Overvoltage Protection: principle, design and installation

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Overvoltage Protection

In this chapter, you will find technical reference about:

- the different types of overvoltage, their characteristics and potential impacts on electrical equipment
- the lightning protection principles, to protect the building structure and the building electrical installation
- how to design the lightning protection
- the characteristics of Surge Protection Devices (SPDs), how to select them, and the important rules to follow when installing them



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1. Overvoltage of atmospheric origin

1.1 Overvoltage definitions

Overvoltage (in a system)

Any voltage between one phase conductor and earth or between phase conductors having a peak value exceeding the corresponding peak of the highest voltage for equipment.

Definition from the International Electrotechnical Vocabulary (IEV 604-03-09).

Various types of overvoltage

An overvoltage is a voltage pulse or wave which is superimposed on the rated voltage of the network (see Fig. 1).

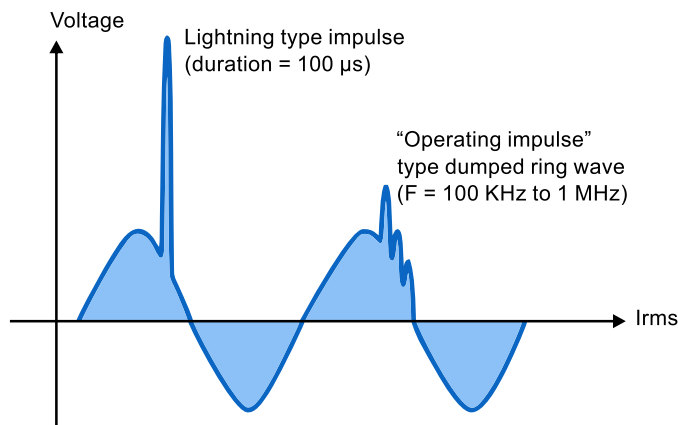


Fig. 1 – Examples of overvoltage

This type of overvoltage is characterized by (see Fig. 2):

- the rise time t_f (in μs);
- the gradient S (in $\text{kV}/\mu\text{s}$).

An overvoltage disturbs equipment and produces electromagnetic radiation. Moreover, the duration of the overvoltage (T) causes an energy peak in the electric circuits which could destroy equipment.

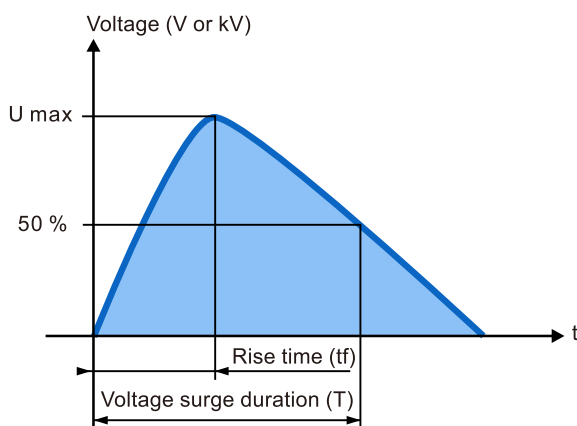


Fig. 2 – Main characteristics of an overvoltage

Four types of overvoltage can disturb electrical installations and loads:

- Switching surges: high-frequency overvoltages or burst disturbance (see Fig. 1) caused by a change in the steady state in an electrical network (during operation of switchgear).

- Power-frequency overvoltages: overvoltages of the same frequency as the network (50, 60 or 400 Hz) caused by a permanent change of state in the network (following a fault: insulation fault, breakdown of neutral conductor, etc.).
- Overvoltages caused by electrostatic discharge: very short overvoltages (a few nanoseconds) of very high frequency caused by the discharge of accumulated electric charges (for example, a person walking on a carpet with insulating soles is electrically charged with a voltage of several kilovolts).
- Overvoltages of atmospheric origin.

1.2 Overvoltage characteristics of atmospheric origin

Lightning strokes in a few figures: Lightning flashes produce an extremely large quantity of pulsed electrical energy (see Figure 4)

- of several thousand amperes (and several thousand volts),
- of high frequency (approximately 1 megahertz),
- of short duration (from a microsecond to a millisecond).

Between 2000 and 5000 storms are constantly undergoing formation throughout the world. These storms are accompanied by lightning strokes which represent a serious hazard for persons and equipment. Lightning flashes hit the ground at an average of 30 to 100 strokes per second, i.e. 3 billion lightning strokes each year.

The table in Figure 3 shows some lightning strike values with their related probability. As can be seen, 50% of lightning strokes have a current exceeding 35 kA and 5% a current exceeding 100 kA. The energy conveyed by the lightning stroke is therefore very high.

Fig. 3 – Examples of lightning discharge values given by the IEC 62305-1 standard (2010 - Table A.3)

Cumulative probability (%)	Peak current (kA)
95	5
50	35
5	100
1	200

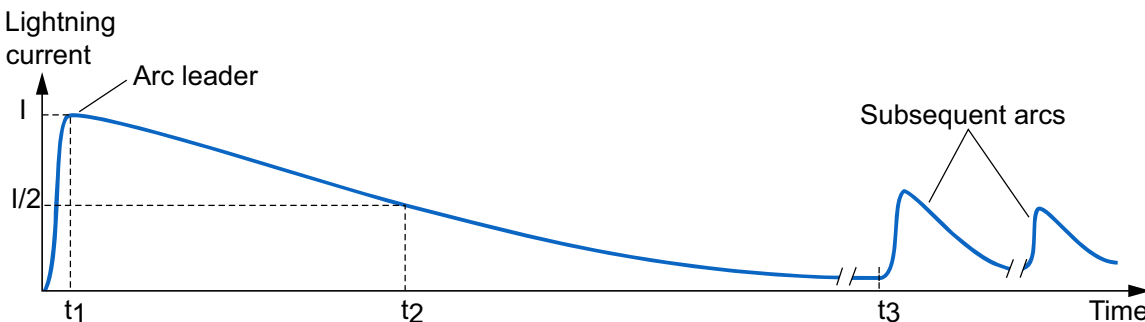


Fig. 4 – Example of lightning current

Lightning also causes a large number of fires, mostly in agricultural areas (destroying houses or making them unfit for use). High-rise buildings are especially prone to lightning strokes.

1.3 Effects on electrical installations

Lightning damages electrical and electronic systems in particular: transformers, electricity meters and electrical appliances on both residential and industrial premises.

The cost of repairing the damage caused by lightning is very high. But it is very hard to assess the consequences of:

- disturbances caused to computers and telecommunication networks;
- faults generated in the running of programmable logic controller programs and control systems.

Moreover, the cost of operating losses may be far higher than the value of the equipment destroyed.

Lightning stroke impacts

Lightning is a high-frequency electrical phenomenon which causes overvoltages on all conductive items, especially on electrical cabling and equipment.

Lightning strokes can affect the electrical (and/or electronic) systems of a building in two ways:

- by direct impact of the lightning stroke on the building (see Fig. 5 a);
- by indirect impact of the lightning stroke on the building:
 - A lightning stroke can fall on an overhead electric power line supplying a building (see Fig. 5 b). The overcurrent and overvoltage can spread several kilometres from the point of impact.
 - A lightning stroke can fall near an electric power line (see Fig. 5 c). It is the electromagnetic radiation of the lightning current that produces a high current and an overvoltage on the electric power supply network. In the latter two cases, the hazardous currents and voltages are transmitted by the power supply network.
 - A lightning stroke can fall near a building (see Fig. 5 d). The earth potential around the point of impact rises dangerously.

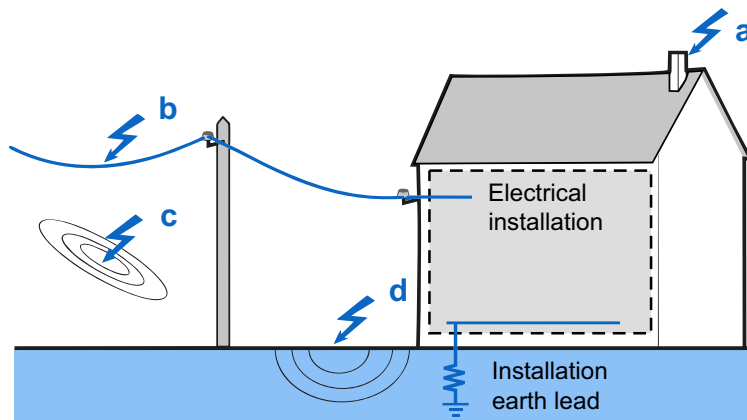


Fig. 5 – Various types of lightning impact

In all cases, the consequences for electrical installations and loads can be dramatic.

Lightning falls on an unprotected building.	Lightning falls near an overhead line.	Lightning falls near a building.
<p>The lightning current flows to earth via the more or less conductive structures of the building with very destructive effects:</p> <ul style="list-style-type: none"> • thermal effects: Very violent overheating of materials, causing fire, • mechanical effects: Structural deformation, • thermal flashover: Extremely dangerous phenomenon in the presence of flammable or explosive materials (hydrocarbons, dust, etc.). 	<p>The lightning current generates overvoltages through electromagnetic induction in the distribution system.</p> <p>These overvoltages are propagated along the line to the electrical equipment inside the buildings.</p>	<p>The lightning stroke generates the same types of overvoltage as those described opposite.</p> <p>In addition, the lightning current rises back from the earth to the electrical installation, thus causing equipment breakdown.</p>
<p>The building and the installations inside the building are generally destroyed</p>	<p>The electrical installations inside the building are generally destroyed.</p>	

Fig. 6 – Consequence of a lightning stroke impact

The various modes of propagation

Common mode

Common-mode overvoltages appear between live conductors and earth: phase-to-earth or neutral-to-earth (see Fig. 7). They are dangerous especially for appliances whose frame is connected to earth due to risks of dielectric breakdown.

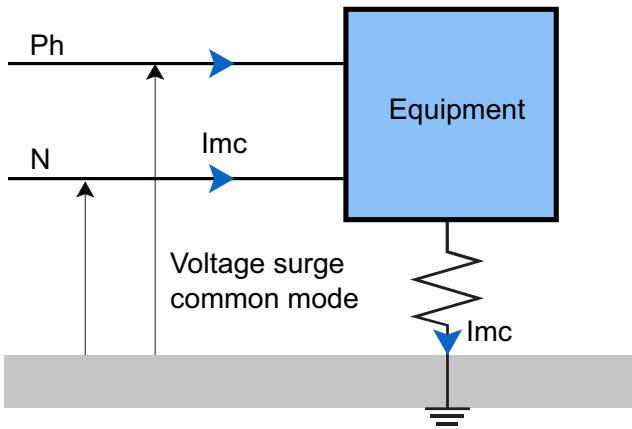


Fig. 7 – Common mode

Differential mode

Differential-mode overvoltages appear between live conductors:

phase-to-phase or phase-to-neutral (see Fig. 8). They are especially dangerous for electronic equipment, sensitive hardware such as computer systems, etc.

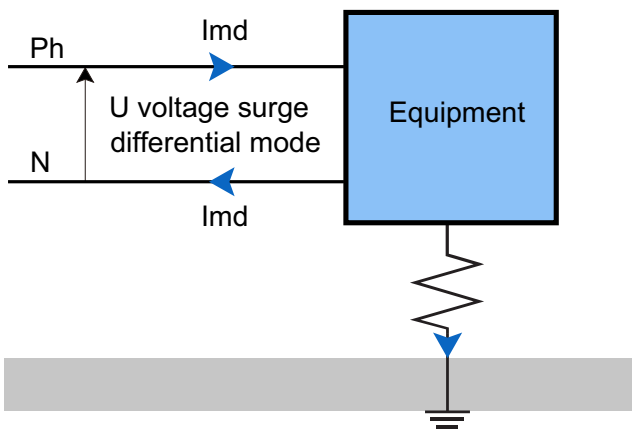


Fig. 8 – Differential mode

1.4 Characterization of the lightning wave

Analysis of the phenomena allows definition of the types of lightning current and voltage waves.

- 2 types of current wave are considered by the IEC standards:
 - 10/350 μ s wave: to characterize the current waves from a direct lightning stroke (see Fig. 9);



Fig. 9 – 10/350 μ s current wave

- 8/20 μs wave: to characterize the current waves from an indirect lightning stroke (see Fig. 10).

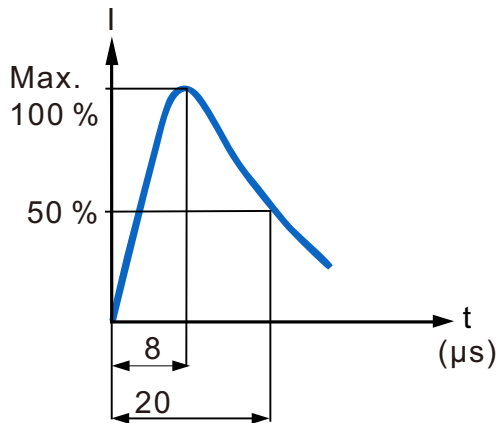


Fig. 10 – 8/20 μs current wave

These two types of lightning current wave are used to define tests on SPDs (IEC standard 61643-11) and equipment immunity to lightning currents.

The peak value of the current wave characterizes the intensity of the lightning stroke.

- The overvoltages created by lightning strokes are characterized by a 1.2/50 μs voltage wave (see Fig. 11).

This type of voltage wave is used to verify equipment's withstand to overvoltages of atmospheric origin (impulse voltage as per IEC 61000-4-5).

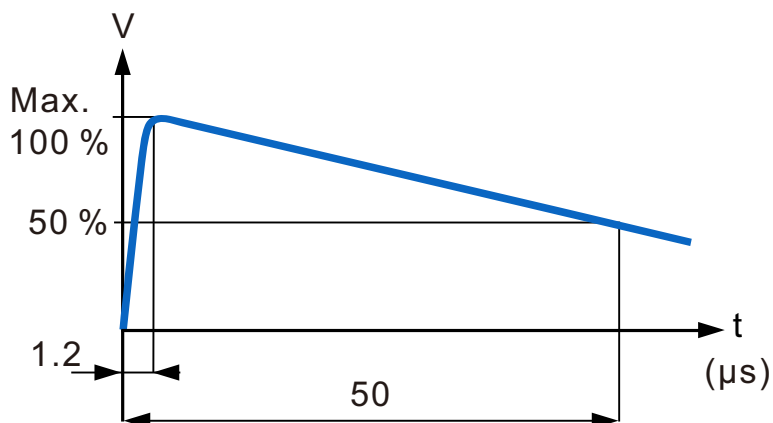


Fig. 11 – 1.2/50 μs voltage wave

2. Principle of lightning protection

2.1 General rules of lightning protection

Procedure to prevent risks of lightning strike

The system for protecting a building against the effects of lightning must include:

- Protection of structures against direct lightning strokes;
- Protection of electrical installations against direct and indirect lightning strokes.

The basic principle for protection of an installation against the risk of lightning strikes is to prevent the disturbing energy from reaching sensitive equipment. To achieve this, it is necessary to:

- Capture the lightning current and channel it to earth via the most direct path (avoiding the vicinity of sensitive equipment);
- Perform equipotential bonding of the installation;
This equipotential bonding is implemented by bonding conductors, supplemented by Surge Protection Devices (SPDs) or spark gaps (e.g., antenna mast spark gap).
- Minimize induced and indirect effects by installing SPDs and/or filters.

Two protection systems are used to eliminate or limit over-voltages: they are known as the building protection system (for the outside of buildings) and the electrical installation protection system (for the inside of buildings).

2.2 Building protection system

The role of the building protection system is to protect it against direct lightning strokes.

The system consists of:

- the capture device: the lightning protection system;
- down-conductors designed to convey the lightning current to earth;
- "crow's foot" earth leads connected together;
- links between all metallic frames (equipotential bonding) and the earth leads.

When the lightning current flows in a conductor, if potential differences appear between it and the frames connected to earth that are located in the vicinity, the latter can cause destructive flashovers.

The 3 types of lightning protection system

Three types of building protection are used:

The lightning rod (simple rod or with triggering system)

The lightning rod is a metallic capture tip placed at the top of the building. It is earthed by one or more conductors (often copper strips) (see Fig. 12).

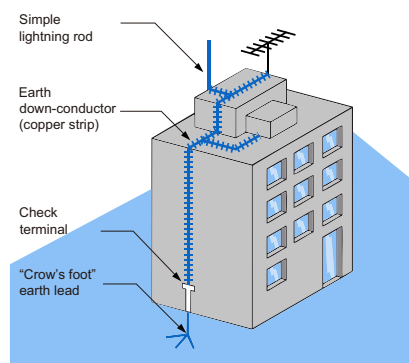


Fig. 12 – Lightning rod (simple rod or with triggering system)

The lightning rod with taut wires

These wires are stretched above the structure to be protected. They are used to protect special structures: rocket launching areas, military applications and protection of high-voltage overhead lines (see Fig. 13).

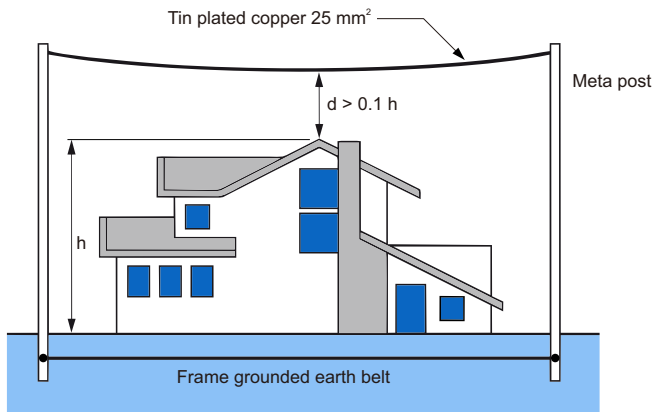


Fig. 13 – Taut wires

The lightning conductor with meshed cage (Faraday cage)

This protection involves placing numerous down conductors/tapes symmetrically all around the building. (see Fig. 14).

This type of lightning protection system is used for highly exposed buildings housing very sensitive installations such as computer rooms.

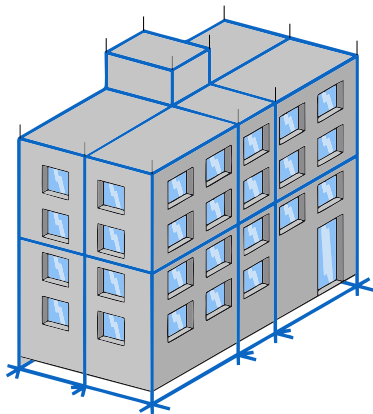


Fig. 14 – Meshed cage (Faraday cage)

Consequences of building protection for the electrical installation's equipment

50% of the lightning current discharged by the building protection system rises back into the earthing networks of the electrical installation (see Fig. 15): the potential rise of the frames very frequently exceeds the insulation withstand capability of the conductors in the various networks (LV, telecommunications, video cable, etc.).

Moreover, the flow of current through the down-conductors generates induced overvoltages in the electrical installation.

As a consequence, the building protection system does not protect the electrical installation: it is therefore compulsory to provide for an electrical installation protection system.

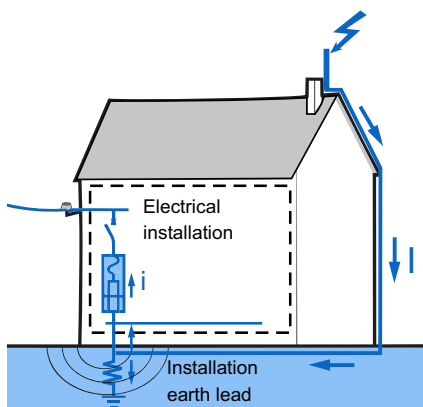


Fig. 15 – Direct lightning back current

2.3 Lightning protection - Electrical installation protection system

The main objective of the electrical installation protection system is to limit overvoltages to values that are acceptable for the equipment.

The electrical installation protection system consists of:

- one or more SPDs depending on the building configuration;
- the equipotential bonding: metallic mesh of exposed conductive parts.

Implementation

The procedure to protect the electrical and electronic systems of a building is as follows.

Search for information

- Identify all sensitive loads and their location in the building.
- Identify the electrical and electronic systems and their respective points of entry into the building.
- Check whether a lightning protection system is present on the building or in the vicinity.
- Become acquainted with the regulations applicable to the building's location.
- Assess the risk of lightning strike according to the geographic location, type of power supply, lightning strike density, etc.

Solution implementation

- Install bonding conductors on frames by a mesh.
- Install a SPD in the LV incoming switchboard.
- Install an additional SPD in each subdistribution board located in the vicinity of sensitive equipment (see Fig. 16).

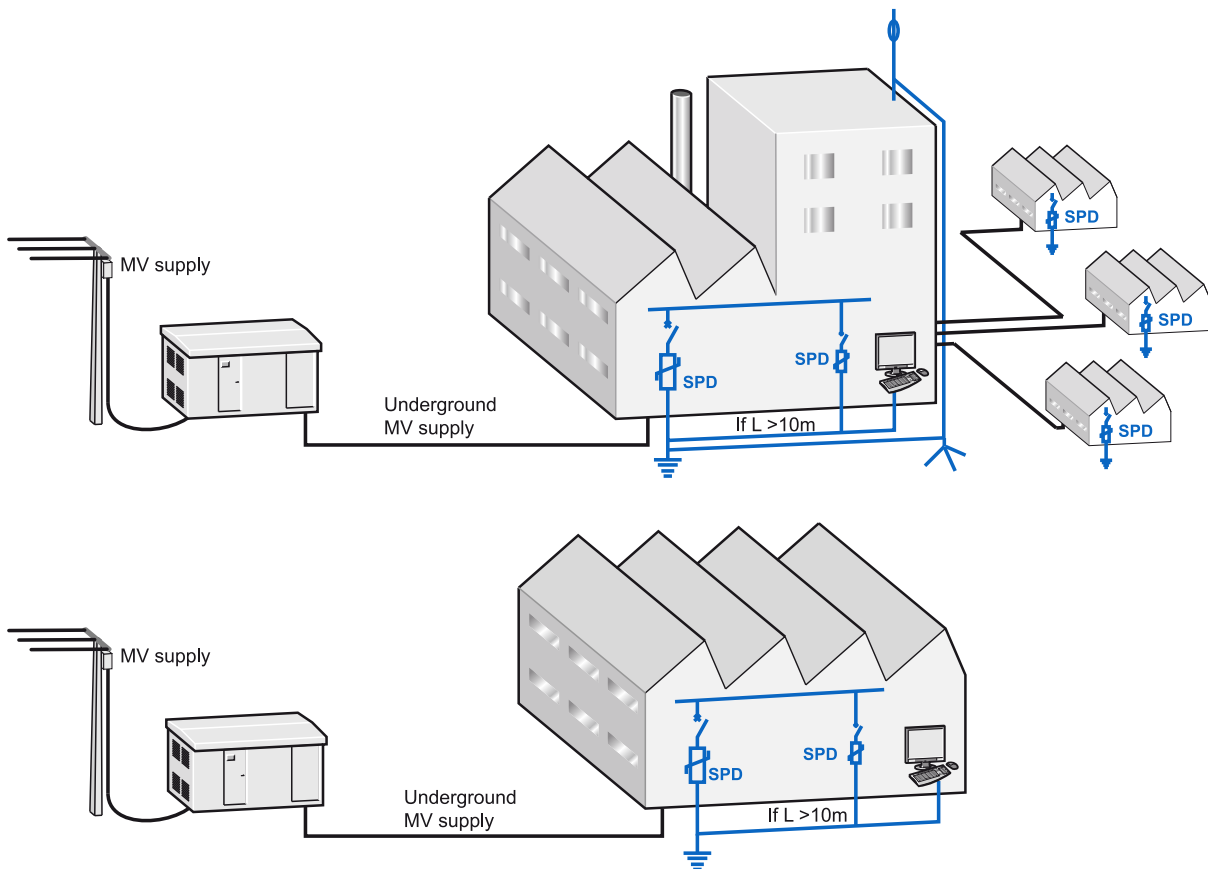


Fig. 16 – Example of protection of a large-scale electrical installation

2.4 The Surge Protection Device (SPD)

Surge Protection Devices (SPD) are used for electric power supply networks, telephone networks, and communication and automatic control buses.

The Surge Protection Device (SPD) is a component of the electrical installation protection system.

This device is connected in parallel on the power supply circuit of the loads that it has to protect (see Fig. 17). It can also be used at all levels of the power supply network.

This is the most commonly used and most efficient type of overvoltage protection.

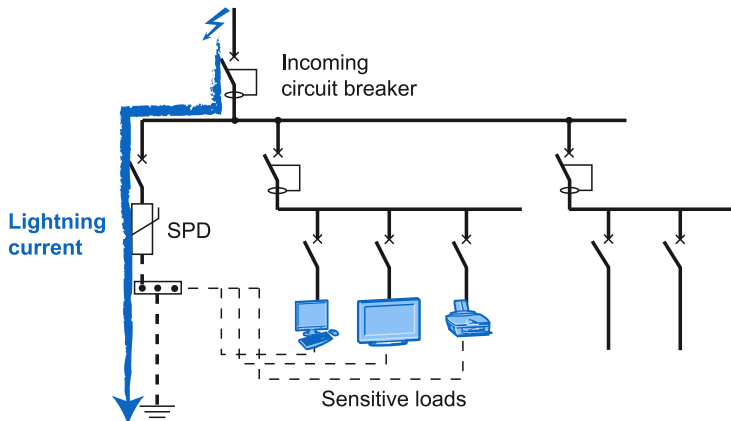


Fig. J17 – Principle of protection system in parallel

SPD connected in parallel has a high impedance. Once the transient overvoltage appears in the system, the impedance of the device decreases so surge current is driven through the SPD, bypassing the sensitive equipment.

Principle

SPD is designed to limit transient overvoltages of atmospheric origin and divert current waves to earth, so as to limit the amplitude of this overvoltage to a value that is not hazardous for the electrical installation and electric switchgear and controlgear.

SPD eliminates overvoltages

- in common mode, between phase and neutral or earth;
- in differential mode, between phase and neutral.

In the event of an overvoltage exceeding the operating threshold, the SPD

- conducts the energy to earth, in common mode;
- distributes the energy to the other live conductors, in differential mode.

The three types of SPD

Type 1 SPD

The Type 1 SPD is recommended in the specific case of service-sector and industrial buildings, protected by a lightning protection system or a meshed cage.

It protects electrical installations against direct lightning strokes. It can discharge the back-current from lightning spreading from the earth conductor to the network conductors.

Type 1 SPD is characterized by a 10/350 μ s current wave.

Type 2 SPD

The Type 2 SPD is the main protection system for all low voltage electrical installations. Installed in each electrical switchboard, it prevents the spread of overvoltages in the electrical installations and protects the loads.

Type 2 SPD is characterized by an 8/20 μ s current wave.

Type 3 SPD

These SPDs have a low discharge capacity. They must therefore mandatorily be installed as a supplement to Type 2 SPD and in the vicinity of sensitive loads.

Type 3 SPD is characterized by a combination of voltage waves (1.2/50 μ s) and current waves (8/20 μ s).

SPD normative definition

	Direct lightning stroke	Indirect lightning stroke	
IEC 61643-1	Class I test	Class II test	Class III test
IEC 61643-11/2011	Type 1 : $\overline{T1}$	Type 2 : $\overline{T2}$	Type 3 : $\overline{T3}$
EN/IEC 61643-11	Type 1	Type 2	Type 3
Former VDE 0675v	B	C	D
Type of test wave	10/350	8/20	1.2/50 + 8/20

Note 1: There exist $\overline{T1} + \overline{T2}$ SPD (or Type 1 + 2 SPD) combining protection of loads against direct and indirect lightning strokes.

Note 2: some $\overline{T2}$ SPD can also be declared as $\overline{T3}$.

Characteristics of SPD

International standard IEC 61643-11 Edition 1.0 (03/2011) defines the characteristics and tests for SPD connected to low voltage distribution systems (see Fig. 19).

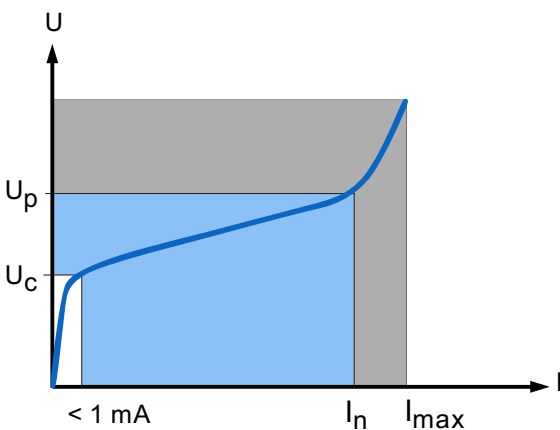


Fig. 19 – Time/current characteristic of a SPD with varistor

In green, the guaranteed operating range of the SPD.

Common characteristics

- U_c : Maximum continuous operating voltage
This is the A.C. or D.C. voltage above which the SPD becomes active. This value is chosen according to the rated voltage and the system earthing arrangement.
- U_p : Voltage protection level (at I_n)
This is the maximum voltage across the terminals of the SPD when it is active. This voltage is reached when the current flowing in the SPD is equal to I_n . The voltage protection level chosen must be below the overvoltage withstand capability of the loads. In the event of lightning strokes, the voltage across the terminals of the SPD generally remains less than U_p .
- I_n : Nominal discharge current
This is the peak value of a current of 8/20 μ s waveform that the SPD is capable of discharging minimum 19 times.

Why is I_n important?

I_n corresponds to a nominal discharge current that a SPD can withstand at least 19 times: a higher value of I_n means a longer life for the SPD, so it is strongly recommended to chose higher values than the minimum imposed value of 5 kA.

Type 1 SPD

- I_{imp} : Impulse current
This is the peak value of a current of 10/350 μ s waveform that the SPD is capable of discharging of discharging at least one time.

Why is I_{imp} important?

IEC 62305 standard requires a maximum impulse current value of 25 kA per pole for three-phase system. This means that for a 3P+N network the SPD should be able to withstand a total maximum impulse current of 100kA coming from the earth bonding.

- I_{fi} : Autoextinguish follow current
Applicable only to the spark gap technology. This is the current (50 Hz) that the SPD is capable of interrupting by itself after flashover. This current must always be greater than the prospective short-circuit current at the point of installation.

Type 2 SPD

- I_{max} : Maximum discharge current
This is the peak value of a current of 8/20 μ s waveform that the SPD is capable of discharging once.

Why is I_{max} important?

If you compare 2 SPDs with the same I_n , but with different I_{max} : the SPD with higher I_{max} value has a higher "safety margin" and can withstand higher surge current without being damaged.

Type 3 SPD

- U_{oc} : Open-circuit voltage applied during class III (Type 3) tests.

Main applications

- Low Voltage SPD
Very different devices, from both a technological and usage viewpoint, are designated by this term. Low voltage SPDs are modular to be easily installed inside LV switchboards.
There are also SPDs adaptable to power sockets, but these devices have a low discharge capacity.
- SPD for communication networks
These devices protect telephone networks, switched networks and automatic control networks (bus) against overvoltages coming from outside (lightning) and those internal to the power supply network (polluting equipment, switchgear operation, etc.).
Such SPDs are also installed in RJ11, RJ45, ... connectors or integrated into loads.

3. Design of the electrical installation protection system

3.1 Design rules of the electrical installation protection system

To protect an electrical installation in a building, simple rules apply for the choice of

- SPD(s);
- its protection system.

For a power distribution system, the main characteristics used to define the lightning protection system and select a SPD to protect an electrical installation in a building are:

- SPD
 - quantity of SPD
 - type
 - level of exposure to define the SPD's maximum discharge current I_{max} .
- Short circuit protection device
 - maximum discharge current I_{max} ;
 - short-circuit current I_{sc} at the point of installation.

The logic diagram in the Figure 20 below illustrates this design rule.

Surge Protective Device (SPD)

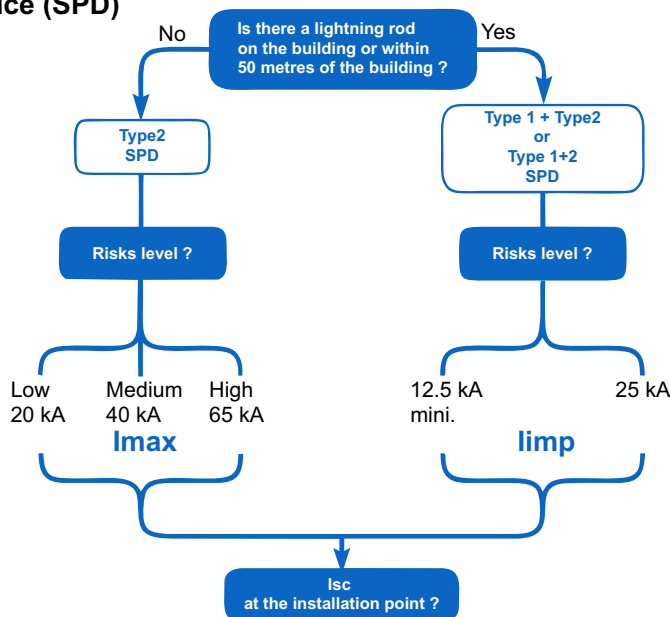


Fig. 20 – Logic diagram for selection of a protection system

Short Circuit Protection Device (SCPD)

The other characteristics for selection of a SPD are predefined for an electrical installation.

- number of poles in SPD;
- voltage protection level U_p ;
- operating voltage U_c .

This sub-section Design of the electrical installation protection system describes in greater detail the criteria for selection of the protection system according to the characteristics of the installation, the equipment to be protected and the environment.

3.2 Elements of the protection system

A SPD must always be installed at the origin of the electrical installation.

Location and type of SPD

The type of SPD to be installed at the origin of the installation depends on whether or not a lightning protection system is present. If the building is fitted with a lightning protection system (as per IEC 62305), a Type 1 SPD should be installed.

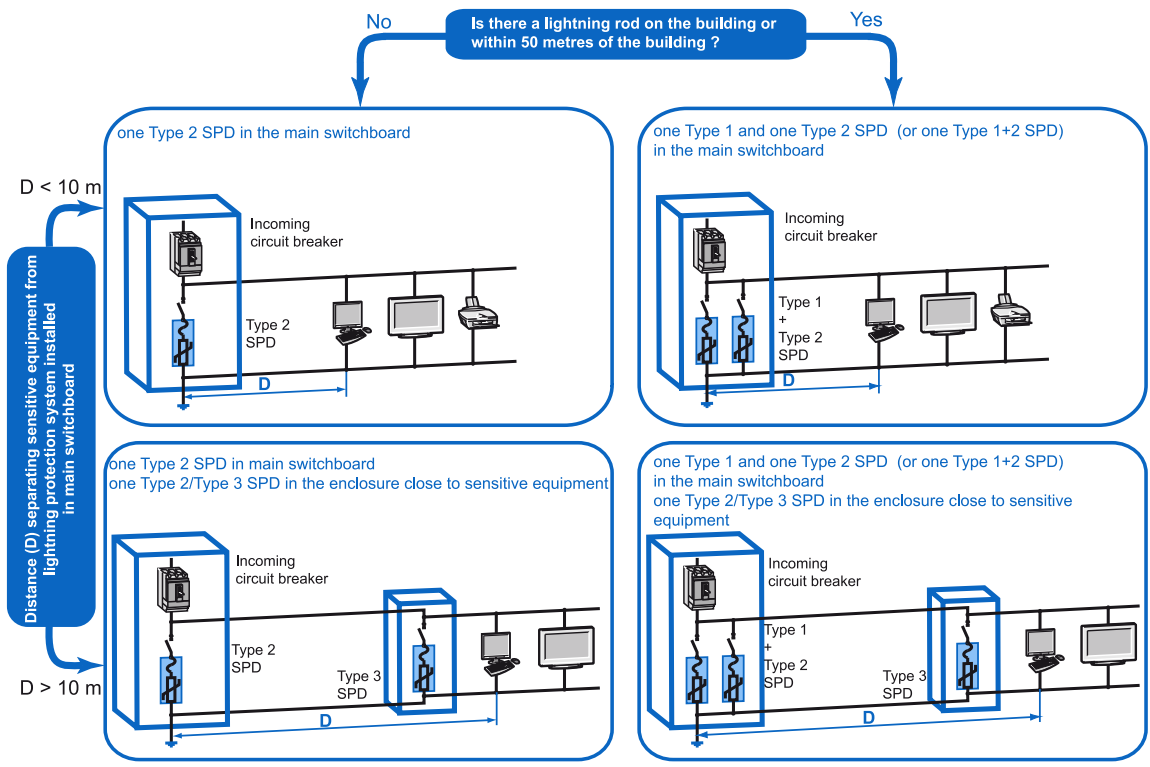
For SPD installed at the incoming end of the installation, the IEC 60364 installation standards lay down minimum values for the following 2 characteristics:

- Nominal discharge current $I_n = 5 \text{ kA (8/20) } \mu\text{s}$;
- Voltage protection level $U_p \text{ (at } I_n) < 2.5 \text{ kV}$.

The number of additional SPDs to be installed is determined by:

- the size of the site and the difficulty of installing bonding conductors. On large sites, it is essential to install a SPD at the incoming end of each subdistribution enclosure.
- the distance separating sensitive loads to be protected from the incoming end protection device. When the loads are located more than 10 meters away from the incoming-end protection device, it is necessary to provide for additional fine protection as close as possible to sensitive loads. The phenomena of wave reflection is increasing from 10 meters see Propagation of a lightning wave
- the risk of exposure. In the case of a very exposed site, the incoming-end SPD cannot ensure both a high flow of lightning current and a sufficiently low voltage protection level. In particular, a Type 1 SPD is generally accompanied by a Type 2 SPD.

The table in Figure 21 below shows the quantity and type of SPD to be set up on the basis of the two factors defined above.



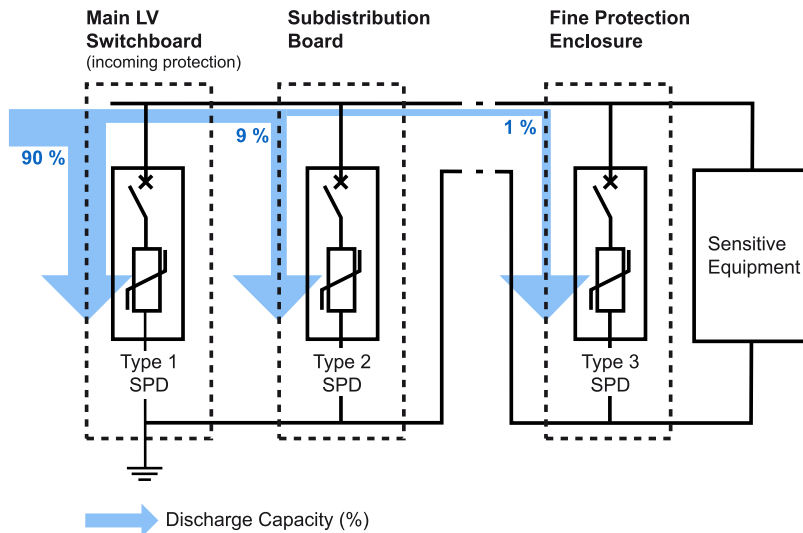
Note: The Type 1 SPD is installed in the electrical switchboard connected to the earth lead of the lightning protection system.

Fig. 21 – The 4 cases of SPD implementation

Protection distributed levels

Several protection levels of SPD allows the energy to be distributed among several SPDs, as shown in Figure 22 in which the three types of SPD are provided for:

- Type 1: when the building is fitted with a lightning protection system and located at the incoming end of the installation it absorbs a very large quantity of energy;
- Type 2: absorbs residual overvoltages;
- Type 3: provides "fine" protection if necessary for the most sensitive equipment located very close to the loads.



Note: The Type 1 and 2 SPD can be combined in a single SPD

Fig. 22 – Fine protection architecture

3.3 Common characteristics of SPDs according to the installation characteristics

Operating voltage U_c

Depending on the system earthing arrangement, the maximum continuous operating voltage U_c of SPD must be equal to or greater than the values shown in the table in Figure 23.

Fig. 23 – Stipulated minimum value of U_c for SPDs depending on the system earthing arrangement (based on Table 534.2 of the IEC 60364-5-53 standard)

SPDs connected between (as applicable)	System configuration of distribution network		
	TN system	TT system	IT system
Line conductor and neutral conductor	$1.1 U / \sqrt{3}$	$1.1 U / \sqrt{3}$	$1.1 U / \sqrt{3}$
Line conductor and PE conductor	$1.1 U / \sqrt{3}$	$1.1 U / \sqrt{3}$	$1.1 U$
Line conductor and PEN conductor	$1.1 U / \sqrt{3}$	N/A	N/A
Neutral conductor and PE conductor	$U / \sqrt{3}^{[a]}$	$U / \sqrt{3}^{[a]}$	$1.1 U / \sqrt{3}$

N/A: not applicable

U: line-to-line voltage of the low-voltage system

a: these values are related to worst-case fault conditions, therefore the tolerance of 10 % is not taken into account.

The most common values of U_c chosen according to the system earthing arrangement.

TT, TN: 260, 320, 340, 350 V

IT: 440, 460 V

Voltage protection level Up (at In)

The IEC 60364-4-44 standard helps with the choice of the protection level Up for the SPD in function of the loads to be protected. The table of Figure 24 indicates the impulse withstand capability of each kind of equipment.

Fig. 24 – Required rated impulse voltage of equipment Uw (table 443.2 of IEC 60364-4-44)

Nominal voltage of the installation ^[a] (V)	Voltage line to neutral derived from nominal voltages a.c. or d.c. up to and including (V)	Required rated impulse withstand voltage of equipment ^[b] (kV)			
		Overvoltage category IV (equipment with very high rated impulse voltage)	Overvoltage category III (equipment with high rated impulse voltage)	Overvoltage category II (equipment with normal rated impulse voltage)	Overvoltage category I (equipment with reduced rated impulse voltage)
		For example, energy meter, telecontrol systems	For example, distribution boards, switches socket-outlets	For example, distribution domestic appliances, tools	For example, sensitive electronic equipment
120/208	150	4	2.5	1.5	0.8
230/400 ^{[c][d]}	300	6	4	2.5	1.5
277/480 ^[c]					
400/690	600	8	6	4	2.5
1000	1000	12	8	6	4
1500 d.c.	1500 d.c.			8	6

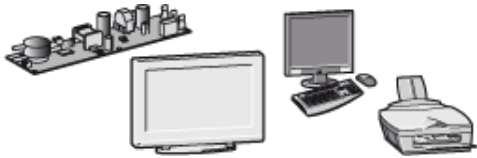

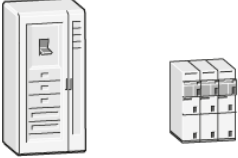
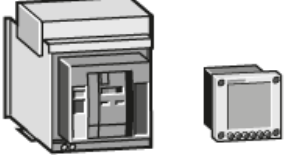
a. According to IEC 60038:2009.

b. This rated impulse voltage is applied between live conductors and PE.

c. In Canada and USA, for voltages to earth higher than 300 V, the rated impulse voltage corresponding to the next highest voltage in this column applies.

d. For IT systems operations at 220-240 V, the 230/400 row shall be used, due to the voltage to earth at the earth fault on one line.

Fig. 25 – Overvoltage category of equipment

	<ul style="list-style-type: none"> Equipment of overvoltage category I is only suitable for use in the fixed installation of buildings where protective means are applied outside the equipment – to limit transient overvoltages to the specified level. Examples of such equipment are those containing electronic circuits like computers, appliances with electronic programmes, etc.
	<ul style="list-style-type: none"> Equipment of overvoltage category II is suitable for connection to the fixed electrical installation, providing a normal degree of availability normally required for current-using equipment. Examples of such equipment are household appliances and similar loads.
	<ul style="list-style-type: none"> Equipment of overvoltage category III is for use in the fixed installation downstream of, and including the main distribution board, providing a high degree of availability. Examples of such equipment are distribution boards, circuit-breakers, wiring systems including cables, bus-bars, junction boxes, switches, socket-outlets) in the fixed installation, and equipment for industrial use and some other equipment, e.g. stationary motors with permanent connection to the fixed installation.
	<ul style="list-style-type: none"> Equipment of overvoltage category IV is suitable for use at, or in the proximity of, the origin of the installation, for example upstream of the main distribution board. Examples of such equipment are electricity meters, primary overcurrent protection devices and ripple control units.

The "installed" U_p performance should be compared with the impulse withstand capability of the loads.

SPD has a voltage protection level U_p that is intrinsic, i.e. defined and tested independently of its installation. In practice, for the choice of U_p performance of a SPD, a safety margin must be taken to allow for the overvoltages inherent in the installation of the SPD (see Figure 26 and Connection of Surge Protection Device).

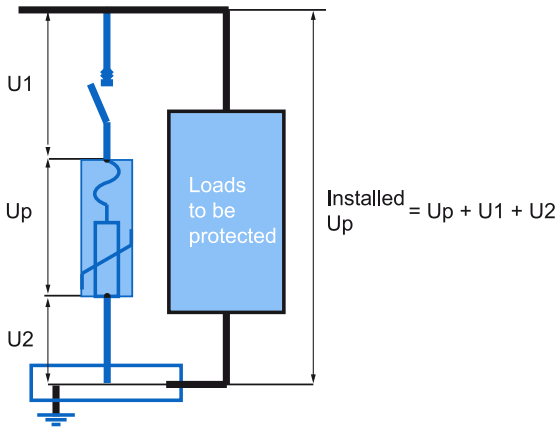


Fig. 26 – Installed U_p

The "installed" voltage protection level U_p generally adopted to protect sensitive equipment in 230/400 V electrical installations is 2.5 kV (overvoltage category II, see Fig. 27).

Note:

If the stipulated voltage protection level cannot be achieved by the incoming-end SPD or if sensitive equipment items are remote (see Elements of the protection system#Location and type of SPD Location and type of SPD), additional coordinated SPD must be installed to achieve the required protection level.

Number of poles

- Depending on the system earthing arrangement, it is necessary to provide for a SPD architecture ensuring protection in common mode (CM) and differential mode (DM).

Fig. 27 – Protection need according to the system earthing arrangement

	TT	TN-C	TN-S	IT
Phase-to-neutral (DM)	Recommended ^[a]	–	Recommended	Not useful
Phase-to-earth (PE or PEN) (CM)	Yes	Yes	Yes	Yes
Neutral-to-earth (PE) (CM)	Yes	–	Yes	Yes ^[b]

a. The protection between phase and neutral can either be incorporated in the SPD placed at the origin of the installation, or be remoted close to the equipment to be protected

Note:

- Common-mode overvoltage
A basic form of protection is to install a SPD in common mode between phases and the PE (or PEN) conductor, whatever the type of system earthing arrangement used.
- Differential-mode overvoltage
In the TT and TN-S systems, earthing of the neutral results in an asymmetry due to earth impedances which leads to the appearance of differential-mode voltages, even though the overvoltage induced by a lightning stroke is common-mode.

2P, 3P and 4P SPDs

(see Fig. 28)

- These are adapted to the IT, TN-C, TN-C-S systems.
- They provide protection merely against common-mode overvoltages.

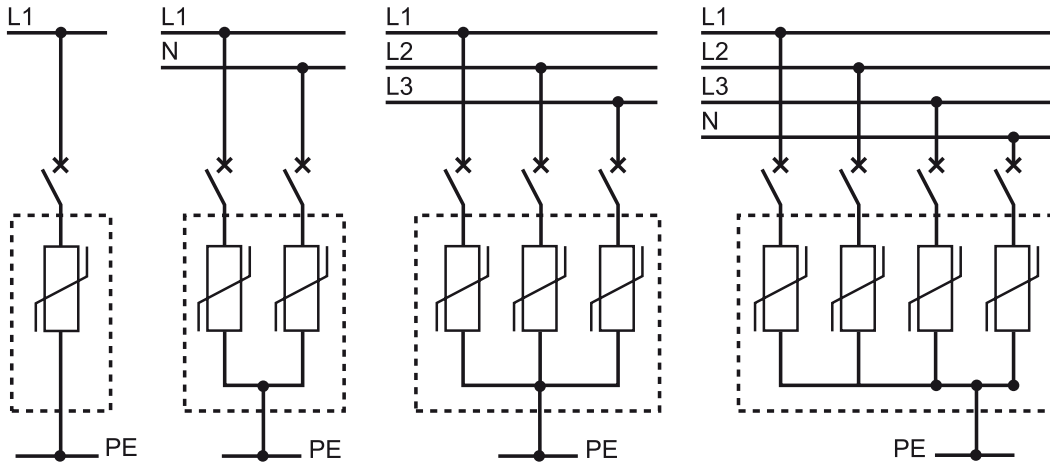


Fig. 28 – 1P, 2P, 3P, 4P SPDs

1P + N, 3P + N SPDs

(see Fig. 29)

- These are adapted to the TT and TN-S systems.
- They provide protection against common-mode and differential-mode overvoltages

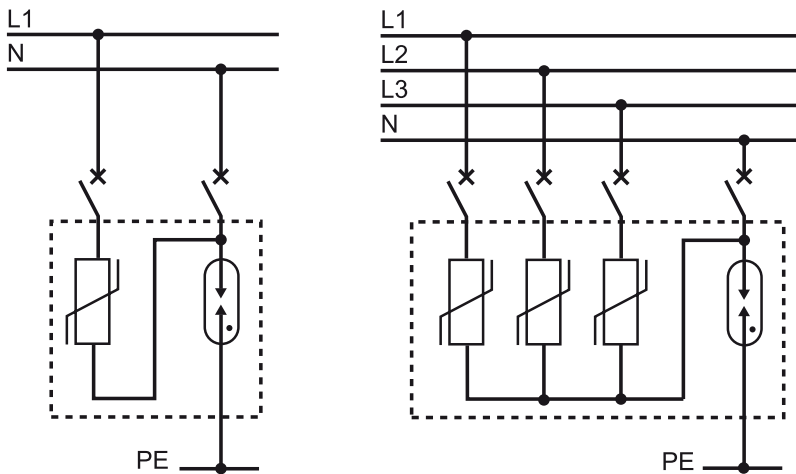


Fig. 29 – 1P + N, 3P + N SPDs

3.4 Selection of a Type 1 SPD

Impulse current limp

- Where there are no national regulations or specific regulations for the type of building to be protected: the impulse current limp shall be at least 12.5 kA (10/350 μ s wave) per branch in accordance with IEC 60364-5-534.
- Where regulations exist: standard IEC 62305-2 defines 4 levels: I, II, III and IV

The table in Figure 31 shows the different levels of limp in the regulatory case.

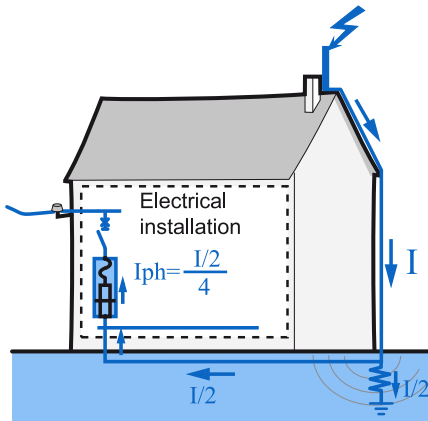


Fig. 30 – Basic example of balanced limp current distribution in 3 phase system

Fig. 31 – Table of limp values according to the building's voltage protection level (based on IEC/EN 62305-2)

Protection level as per EN 62305-2	External lightning protection system designed to handle direct flash of:	Minimum required limp for Type 1 SPD for line-neutral network
I	200 kA	25 kA/pole
II	150 kA	18.75 kA/pole
III / IV	100 kA	12.5 kA/pole

Autoextinguish follow current I_{fi}

This characteristic is applicable only for SPDs with spark gap technology. The autoextinguish follow current I_{fi} must always be greater than the prospective short-circuit current I_{sc} at the point of installation.

3.5 Selection of a Type 2 SPD

Maximum discharge current I_{max}

The maximum discharge current I_{max} is defined according to the estimated exposure level relative to the building's location.

The value of the maximum discharge current (I_{max}) is determined by a risk analysis (see table in Figure 32).

Fig. 32 – Recommended maximum discharge current I_{max} according to the exposure level

	Low	Medium	High
Building environment	Building located in an urban or suburban area of grouped housing	Building located in a plain	Building where there is a specific risk: pylon, tree, mountainous region, wet area or pond, etc.
Recommended I_{max} value (kA)	20	40	65

3.6 Selection of external Short Circuit Protection Device (SCPD)

The protection devices (thermal and short circuit) must be coordinated with the SPD to ensure reliable operation, i.e.

- ensure continuity of service:
 - withstand lightning current waves
 - not generate excessive residual voltage.
- ensure effective protection against all types of overcurrent:
 - overload following thermal runaway of the varistor;
 - short circuit of low intensity (impedant);
 - short circuit of high intensity.

Risks to be avoided at end of life of the SPDs

Due to ageing

In the case of natural end of life due to ageing, protection is of the thermal type. SPD with varistors must have an internal disconnecter which disables the SPD.

Note: End of life through thermal runaway does not concern SPD with gas discharge tube or encapsulated spark gap.

Due to a fault

The causes of end of life due to a short-circuit fault are:

- Maximum discharge capacity exceeded.
This fault results in a strong short circuit.
- A fault due to the distribution system (neutral/phase switchover, neutral disconnection).
- Gradual deterioration of the varistor.

The latter two faults result in an impedant short circuit.

The installation must be protected from damage resulting from these types of fault: the internal (thermal) disconnecter defined above does not have time to warm up, hence to operate.

A special device called "external Short Circuit Protection Device (external SCPD)", capable of eliminating the short circuit, should be installed. It can be implemented by a circuit breaker or fuse device.

Characteristics of the external SCPD

The external SCPD should be coordinated with the SPD. It is designed to meet the following two constraints:

Lightning current withstand

The lightning current withstand is an essential characteristic of the SPD's external Short Circuit Protection Device.

The external SCPD must not trip upon 15 successive impulse currents at I_n .

Short-circuit current withstand

- The breaking capacity is determined by the installation rules (IEC 60364 standard):
The external SCPD should have a breaking capacity equal to or greater than the prospective short-circuit current I_{sc} at the installation point (in accordance with the IEC 60364 standard).
- Protection of the installation against short circuits
In particular, the impedant short circuit dissipates a lot of energy and should be eliminated very quickly to prevent damage to the installation and to the SPD. The right association between a SPD and its external SCPD must be given by the manufacturer.

Installation mode for the external SCPD

Device "in series"

The SCPD is described as "in series" (see Fig. 33) when the protection is performed by the general protection device of the network to be protected (for example, connection circuit breaker upstream of an installation).

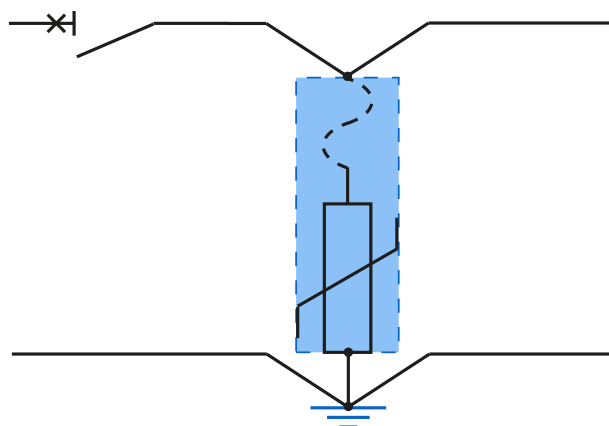


Fig. 33 – SCPD "in series"

Device "in parallel"

The SCPD is described as "in parallel" (see Fig. 34) when the protection is performed specifically by a protection device associated with the SPD.

- The external SCPD is called a "disconnecting circuit breaker" if the function is performed by a circuit breaker.
- The disconnecting circuit breaker may or may not be integrated into the SPD.

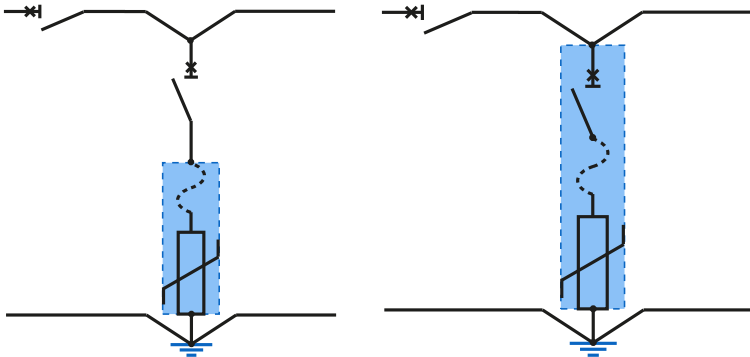


Fig. J34 – SCPD "in parallel"

Note:

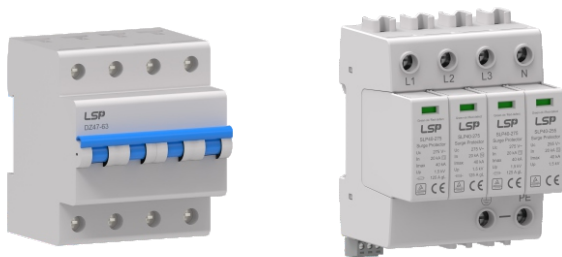
In the case of a SPD with gas discharge tube or encapsulated spark gap, the SCPD allows the current to be cut immediately after use.

Guarantee of protection

The external SCPD should be coordinated with the SPD, and tested and guaranteed by the SPD manufacturer in accordance with the recommendations of the IEC 61643-11 standard. It should also be installed in accordance with the manufacturer's recommendations. As an example, see the Arrester Electric SCPD+SPD coordination tables.

When this device is integrated, conformity with product standard IEC 61643-11 naturally ensures protection.

Fig. J35 – SPDs with external SCPD, non-integrated (DZ47-63 + SLP40)



Summary of external SCPDs characteristics

A detailed analysis of the characteristics is given in section Detailed characteristics of the external SCPD .

The table in Figure 36 shows, on an example, a summary of the characteristics according to the various types of external SCPD.

Fig. 36 – Characteristics of end-of-life protection of a Type 2 SPD according to the external SCPDs

Installation mode for the external SCPD	In series	In parallel		
		Fuse protection associated	Circuit breaker protection associated	Circuit breaker protection integrated
Surge protection of equipment	=	=	=	=
	SPDs protect the equipment satisfactorily whatever the kind of associated external SCPD			
Protection of installation at end of life	-	=	+	++
	No guarantee of protection possible	Manufacturer's guarantee		Full guarantee
		Protection from impedant short circuits not well ensured	Protection from short circuits perfectly ensured	
Continuity of service at end of life	--	+	+	+
	The complete installation is shut down	Only the SPD circuit is shut down		
Maintenance at end of life	--	=	+	+
	Shutdown of the installation required	Change of fuses	Immediate resetting	

4. Installation of Surge Protection Device

4.1 Connection of Surge Protection Device

Connections of a SPD to the loads should be as short as possible in order to reduce the value of the voltage protection level (installed U_p) on the terminals of the protected equipment.

The total length of SPD connections to the network and the earth terminal block should not exceed 50 cm.

One of the essential characteristics for the protection of equipment is the maximum voltage protection level (installed U_p) that the equipment can withstand at its terminals. Accordingly, a SPD should be chosen with a voltage protection level U_p adapted to protection of the equipment (see Fig. 37). The total length of the connection conductors is

$$L = L_1 + L_2 + L_3.$$

For high-frequency currents, the impedance per unit length of this connection is approximately $1 \mu\text{H/m}$.

Hence, applying Lenz's law to this connection: $\Delta U = L di/dt$

The normalized $8/20 \mu\text{s}$ current wave, with a current amplitude of 8 kA, accordingly creates a voltage rise of 1000 V per metre of cable.

$$\Delta U = 1 \times 10^{-6} \times 8 \times 10^3 / 8 \times 10^{-6} = 1000 \text{ V}$$

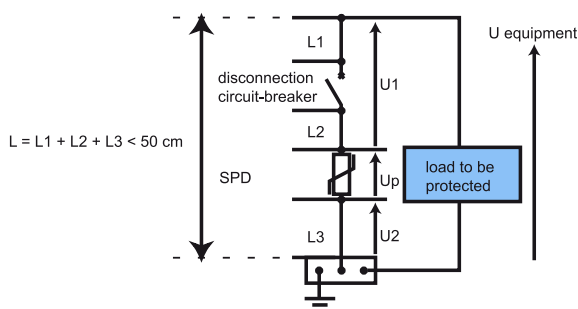


Fig. 37 – Connections of a SPD $L < 50 \text{ cm}$

As a result the voltage across the equipment terminals, $U_{\text{equipment}}$, is:

$$U_{\text{equipment}} = U_p + U_1 + U_2$$

If $L_1 + L_2 + L_3 = 50 \text{ cm}$, and the wave is $8/20 \mu\text{s}$ with an amplitude of 8 kA, the voltage across the equipment terminals will be $U_p + 500 \text{ V}$.

Connection in plastic enclosure

Figure 38 below shows how to connect a SPD in plastic enclosure.

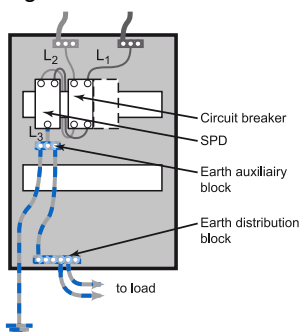


Fig. 38 – Example of connection in plastic enclosure

Connection in metallic enclosure

In the case of a switchgear assembly in a metallic enclosure, it may be wise to connect the SPD directly to the metallic enclosure, with the enclosure being used as a protective conductor (see Fig. 39).

This arrangement complies with standard IEC 61439-2 and the Assembly manufacturer must make sure that the characteristics of the enclosure make this use possible.

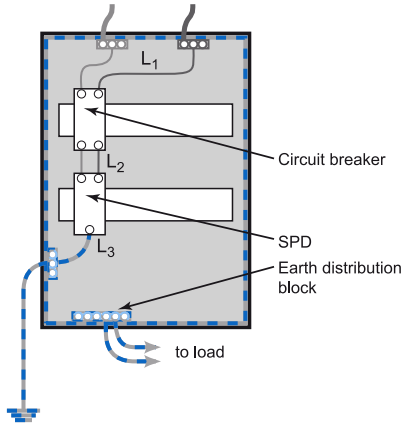


Fig. 39 – Example of connection in metallic enclosure

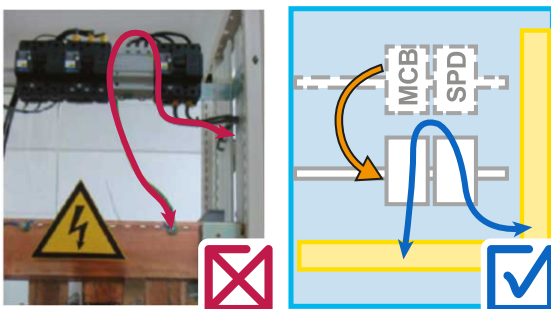
Conductor cross section

The recommended minimum conductor cross section takes into account:

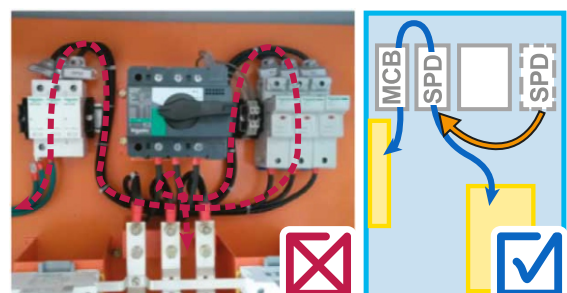
- The normal service to be provided: Flow of the lightning current wave under a maximum voltage drop (50 cm rule). Note: Unlike applications at 50 Hz, the phenomenon of lightning being high-frequency, the increase in the conductor cross section does not greatly reduce its high-frequency impedance.
- The conductors' withstand to short-circuit currents: The conductor must resist a short-circuit current during the maximum protection system cutoff time. IEC 60364 recommends at the installation incoming end a minimum cross section of:
 - 4 mm² (Cu) for connection of Type 2 SPD;
 - 16 mm² (Cu) for connection of Type 1 SPD (presence of lightning protection system).

Examples of good and bad SPD installations

Fig. 40 – Examples of good and bad SPD installations



Example 1: Equipment installation design should be done in accordance to installation rules: cables length shall be less than 50 cm.



Example 2 : Positioning of devices should be linked to installation rules: reduce length of cables < 50 cm and keep the loop area rule of reducing impact of magnetic fields created by lightning current.

4.2 Cabling rules of Surge Protection Device

Rule 1

The first rule to comply with is that the length of the SPD connections between the network (via the external SCPD) and the earthing terminals

Figure 41 shows the two possibilities for connection of a SPD.

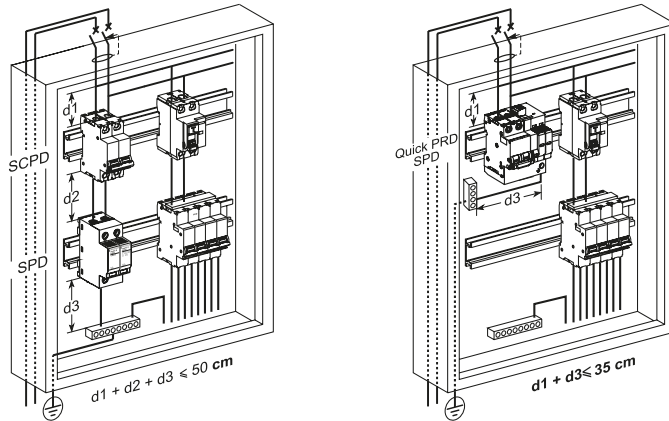


Fig. 41 – SPD with separate or integrated external SCPD

Rule 2

The conductors of protected outgoing feeders:

- should be connected to the terminals of the external SCPD or the SPD;
- should be separated physically from the polluted incoming conductors.

They are located to the right of the terminals of the SPD and the SCPD (see Figure 42).

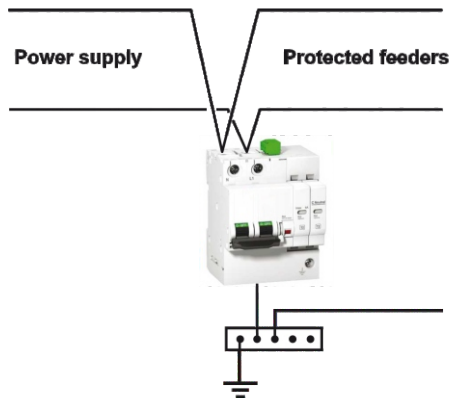


Fig. 42 – The connections of protected outgoing feeders are to the right of the SPD terminals

Rule 3

The incoming feeder phase, neutral and protection (PE) conductors should run one beside another in order to reduce the loop surface (see Fig. 43).

Rule 4

The incoming conductors of the SPD should be remote from the protected outgoing conductors to avoid polluting them by coupling (see Fig. 43).

Rule 5

The cables should be pinned against the metallic parts of the enclosure (if any) in order to minimize the surface of the frame loop and hence benefit from a shielding effect against EM disturbances.

In all cases, it must be checked that the frames of switchboards and enclosures are earthed via very short connections.

Finally, if shielded cables are used, big lengths should be avoided, because they reduce the efficiency of shielding (see Fig. 43).

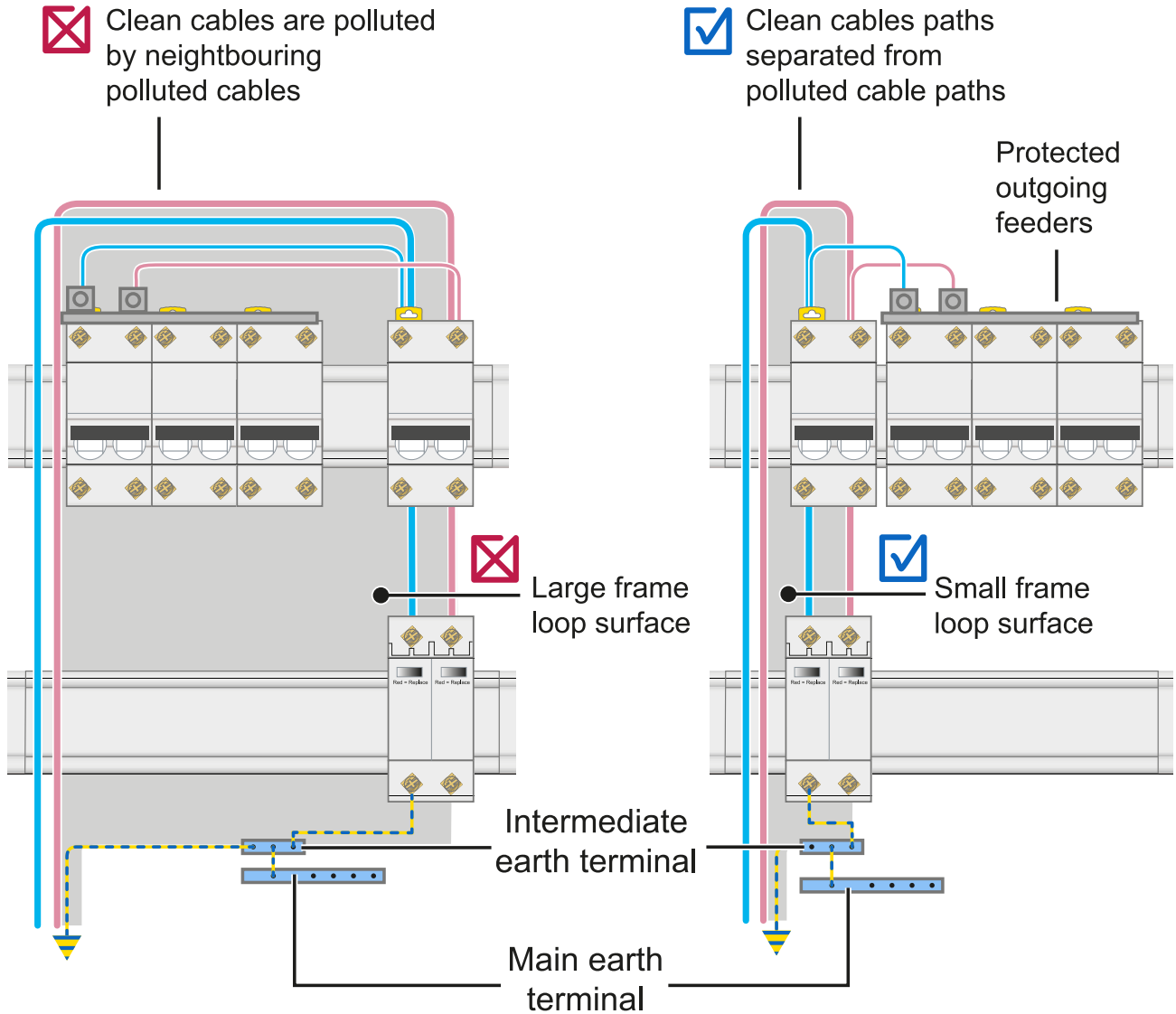


Fig. 43 – Example of improvement of EMC by a reduction in the loop surfaces and common impedance in an electric enclosure

5. Surge protection Application examples

5.1 SPD application example in Supermarket

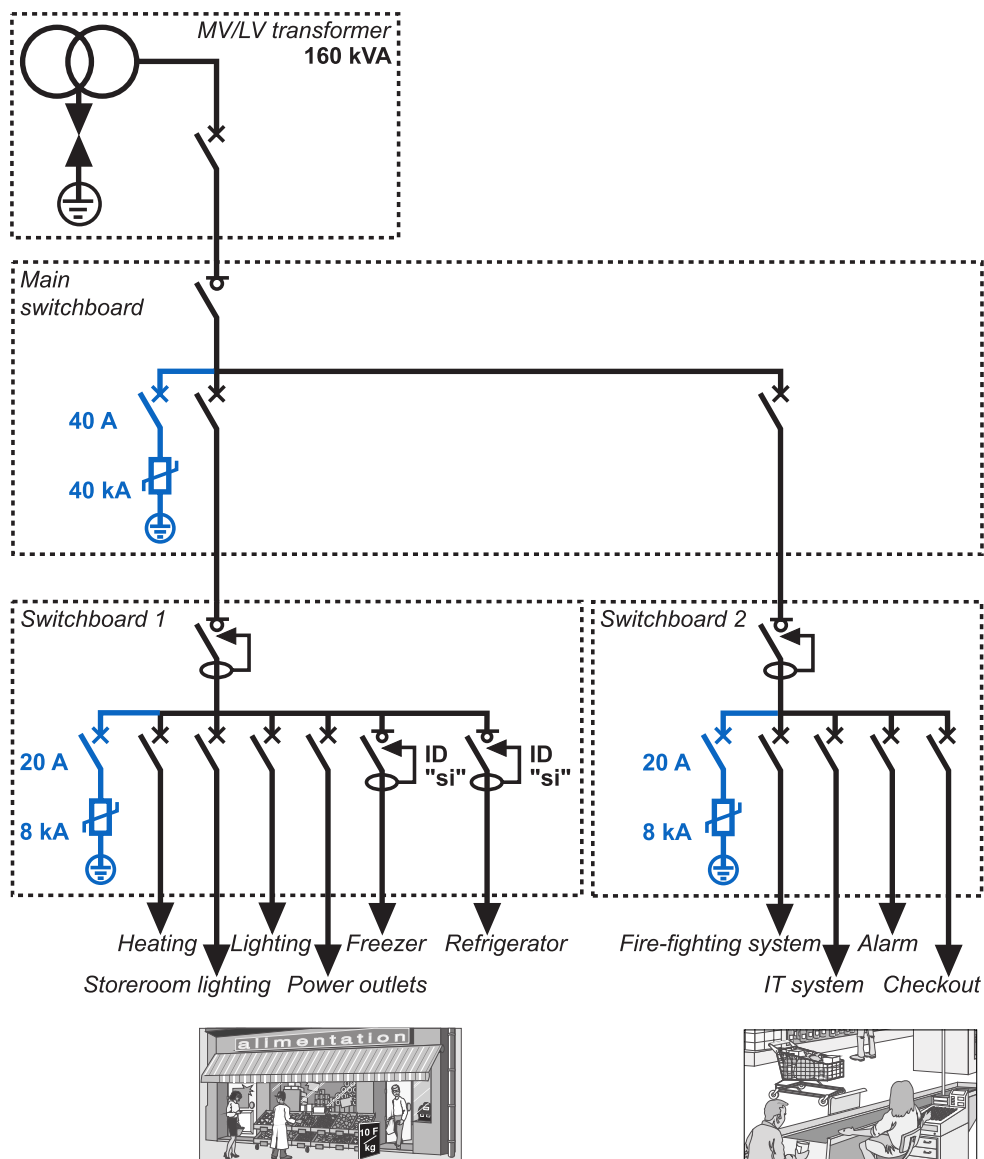


Fig. 44 – Application example: supermarket

Solutions and schematic diagram

- The surge arrester selection guide has made it possible to determine the precise value of the surge arrester at the incoming end of the installation and that of the associated disconnection circuit breaker.
- As the sensitive devices ($U_{imp} < 1.5 \text{ kV}$) are located more than 10m from the incoming protection device, the fine protection surge arresters must be installed as close as possible to the loads.
- To ensure better continuity of service for cold room areas:
 - "si" type residual current circuit breakers will be used to avoid nuisance tripping caused by the rise in earth potential as the lightning wave passes through.
- For protection against atmospheric overvoltages:
 - install a surge arrester in the main switchboard

- install a fine protection surge arrester in each switchboard (1 and 2) supplying the sensitive devices situated more than 10m from the incoming surge arrester
- install a surge arrester on the telecommunications network to protect the devices supplied, for example fire alarms, modems, telephones, faxes.

Cabling recommendations

- Ensure the equipotentiality of the earth terminations of the building.
- Reduce the looped power supply cable areas.

Installation recommendations

- Install a surge arrester, $I_{max} = 40 \text{ kA}$ ($8/20 \mu\text{s}$) and a iC60 disconnection circuit breaker rated at 40 A.
- Install fine protection surge arresters, $I_{max} = 8 \text{ kA}$ ($8/20 \mu\text{s}$) and the associated iC60 disconnection circuit breakers rated at 10 A

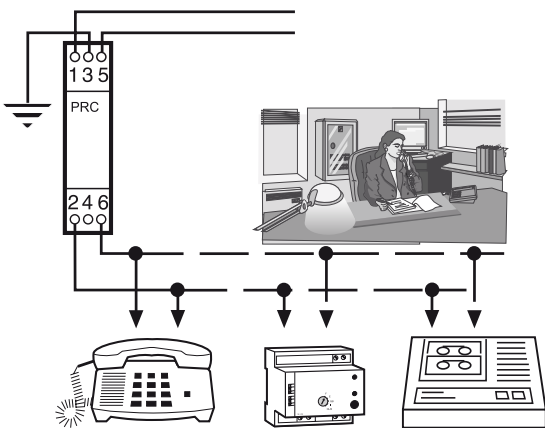


Fig. 45 – Telecommunications network

5.2 SPD for photovoltaic applications

Overvoltage may occur in electrical installations for various reasons. It may be caused by:

- The distribution network as a result of lightning or any work carried out.
- Lightning strikes (nearby or on buildings and PV installations, or on lightning conductors).
- Variations in the electrical field due to lightning.

Like all outdoor structures, PV installations are exposed to the risk of lightning which varies from region to region. Preventive and arrest systems and devices should be in place.

Protection by equipotential bonding

The first safeguard to put in place is a medium (conductor) that ensures equipotential bonding between all the conductive parts of a PV installation.

The aim is to bond all grounded conductors and metal parts and so create equal potential at all points in the installed system.

Protection by surge protection devices (SPDs)

SPDs are particularly important to protect sensitive electrical equipments like AC/DC Inverter, monitoring devices and PV modules, but also other sensitive equipments powered by the 230 VAC electrical distribution network. The following method of risk assessment is based on the evaluation of the critical length L_{crit} and its comparison with L the cumulative length of the d.c. lines.

SPD protection is required if $L \geq L_{crit}$.

L_{crit} depends on the type of PV installation and is calculated as the following table (Fig. 46) sets out:

Fig. 46 – SPD DC choice

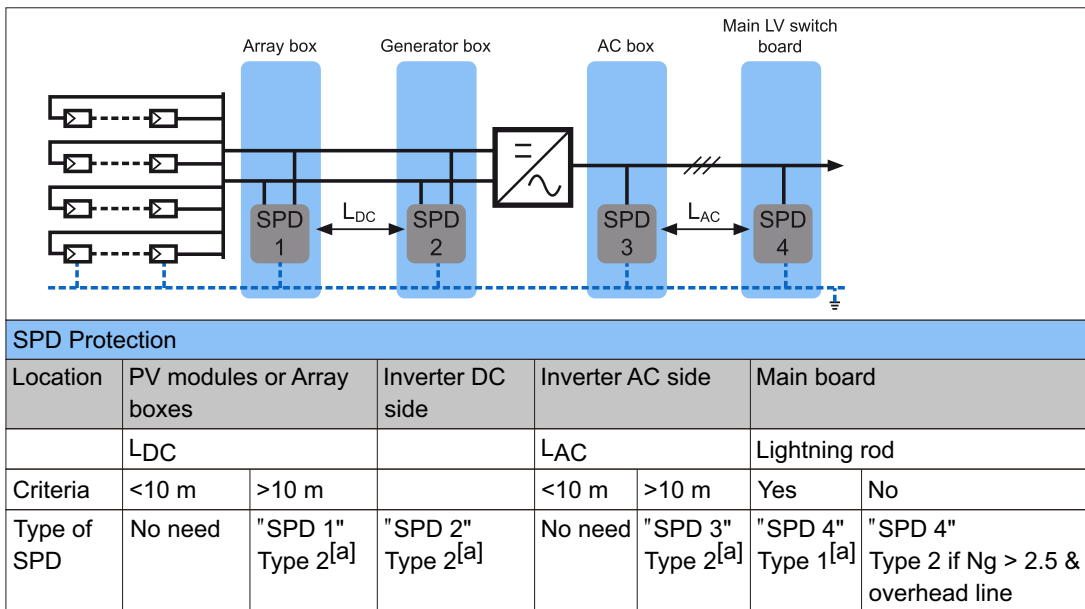
Type of installation	Individual residential premises	Terrestrial production plant	Service/Industrial/Agricultural/Buildings
L_{crit} (in m)	115/ N_g	200/ N_g	450/ N_g
$L \geq L_{crit}$	Surge protective device(s) compulsory on DC side		
$L < L_{crit}$	Surge protective device(s) not compulsory on DC side		

L is the sum of:

- the sum of distances between the inverter(s) and the junction box(es), taking into account that the lengths of cable located in the same conduit are counted only once, and
- the sum of distances between the junction box and the connection points of the photovoltaic modules forming the string, taking into account that the lengths of cable located in the same conduit are counted only once.

N_g is arc lightning density (number of strikes/ km^2 /year).

Fig. 47 – SPD selection



a. Type 1 separation distance according to EN 62305 is not observed.

Installing an SPD

The number and location of SPDs on the DC side depend on the length of the cables between the solar panels and inverter. The SPD should be installed in the vicinity of the inverter if the length is less than 10 metres. If it is greater than 10 metres, a second SPD is necessary and should be located in the box close to the solar panel, the first one is located in the inverter area.

To be efficient, SPD connection cables to the L+ / L- network and between the SPD's earth terminal block and ground busbar must be as short as possible – less than 2.5 metres ($d1+d2 < 50$ cm).

Safe and reliable photovoltaic energy generation

Depending on the distance between the "generator" part and the "conversion" part, it may be necessary to install two surge arresters or more, to ensure protection of each of the two parts.

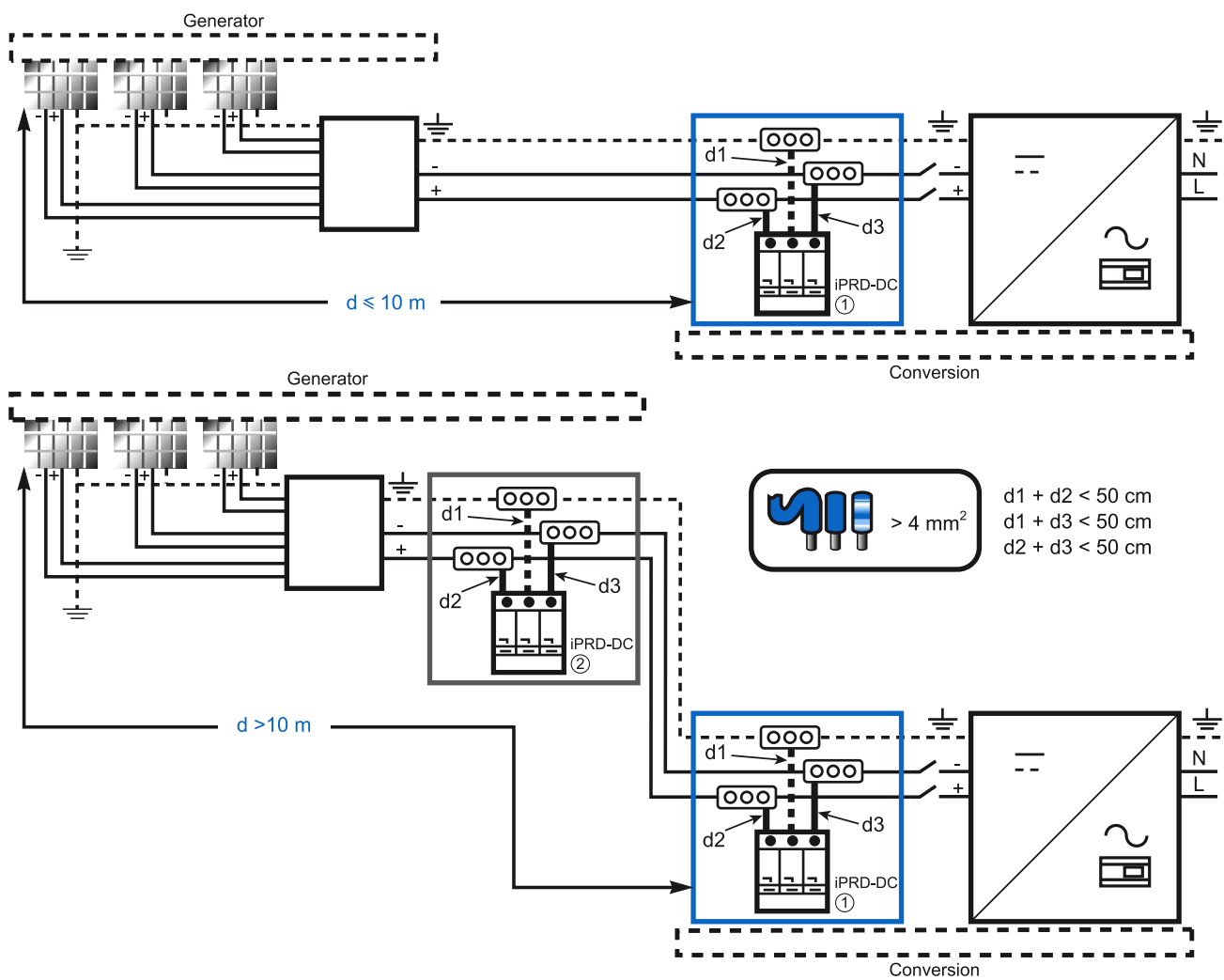


Fig. 48 – SPD location

6. Surge protection technical supplements

6.1 Lightning protection standards

The IEC 62305 standard parts 1 to 4 (NF EN 62305 parts 1 to 4) reorganizes and updates the standard publications IEC 61024 (series), IEC 61312 (series) and IEC 61663 (series) on lightning protection systems.

Part 1 - General principles

This part presents general information on lightning and its characteristics and general data, and introduces the other documents.

Part 2 - Risk management

This part presents the analysis making it possible to calculate the risk for a structure and to determine the various protection scenarios in order to permit technical and economic optimization.

Part 3 - Physical damage to structures and life hazard

This part describes protection from direct lightning strokes, including the lightning protection system, down-conductor, earth lead, equipotentiality and hence SPD with equipotential bonding (Type 1 SPD).

Part 4 - Electrical and electronic systems within structures

This part describes protection from the induced effects of lightning, including the protection system by SPD (Types 2 and 3), cable shielding, rules for installation of SPD, etc.

This series of standards is supplemented by:

- the IEC 61643 series of standards for the definition of surge protection products (see The components of a SPD);
- the IEC 60364-4 and -5 series of standards for application of the products in LV electrical installations (see End-of-life indication of a SPD).

6.2 The components of a SPD

The SPD chiefly consists of (see Fig. 49):

- 1) one or more nonlinear components: the live part (varistor, gas discharge tube, etc.);
- 2) a thermal protective device (internal disconnecter) which protects it from thermal runaway at end of life (SPD with varistor);
- 3) an indicator which indicates end of life of the SPD;
Some SPDs allow remote reporting of this indication;
- 4) an external SCPD which provides protection against short circuits (this device can be integrated into the SPD).

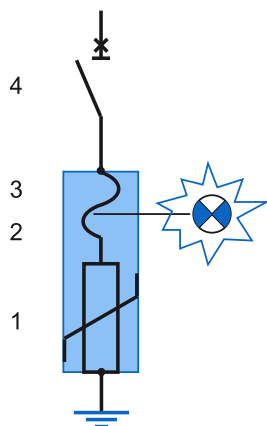


Fig. 49 – Diagram of a SPD





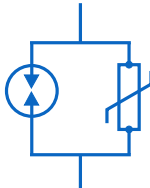
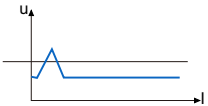
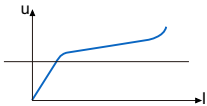
Technology of the live part

Several technologies are available to implement the live part. They each have advantages and disadvantages:

- Zener diodes;
- The gas discharge tube (controlled or not controlled);
- The varistor (zinc oxide varistor).

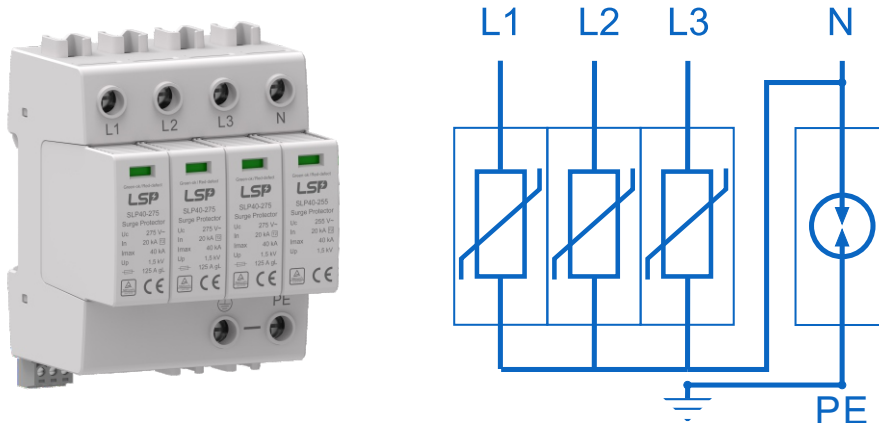
The table below shows the characteristics and the arrangements of 3 commonly used technologies.

Fig. 50 – Summary performance table

Component	Gas Discharge Tube (GDT)	Encapsulated spark gap	Zinc oxide varistor Tube (GDT)	GDT and varistor in series	Encapsulated spark gap and varistor in parallel
Characteristics					
Operating mode	Voltage switching	Voltage switching	Voltage limiting	Voltage-switching and -limiting in series	Voltage-switching and -limiting in parallel
Operating curves					
Application	<ul style="list-style-type: none"> • Telecom network • LV network (associated with varistor) 	LV network	LV network	LV network	LV network
SPD Type	Type 2	Type 1	Type1 or Type 2	Type1 + Type 2	Type1 + Type 2

Note: Two technologies can be installed in the same SPD (see Fig. 51)

Fig. 51 – The Schneider Electric brand iPRD SPD incorporates a gas discharge tube between neutral and earth and varistors between phase and neutral



6.3 End-of-life indication of a SPD

End-of-life indicators are associated with the internal disconnecter and the external SCPD of the SPD to inform the user that the equipment is no longer protected against overvoltages of atmospheric origin.

Local indication

This function is generally required by the installation codes. The end-of-life indication is given by an indicator (luminous or mechanical) to the internal disconnecter and/or the external SCPD.

When the external SCPD is implemented by a fuse device, it is necessary to provide for a fuse with a striker and a base equipped with a tripping system to ensure this function.

Integrated disconnecting circuit breaker

The mechanical indicator and the position of the control handle allow natural end-of-life indication.

Local indication and remote reporting

Local indication

Surge Protection Device (see Fig. 52) is fitted with local mechanical status indicators:

- the (red) mechanical indicator of the SPD;
- the (red) mechanical indicator on each cartridge indicates cartridge end of life.



Fig. 52 – SLP40-XXX/3S+1 SPD of the Arrester Electric brand

Remote reporting

(see Fig. 53)

Surge Protection Device is fitted with an indication contact which allows remote reporting of:

- cartridge end of life;
- a missing cartridge, and when it has been put back in place;
- a fault on the network (short circuit, disconnection of neutral, phase/neutral reversal);
- local manual switching.

As a result, remote monitoring of the operating condition of the installed SPDs makes it possible to ensure that these protective devices in standby state are always ready to operate.

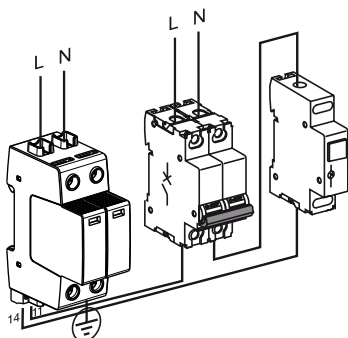


Fig. 53 – Installation of indicator light with a AC SPD

Maintenance at end of life

When the end-of-life indicator indicates shutdown, the SPD (or the cartridge in question) must be replaced.

6.4 Detailed characteristics of the external SCPD

Current wave withstand

The current wave withstand tests on external SCPDs show as follows:

- For a given rating and technology (NH or cylindrical fuse), the current wave withstand capability is better with an aM type fuse (motor protection) than with a gG type fuse (general use).
- For a given rating, the current wave withstand capability is better with a circuit breaker than with a fuse device.

Figure 54 below shows the results of the voltage wave withstand tests:

- to protect a SPD defined for $I_{max} = 20$ kA, the external SCPD to be chosen is either a MCB 16 A or a Fuse aM 63 A, Note: in this case, a Fuse gG 63 A is not suitable.
- to protect a SPD defined for $I_{max} = 40$ kA, the external SCPD to be chosen is either a MCB 40 A or a Fuse aM 125 A,

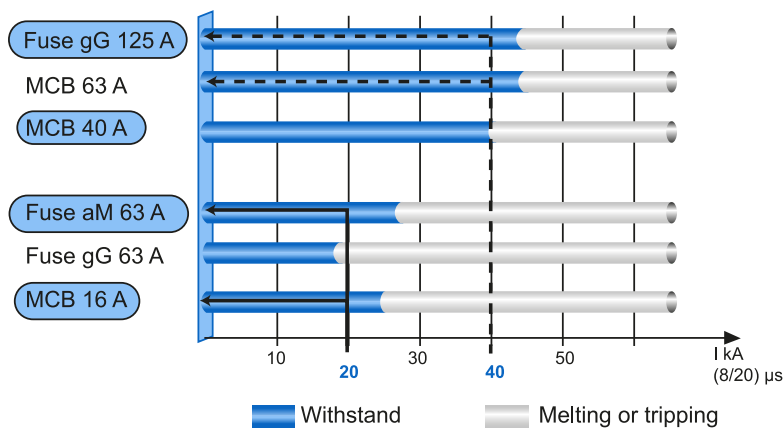


Fig. 54 – Comparison of SCPDs voltage wave withstand capabilities for $I_{max} = 20$ kA and $I_{max} = 40$ kA

Installed Up voltage protection level

In general:

- The voltage drop across the terminals of a circuit breaker is higher than that across the terminals of a fuse device. This is because the impedance of the circuit-breaker components (thermal and magnetic tripping devices) is higher than that of a fuse.

However:

- The difference between the voltage drops remains slight for current waves not exceeding 10 kA (95% of cases);
- The installed Up voltage protection level also takes into account the cabling impedance. This can be high in the case of a fuse technology (protection device remote from the SPD) and low in the case of a circuit-breaker technology (circuit breaker close to, and even integrated into the SPD).

Note: The installed Up voltage protection level is the sum of the voltage drops:

- in the SPD;
- in the external SCPD;
- in the equipment cabling

Protection from impedant short circuits

An impedant short circuit dissipates a lot of energy and should be eliminated very quickly to prevent damage to the installation and to the SPD.

Figure 55 compares the response time and the energy limitation of a protection system by a 63 A aM fuse and a 25 A circuit breaker.

These two protection systems have the same 8/20 μ s current wave withstand capability (27 kA and 30 kA respectively).

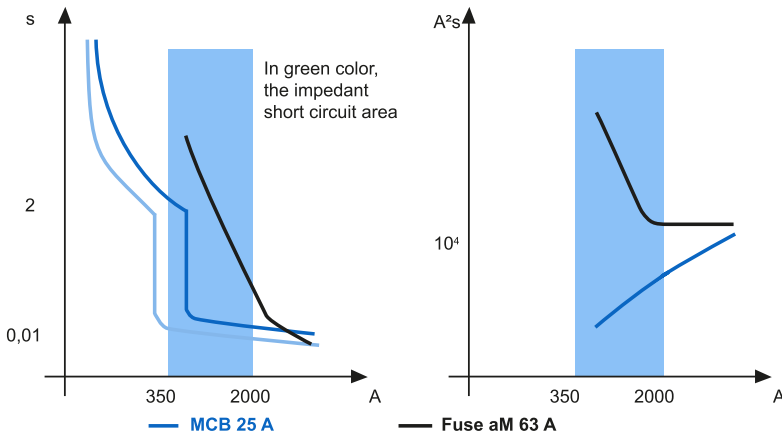


Fig. 55 – Comparison of time/current and energy limitations curves for a circuit breaker and a fuse having the same 8/20 μ s current wave withstand capability

6.5 Propagation of a lightning wave

Electrical networks are low-frequency and, as a result, propagation of the voltage wave is instantaneous relative to the frequency of the phenomenon: at any point of a conductor, the instantaneous voltage is the same.

The lightning wave is a high-frequency phenomenon (several hundred kHz to a MHz):

- The lightning wave is propagated along a conductor at a certain speed relative to the frequency of the phenomenon. As a result, at any given time, the voltage does not have the same value at all points on the medium (see Fig. 56).

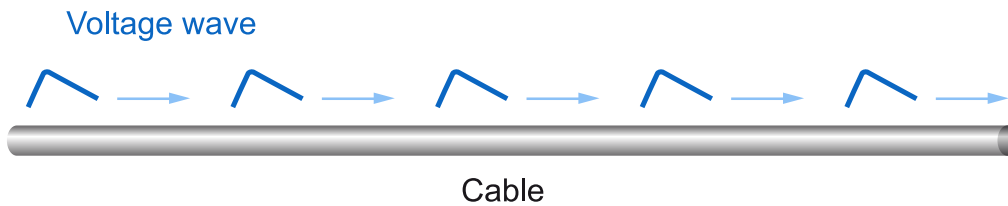


Fig. 56 – Propagation of a lightning wave in a conductor

- A change of medium creates a phenomenon of propagation and/or reflection of the wave depending on:
 - the difference of impedance between the two media;
 - the frequency of the progressive wave (steepness of the rise time in the case of a pulse);
 - the length of the medium.

In the case of total reflection in particular, the voltage value may double.

Example: case of protection by a SPD

Modelling of the phenomenon applied to a lightning wave and tests in laboratory showed that a load powered by 30 m of cable protected upstream by a SPD at voltage U_p sustains, due to reflection phenomena, a maximum voltage of $2 \times U_p$ (see Fig. 57). This voltage wave is not energetic.

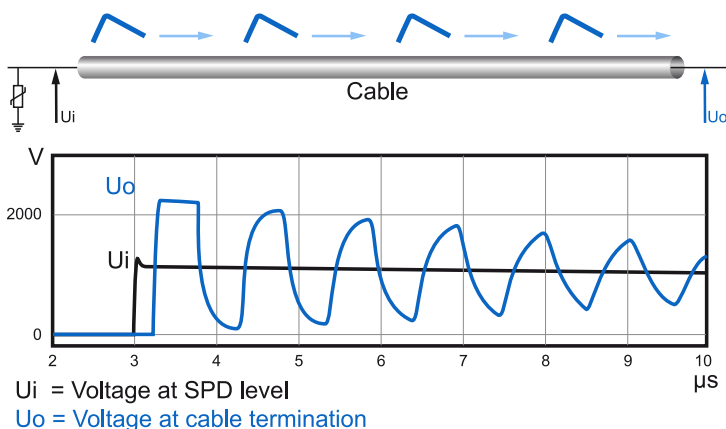


Fig. 57 – Reflection of a lightning wave at the termination of a cable

U_i = Voltage at SPD level
 U_o = Voltage at cable termination

Corrective action

Of the three factors (difference of impedance, frequency, distance), the only one that can really be controlled is the length of cable between the SPD and the load to be protected. The greater this length, the greater the reflection.

Generally for the overvoltage fronts faced in a building, reflection phenomena are significant from 10 m and can double the voltage from 30 m (see Fig. 58).

It is necessary to install a second SPD in fine protection if the cable length exceeds 10 m between the incoming-end SPD and the equipment to be protected.

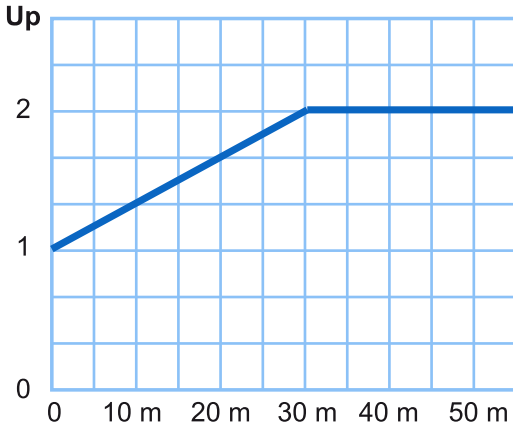


Fig. 58 – Maximum voltage at the extremity of the cable according to its length to a front of incident voltage =4kV/us

6.6 Example of lightning current in TT system

Common mode SPD between phase and PE or phase and PEN is installed whatever type of system earthing arrangement (see Fig. 59).

The neutral earthing resistor R1 used for the pylons has a lower resistance than the earthing resistor R2 used for the installation.

The lightning current will flow through circuit ABCD to earth via the easiest path. It will pass through varistors V1 and V2 in series, causing a differential voltage equal to twice the U_p voltage of the SPD ($U_{p1} + U_{p2}$) to appear at the terminals of A and C at the entrance to the installation in extreme cases.

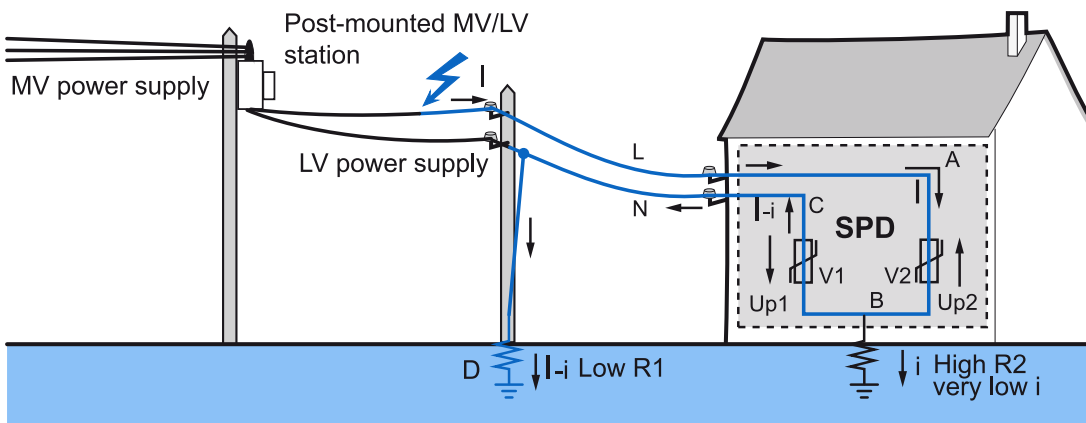


Fig. 59 – Common protection only

To protect the loads between Ph and N effectively, the differential mode voltage (between A and C) must be reduced.

Another SPD architecture is therefore used (see Fig. 60)

The lightning current flows through circuit ABH which has a lower impedance than circuit ABCD, as the impedance of the component used between B and H is null (gas filled spark gap). In this case, the differential voltage is equal to the residual voltage of the SPD (U_{p2}).

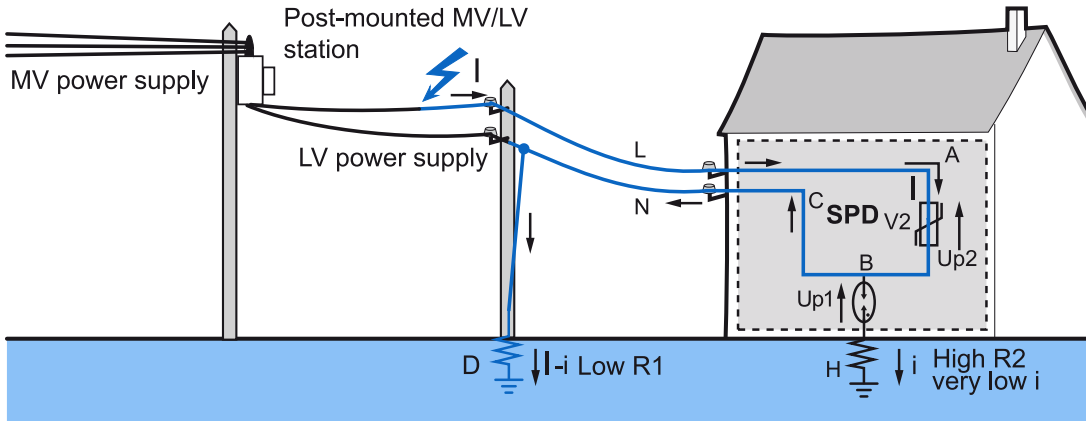


Fig. 60 – Common and differential protection



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