4 Installation of SPDs

4.1 Connection

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 Up) 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 Up) that the equipment can withstand at its terminals. Accordingly, a SPD should be chosen with a voltage protection level Up adapted to protection of the equipment (see **Fig. J38**). The total length of the connection conductors is
L = L1+L2+L3.
For high-frequency currents, the impedance per unit length of this connection is approximately 1 µH/m.
Hence, applying Lenz's law to this connection: ΔU = L di/dt
The normalized 8/20 µs current wave, with a current amplitude of 8 kA, accordingly creates a voltage rise of 1000 V per metre of cable.
$\Delta U = 1 \times 10^{-6} \times 8 \times 10^{3} / 8 \times 10^{-6} = 1000$ V

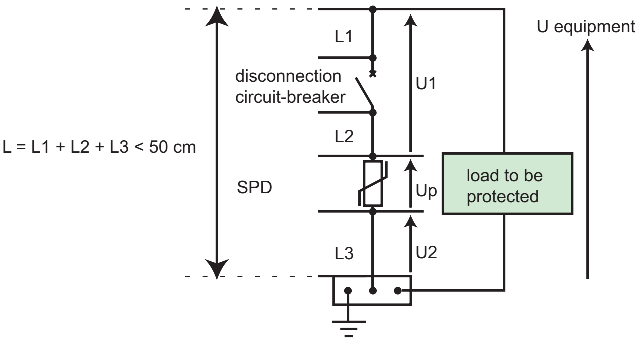


Fig. J38 : Connections of a SPD L < 50 cm

As a result the voltage across the equipment terminals, installed Up, is:
installed Up = Up + U1 + U2
If L1+L2+L3 = 50 cm, and the wave is 8/20 µs with an amplitude of 8 kÂ, the voltage across the equipment terminals will be Up + 500 V.

4.1.1 Connection in plastic enclosure

Figure J39a below shows how to connect a SPD in plastic enclosure.

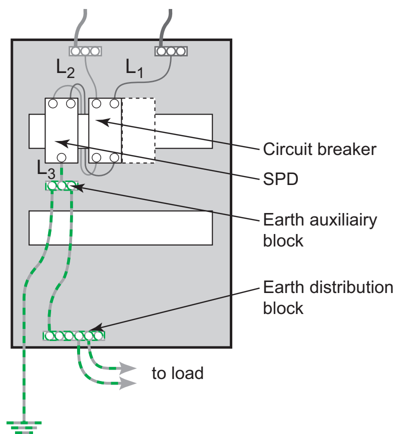


Fig. J39a : Example of connection in plastic enclosure

4.1.2 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. J39b**).
This arrangement complies with standard IEC 60439-1 and the manufacturer of the switchgear assembly must make sure that the characteristics of the enclosure make this use possible.

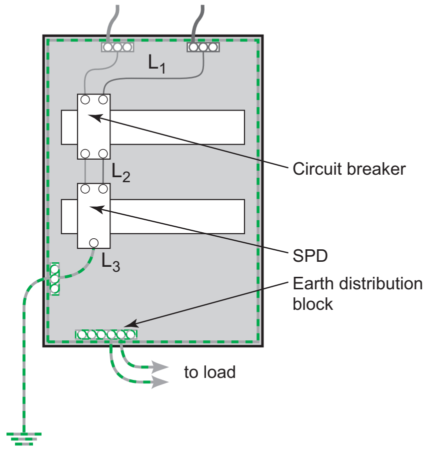


Fig. J39b : Example of connection in metallic enclosure

4.1.3 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).

4.2 Cabling rules

■ **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 terminal block should not exceed 50 cm.
Figure J40 shows the two possibilities for connection of a SPD.

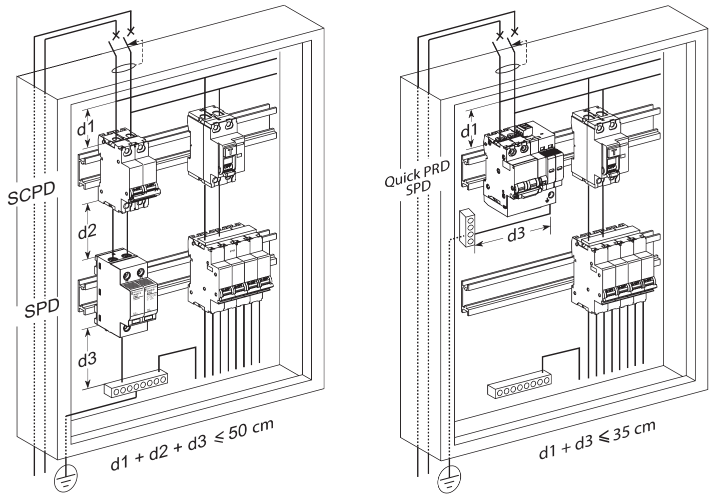


Fig. 40 : SPD with separate or integrated external SCPD

■ **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 **Fig. J41**).

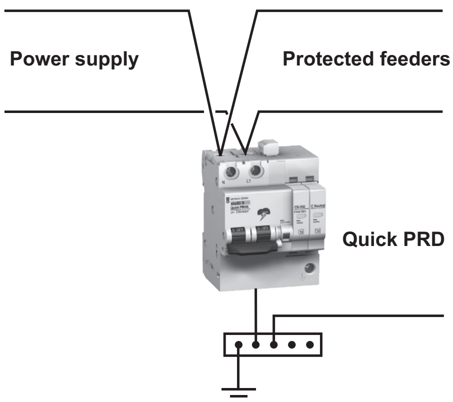


Fig. 41 : The connections of protected outgoing feeders are to the right of the SPD terminals

■ **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. J42**).

■ **Rule 4:**
The incoming conductors of the SPD should be remote from the protected outgoing conductors to avoid polluting them by coupling (see Fig. J42).

■ **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. J42).

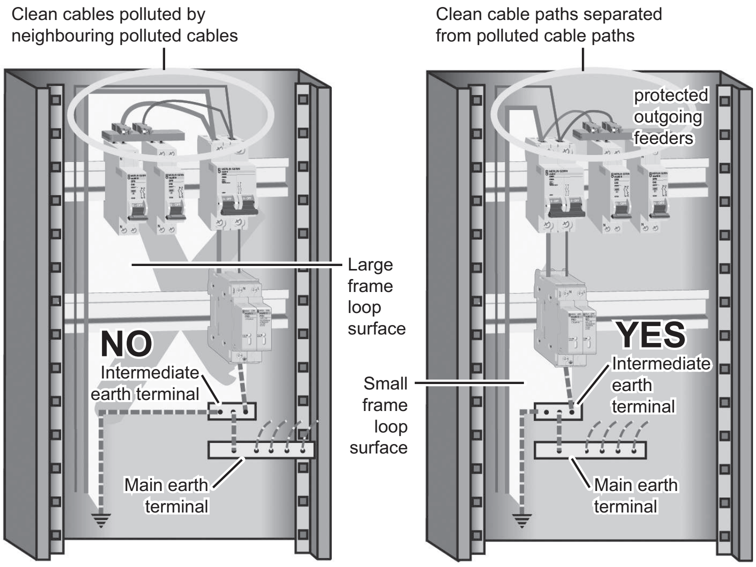


Fig. 42 : Example of improvement of EMC by a reduction in the loop surfaces and common impedance in an electric enclosure

5 Application

5.1 Installation examples

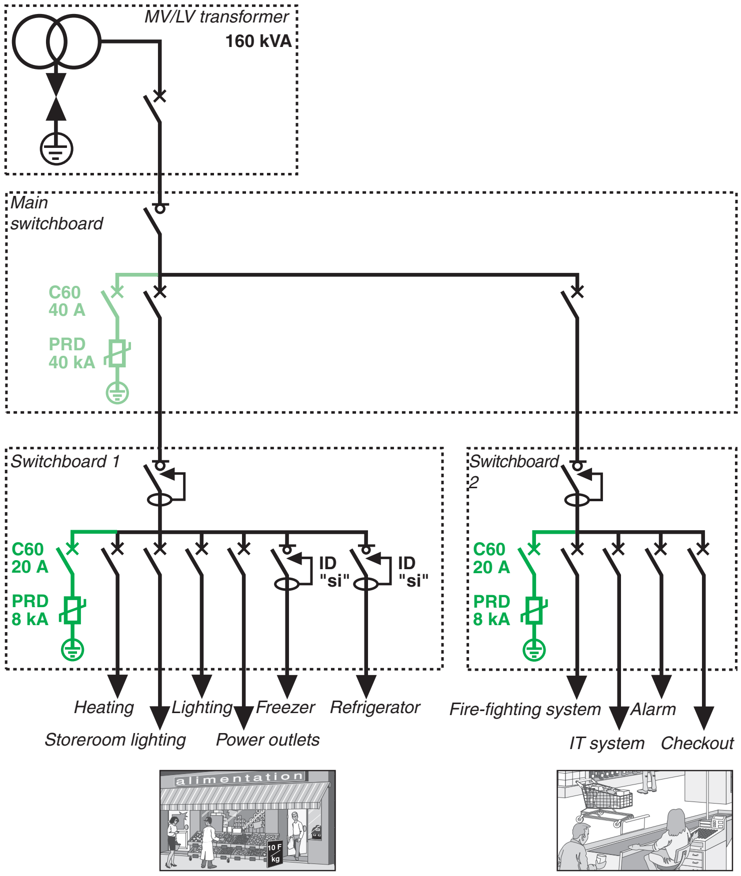


Fig. J43 : Application example: supermarket

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 (Uimp < 1.5 kV) are located more than 30 m 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 30 m 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, Imax = 40 kA (8/20 µs) and a C60 disconnection circuit breaker rated at 20 A.
■ Install fine protection surge arresters, Imax = 8 kA (8/20 µs) and the associated C60 disconnection circuit breakers rated at 20

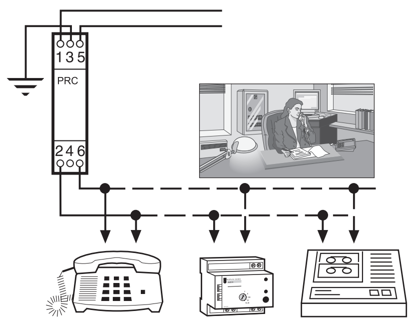


Fig. J44 : Telecommunications network

6 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 sub-section 2);

■ the IEC 60364-4 and -5 series of standards for application of the products in LV electrical installations (see sub-section 3).

6.2 The components of a SPD

The SPD chiefly consists of (see **Fig. J45**):
1) one or more nonlinear components: the live part (varistor, gas discharge tube, etc.);
2) a thermal protective device (internal disconnector) 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).

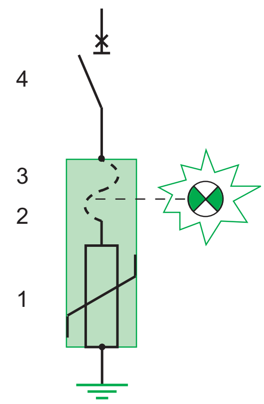


Fig. J45 : Diagram of a SPD

6.2.1 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.

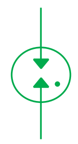
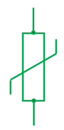
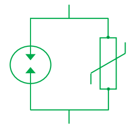
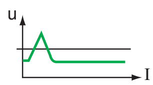
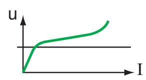
Component	Gas Discharge Tube (GDT)	Encapsulated spark gap	Zinc oxide varistor	GDT and varistor in series	Encapsulated spark gap and varistor in parallel
Characteristics					
					
Operating mode	Voltage switching	Voltage switching	Voltage limiting	Voltage-switching and -limiting in series	Voltage-switching and -limiting in parallel
Operating curves					
Application	■ Telecom network ■ LV network (associated with varistor)	LV network	LV network	LV network	LV network
SPD Type	Type 2	Type 1	Type 1 ou Type 2	Type 1+ Type 2	Type 1+ Type 2

Fig. J46 : Summary performance table

Note: Two technologies can be installed in the same SPD (see **Fig. J47**)

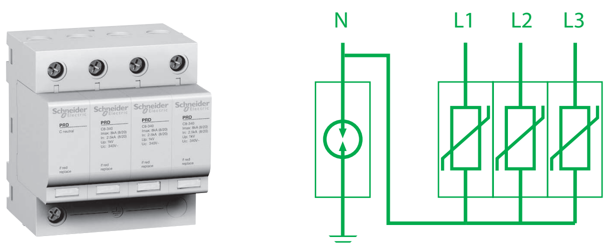


Fig. J47 : The Schneider Electric brand PRD SPD incorporates a gas discharge tube between neutral and earth and varistors between phase and neutral

6.3 End-of-life indication

End-of-life indicators are associated with the internal disconnector and the external SCPD of the SPD to informs 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 disconnector 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.

Fig. J48 : Quick PRD 3P +N SPD of the Schneider Electric brand

6.3.1 Local indication and remote reporting

Quick PRD SPD of the Schneider Electric brand is of the "ready to wire" type with an integrated disconnecting circuit breaker.

Local indication

Quick PRD SPD (see **Fig. J48**) is fitted with local mechanical status indicators:

- the (red) mechanical indicator and the position of the disconnecting circuit breaker handle indicate shutdown of the SPD;
- the (red) mechanical indicator on each cartridge indicates cartridge end of life.

Remote reporting (see Fig. J49)

Quick PRD SPD 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.

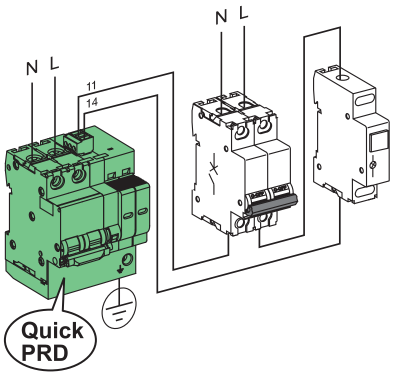


Fig. J49 : Installation of indicator light with a Quick PRD SPD

6.3.2 Maintenance at end of life

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

In the case of the Quick PRD SPD, maintenance is facilitated:

- The cartridge at end of life (to be replaced) is easily identifiable by the Maintenance Department.
- The cartridge at end of life can be replaced in complete safety, because a safety device prohibits closing of the disconnecting circuit breaker if a cartridge is missing.

6.4 Detailed characteristics of the external SCPD

6.4.1 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 J50 below shows the results of the voltage wave withstand tests:

- to protect a SPD defined for Imax = 20 kA, the external SCPD to be chosen is either a MCCB 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 Imax = 40 kA, the external SCPD to be chosen is either a MCCB 63 A or a Fuse aM 125 A,

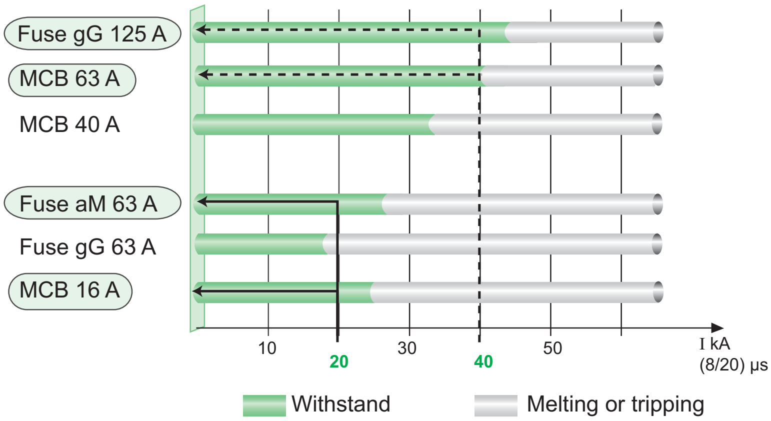


Fig. J50 : Comparison of SCPDs voltage wave withstand capabilities for Imax = 20 kA and Imax = 40 kA

6.4.2 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.

6.4.3 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 J51 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 µs current wave withstand capability (27 kA and 30 kA respectively).

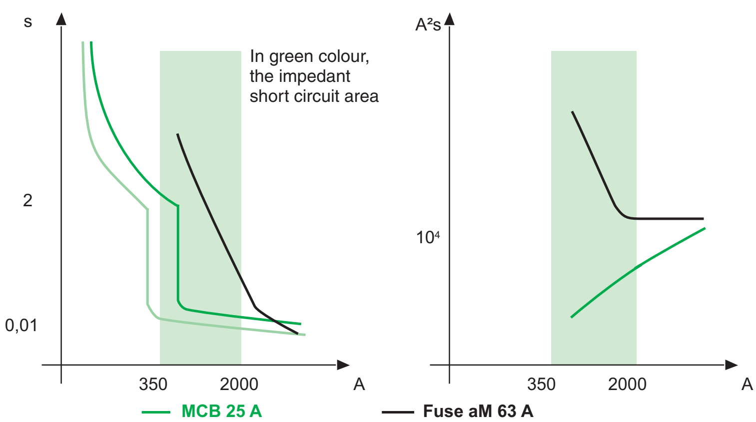


Fig. J51 : Comparison of time/current and energy limitations curves for a circuit breaker and a fuse having the same 8/20 µs current wave withstand capability

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. J52**).

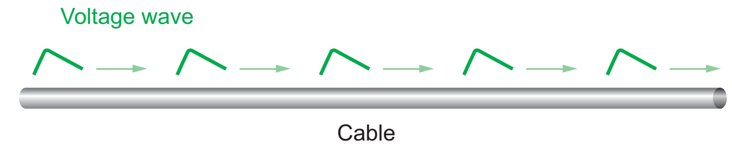


Fig. J52 : Propagation of a lightning wave in a conductor

- 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 Up sustains, due to reflection phenomena, a maximum voltage of 2 x Up (see **Fig. J53**). This voltage wave is not energetic.

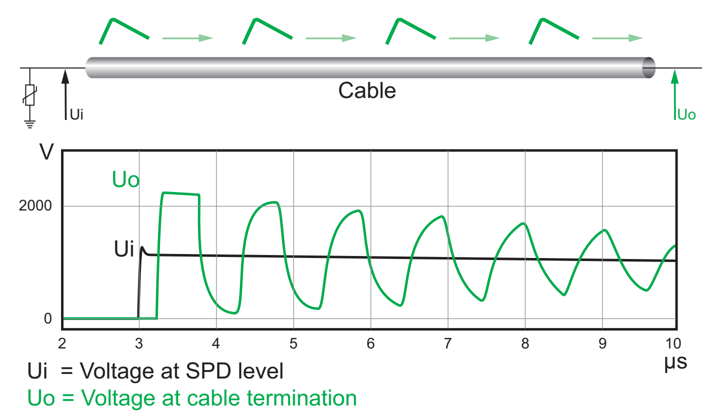


Fig. J53 : Reflection of a lightning wave at the termination of a cable

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. J54**).
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.

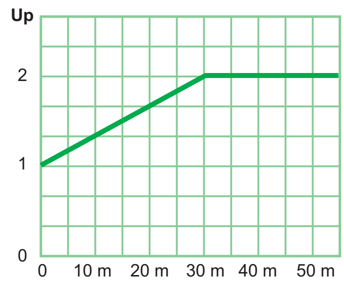


Fig. J54 : Reflection of a lightning wave at the termination of a cable

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. J55**).
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 Up voltage of the SPD (Up1 + Up2) to appear at the terminals of A and C at the entrance to the installation in extreme cases.

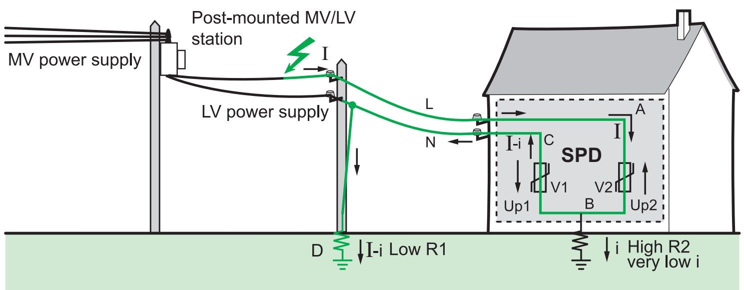


Fig. J55 : Common protection only

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. J56**)
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 (Up2).

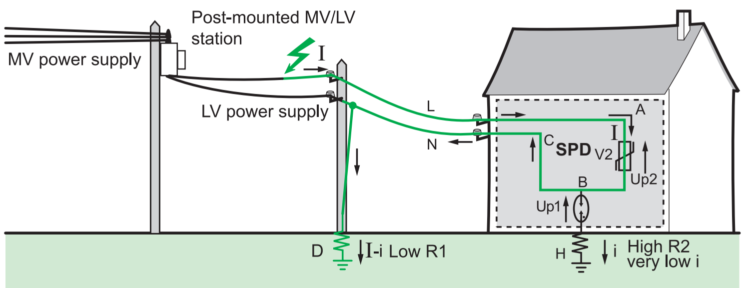


Fig. J56 : Common and differential protection