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

2.4 The Surge Protection Device (SPD)

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. J17**). 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.

SPD Connected after the main breaker in parallel with the installation

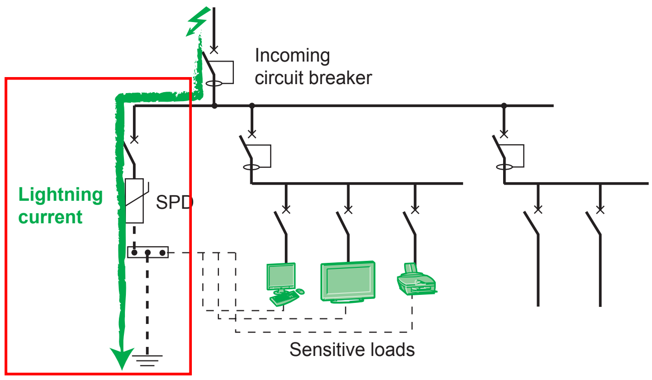

Fig. J17 : Principle of protection system in parallel

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 µs 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 µs 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 µs) and current waves (8/20 µs).

■ **SPD normative definition**

	Direct lightning stroke	Indirect lightning stroke	
IEC 61643-1	Class I test	Class II test	Class III test
IEC 61643-11/2007	Type 1: **T1**	Type 2 : **T2**	Type 3 : **T3**
EN/IEC 61643-11	Type 1	Type 2	Type 3
Former VDE 0675v	B	C	D

Note 1: *There exist* T1 + T2 *SPD (or Type 1 + 2 SPD) combining protection of loads against direct and indirect lightning strokes.*
Note 2: *some* T2 *SPD can also be declared as* T3.

Fig. J18 : SPD standard definition

2.4.1 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. J19**).

■ **Common characteristics**

□ Uc: 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.

□ Up: Voltage protection level (at In)

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 In. The voltage protection level chosen must be below the overvoltage withstand capability of the loads (see section 3.2). In the event of lightning strokes, the voltage across the terminals of the SPD generally remains less than Up.

□ In: Nominal discharge current

This is the peak value of a current of 8/20 µs waveform that the SPD is capable of discharging 15 times.

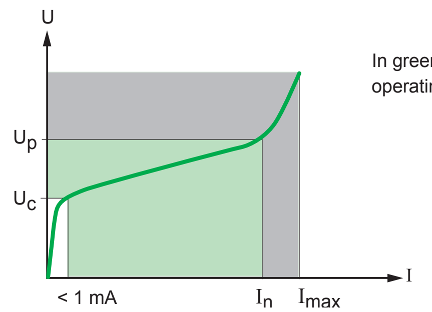

Fig. J19 : Time/current characteristic of a SPD with varistor

■ **Type 1 SPD**

□ Iimp: Impulse current

This is the peak value of a current of 10/350 µs waveform that the SPD is capable of discharging 5 times.

□ Ifi: 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**

□ Imax: Maximum discharge current

This is the peak value of a current of 8/20 µs waveform that the SPD is capable of discharging once.

■ **Type 3 SPD**

□ Uoc: Open-circuit voltage applied during class III (Type 3) tests.

2.4.2 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 telephon 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

To protect an electrical installation in a building, simple rules apply for the choice of
- *SPD(s);*
- *its protection system.*

3.1 Design rules

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 Imax.
- Short circuit protection device
  - maximum discharge current Imax;
  - short-circuit current Isc at the point of installation.

The logic diagram in the **Figure J20** below illustrates this design rule.

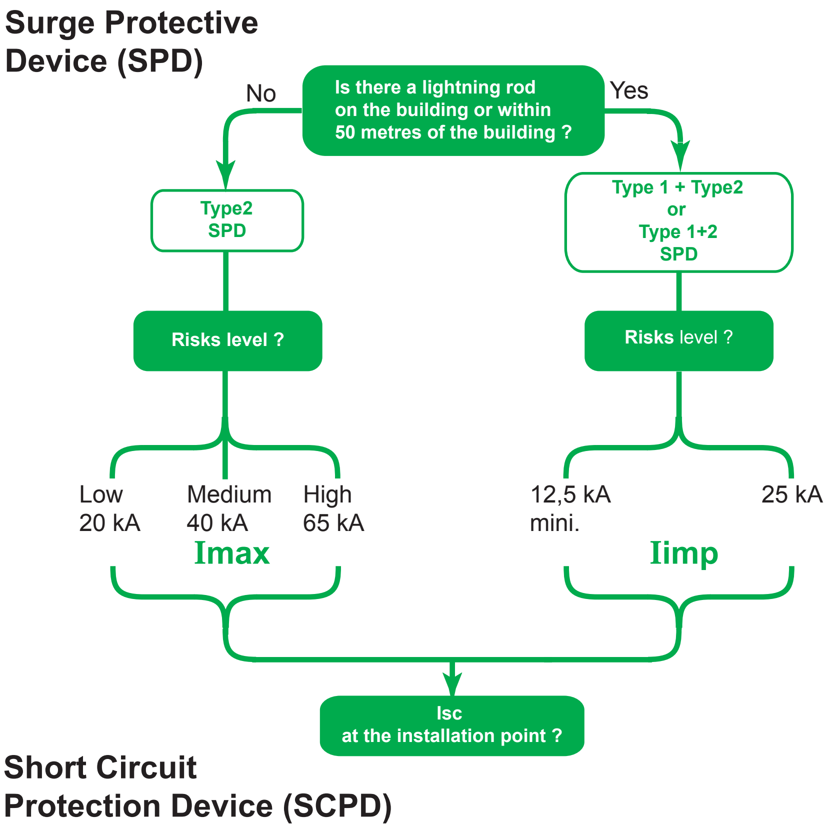

Fig. J20 : Logic diagram for selection of a protection system

The other characteristics for selection of a SPD are predefined for an electrical installation.
- number of poles in SPD;
- voltage protection level Up;
- operating voltage Uc.

This sub-section J3 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.

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

3.2 Elements of the protection system

3.2.1 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 **In = 5 kA (8/20) µs**;
- Voltage protection level **Up (at In) < 2.5 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 30 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 chapter 6.5)
- 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 J21** below shows the quantity and type of SPD to be set up on the basis of the two factors defined above.

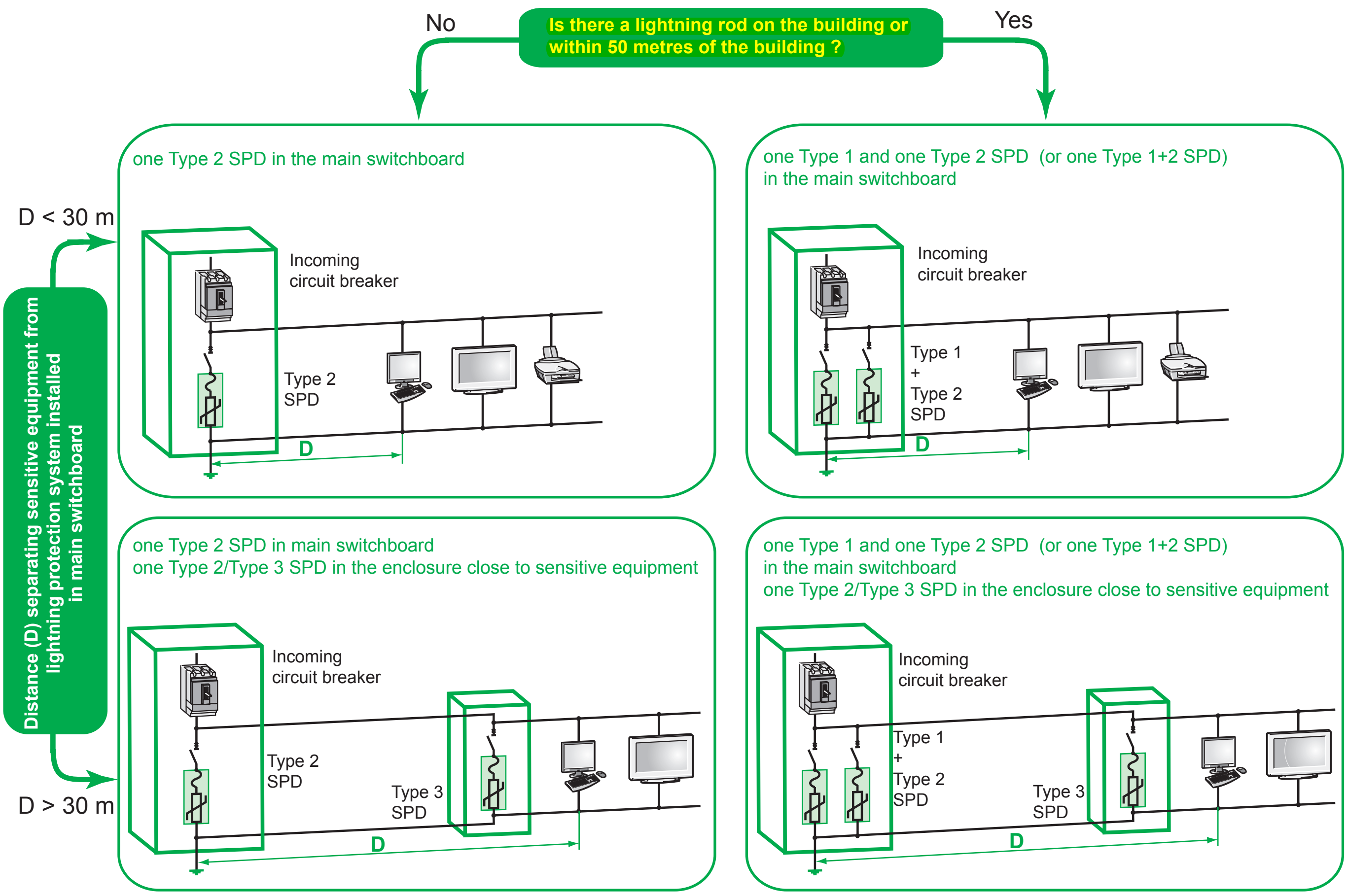

Fig. J21 : The 4 cases of SPD implementation

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

3.4 Selection of a Type 1 SPD

3.4.1 Impulse current Iimp

- Where there are no national regulations or specific regulations for the type of building to be protected:

the impulse current Iimp shall be at least 12.5 kA (10/350 µs wave) per branch in accordance with IEC 60364-5-534.

- Where regulations exist:

standard 62305-2 defines 4 levels: I, II, III and IV
The table in **Figure J31** shows the different levels of Iimp in the regulatory case.

Protection level as per EN 62305-2	External lightning protection system designed to handle direct flash of:	Minimum required Iimp 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

Fig. J31 : Table of Iimp values according to the building's voltage protection level (based on IEC/ EN 62305-2)

3.4.2 Autoextinguish follow current Ifi

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

3.5 Selection of a Type 2 SPD

3.5.1 Maximum discharge current Imax

The maximum discharge current Imax is defined according to the estimated exposure level relative to the building's location.

The value of the maximum discharge current (Imax) is determined by a risk analysis (see table in **Figure J32**).

	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 Imax value (kÂ)	20	40	65

Fig. J32 : Recommended maximum discharge current Imax according to the exposure level

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.

3.6 Selection of external Short Circuit Protection Device (SCPD)

3.6.1 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 disconnector 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) disconnector 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.

3.6.2 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 In.

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 Isc 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.

3.6.3 Installation mode for the external SCPD

■ **Device "in series"**

The SCPD is described as "in series" (see **Fig. J33**) 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).

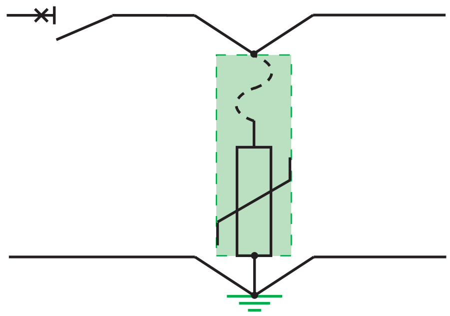

Fig. J33 : SCPD "in series"

■ **Device "in parallel"**

The SCPD is described as "in parallel" (see **Fig. J34**) 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.

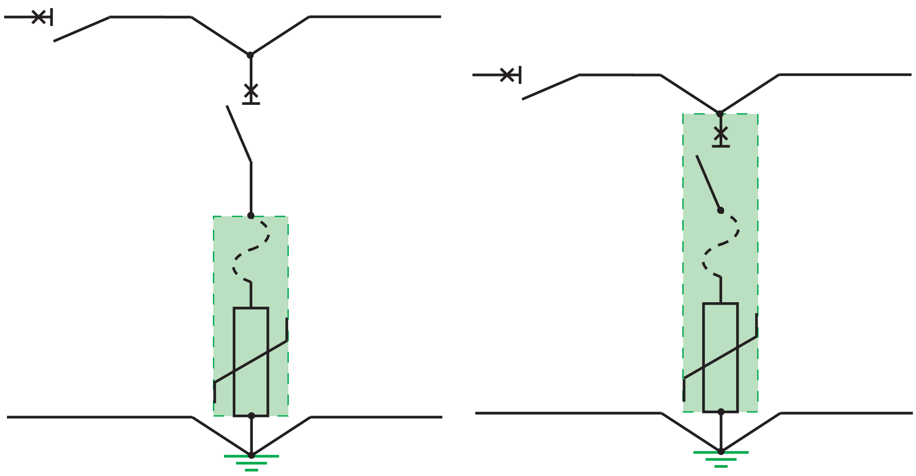

Fig. J34 : SCPD "in parallel"

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.

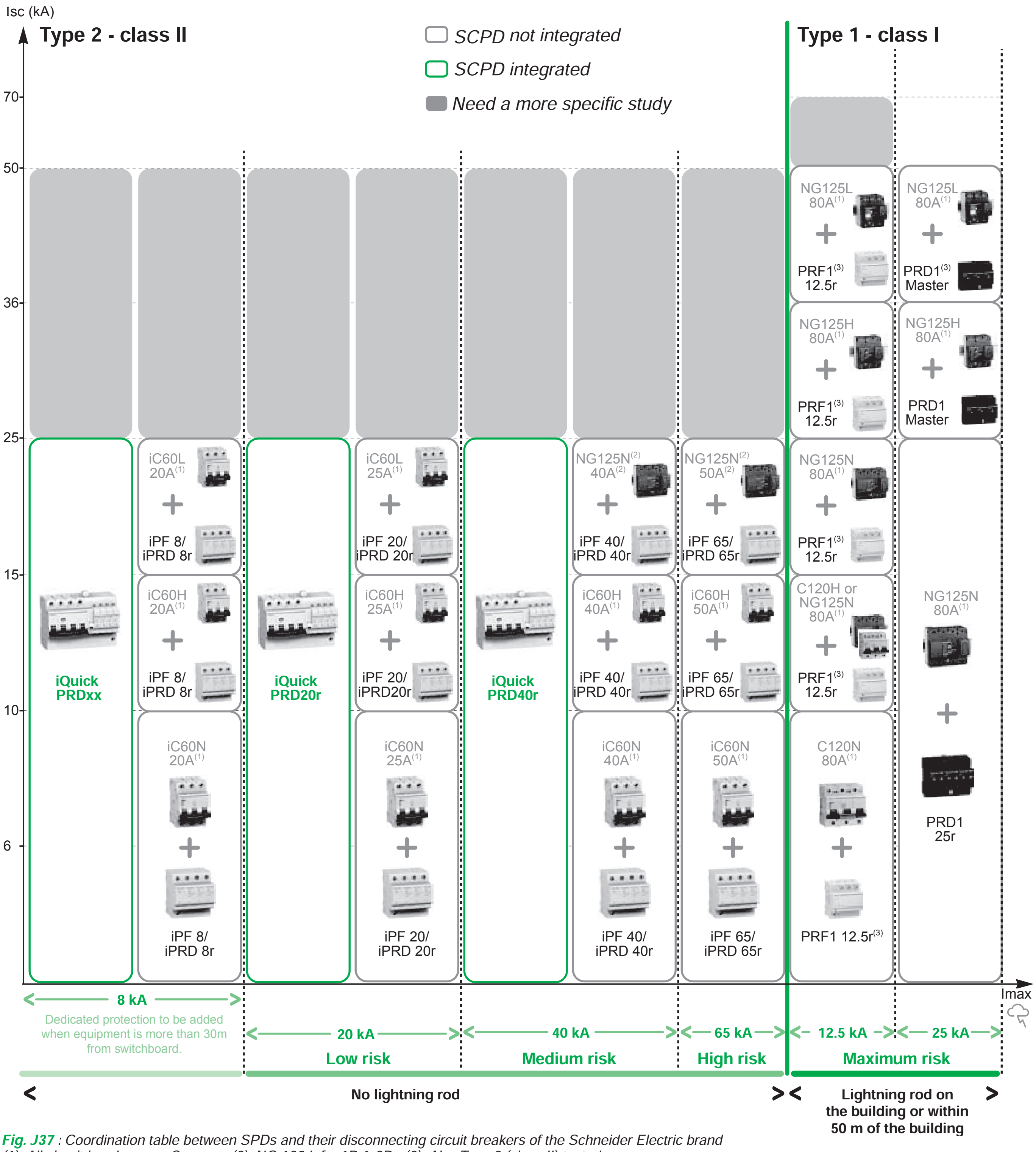

Fig. J37 : Coordination table between SPDs and their disconnecting circuit breakers of the Schneider Electric brand
(1): All circuit breakers are C curve - (2): NG 125 L for 1P & 2P - (3): Also Type 2 (class II) tested

3.7.1 Coordination with upstream protection devices

Coordination with overcurrent protection devices
In an electrical installation, the external SCPD is an apparatus identical to the protection apparatus: this makes it possible to apply **discrimination and cascading** techniques for technical and economic optimization of the protection plan.

Coordination with residual current devices
If the SPD is installed downstream of an earth leakage protection device, the latter should be of the "si" or selective type with an immunity to pulse currents of at least 3 kA (8/20 μs current wave).

Note: S type residual current devices in conformity with the IEC 61008 or IEC 61009-1 standards comply with this requirement.

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

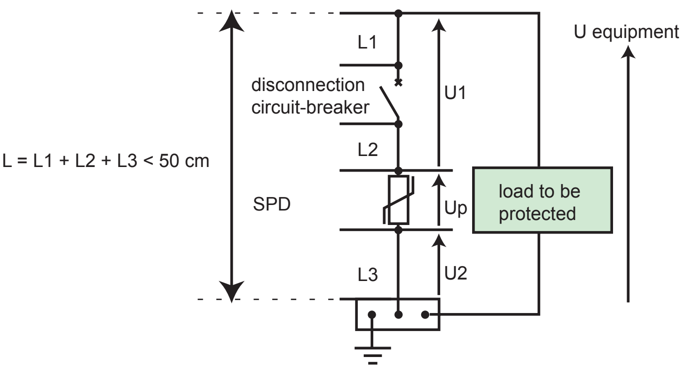

Fig. J38 : Connections of a SPD L < 50 cm

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.

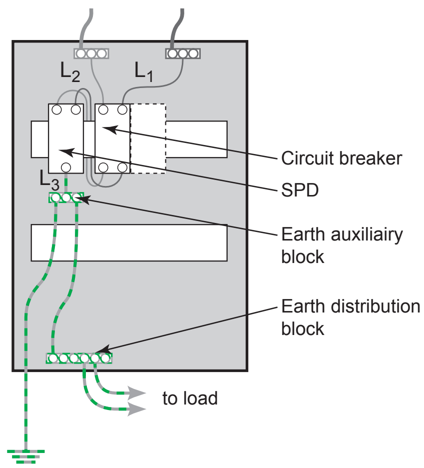

Fig. J39a : Example of connection in plastic enclosure

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 61439-2 and the ASSEMBLY manufacturer must make sure that the characteristics of the enclosure make this use possible.

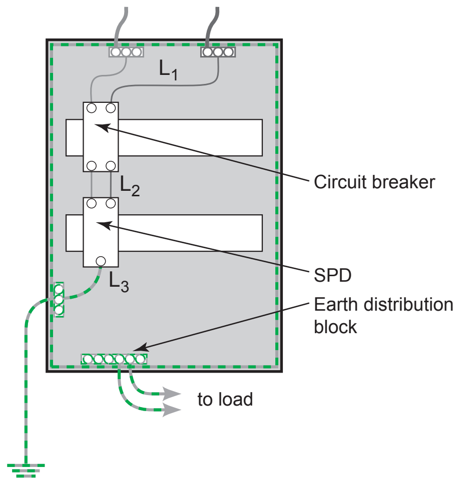

Fig. J39b : Example of connection in metallic enclosure

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.

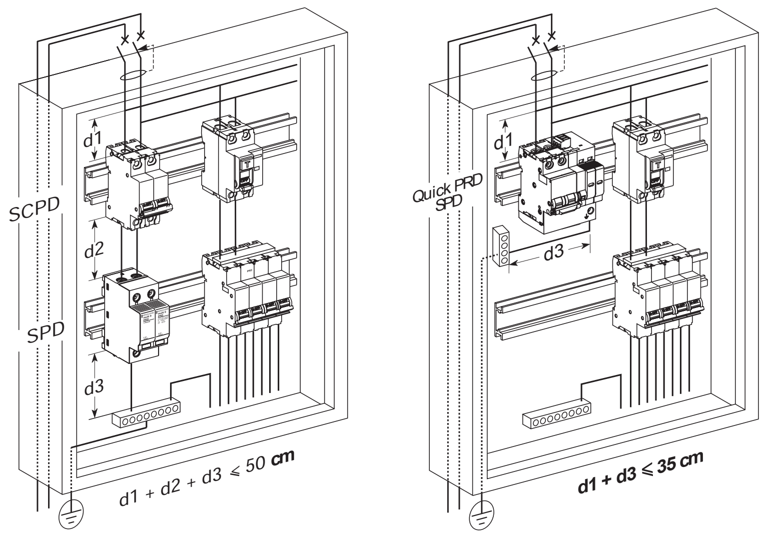

Fig. J40 : SPD with separate or integrated external SCPD

■ **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**).

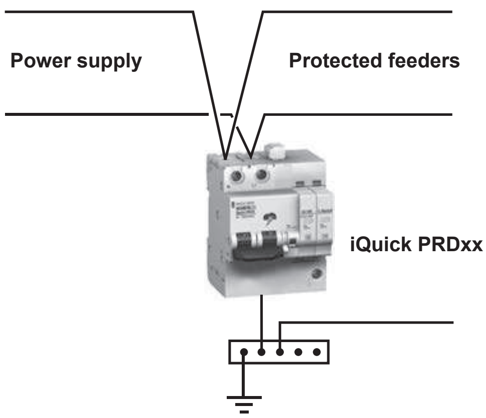

Fig. J41 : The connections of protected outgoing feeders are to the right of the SPD terminals

■ **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).

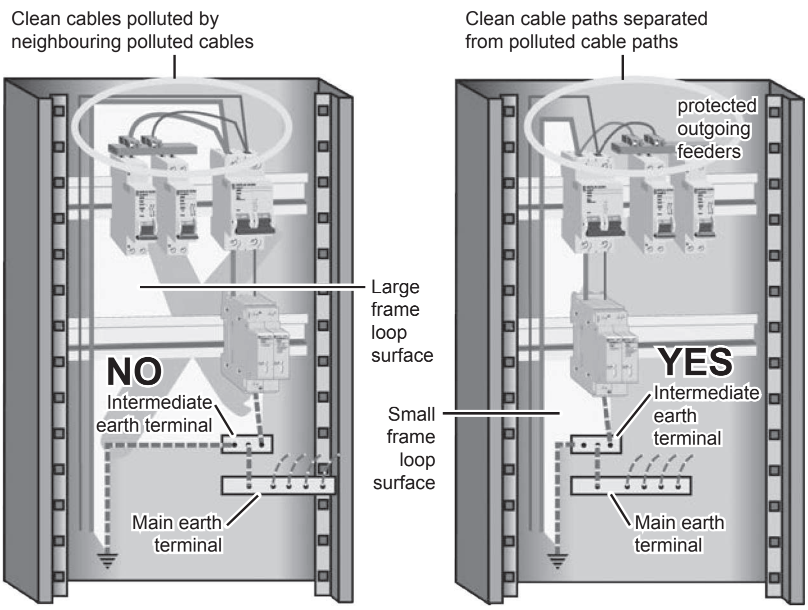

Fig. J42 : Example of improvement of EMC by a reduction in the loop surfaces and common impedance in an electric enclosure

5 Application

5.1 Installation examples

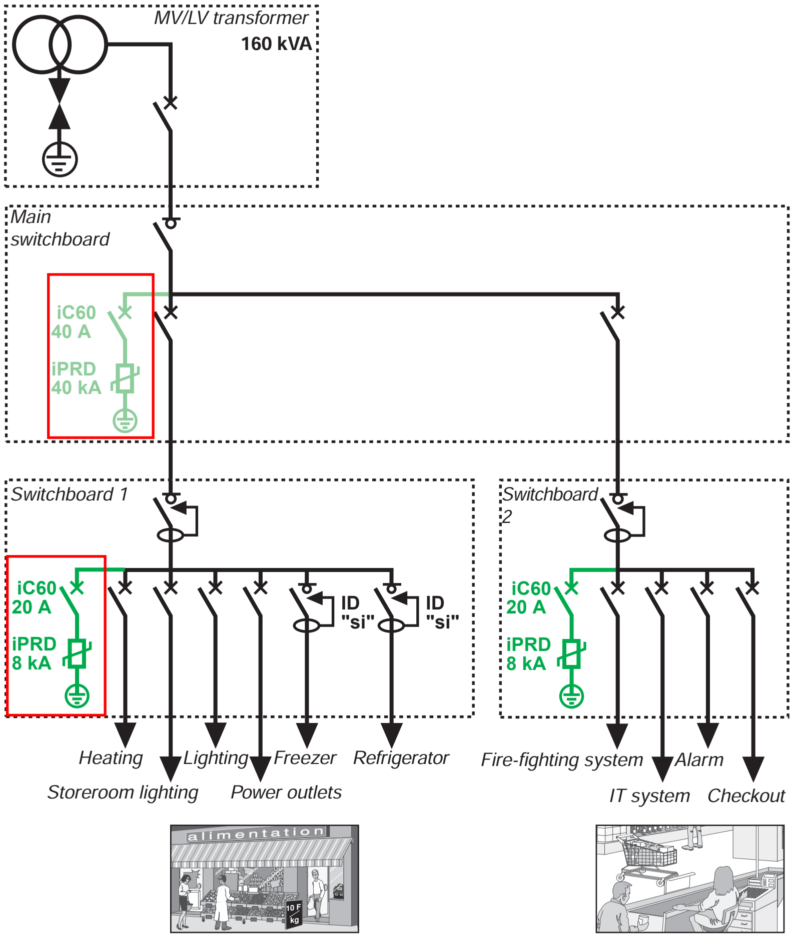

Fig. J43 : *Application example: supermarket*

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 iC60 disconnection circuit breaker rated at 20 A.
■ Install fine protection surge arresters, Imax = 8 kA (8/20 µs) and the associated iC60 disconnection circuit breakers rated at 20

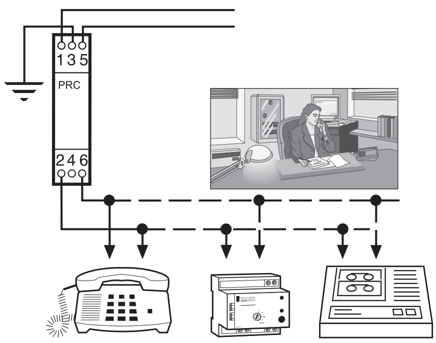

Fig. J44 : *Telecommunications network*