2 Principle of lightning protection

2.1 General rules

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.*

Procedure to prevent risks of lightning strike

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 overvoltages: 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.

2.2.1 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. J12**).

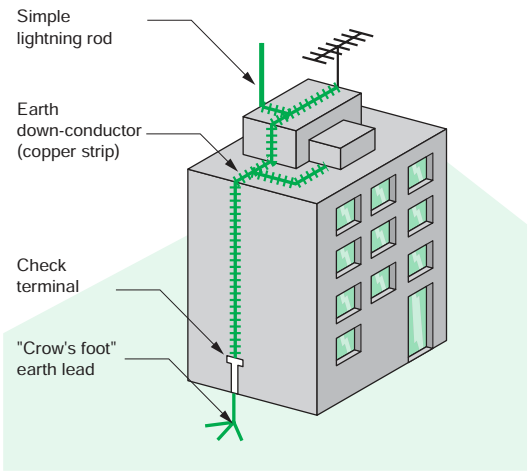


***Fig. J12** : Lightning rod (simple rod or with triggering system)*

J7

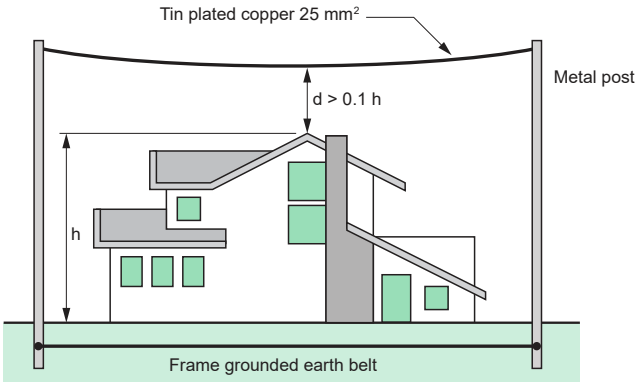


Fig. J13 : Taut wires

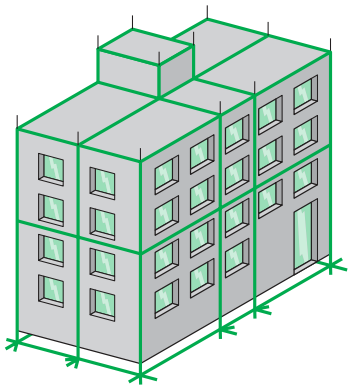


Fig. J14 : Meshed cage (Faraday cage)

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.

■ **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. J13**).

■ **The lightning conductor with meshed cage (Faraday cage)**
This protection involves placing numerous down conductors/tapes symmetrically all around the building. (see **Fig. J14**).
This type of lightning protection system is used for highly exposed buildings housing very sensitive installations such as computer rooms.

2.2.2 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. J15**): 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.

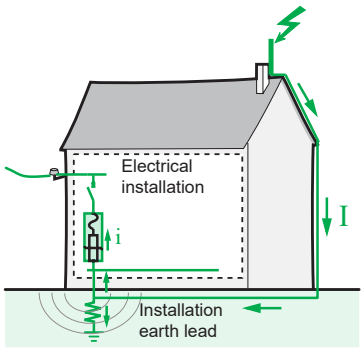


Fig. J15 : Direct lightning back current

2.3 Electrical installation protection system

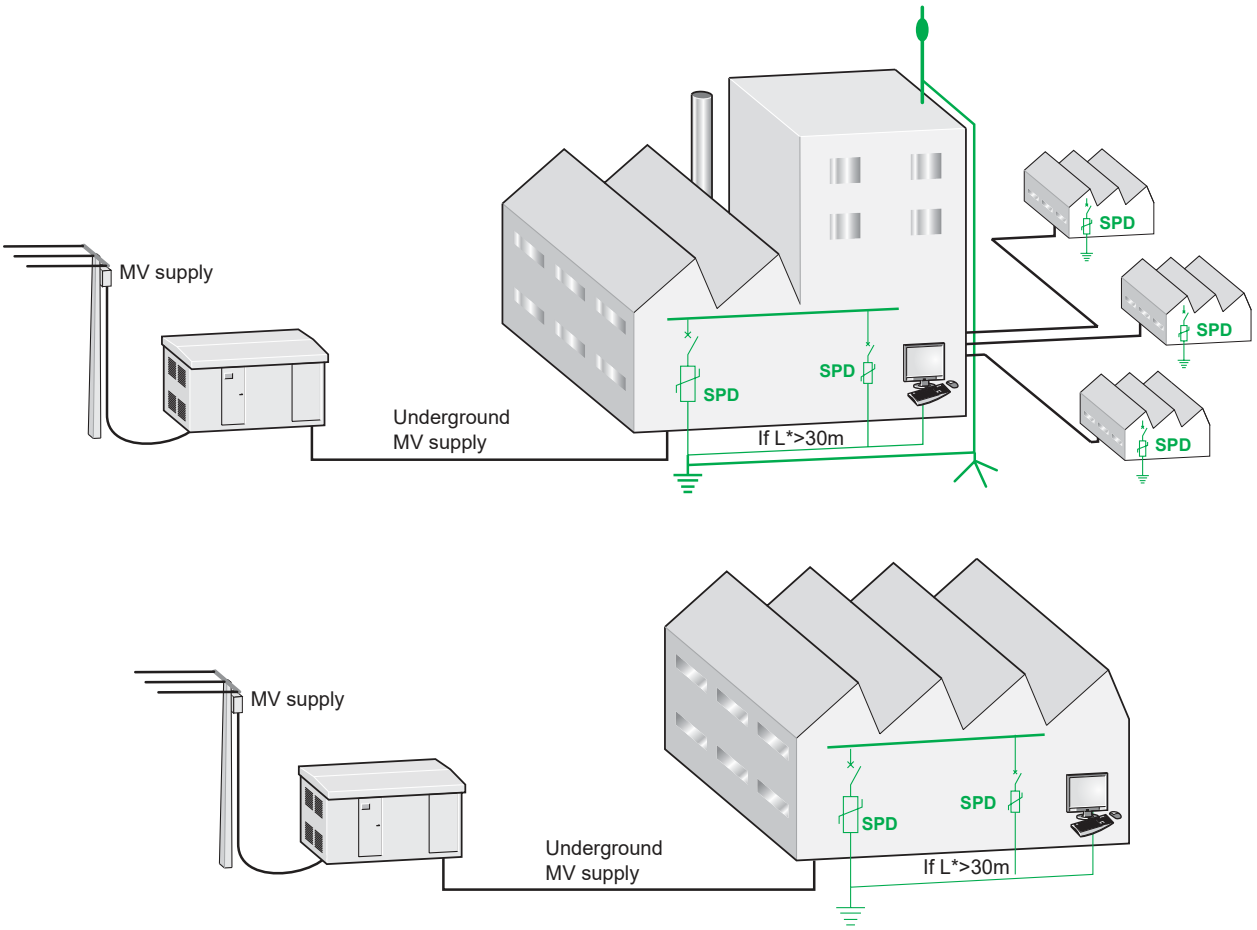
The main objective of the electrical installation protection system is to limit overvoltages to values that are acceptable for the equipment.
The electrical installation protection system consists of:
- one or more SPDs depending on the building configuration;
- the equipotential bonding: metallic mesh of exposed conductive parts.

2.3.1 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. J16**).



** the phenomena of wave reflection is increasing from L=10m*

***Fig. J16** : Example of protection of a large-scale electrical installation*

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.

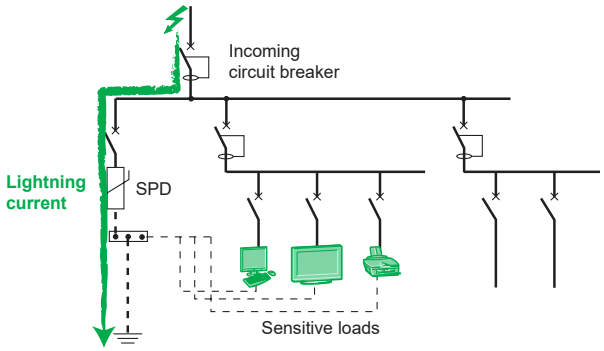


***Fig. J17** : Principle of protection system in parallel*

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.

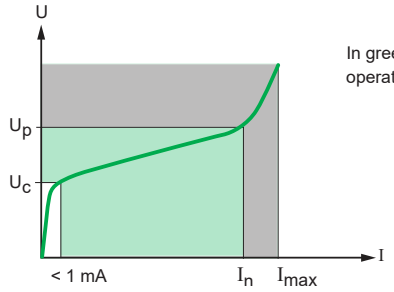


***Fig. J19** : Time/current characteristic of a SPD with varistor*

■ **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.

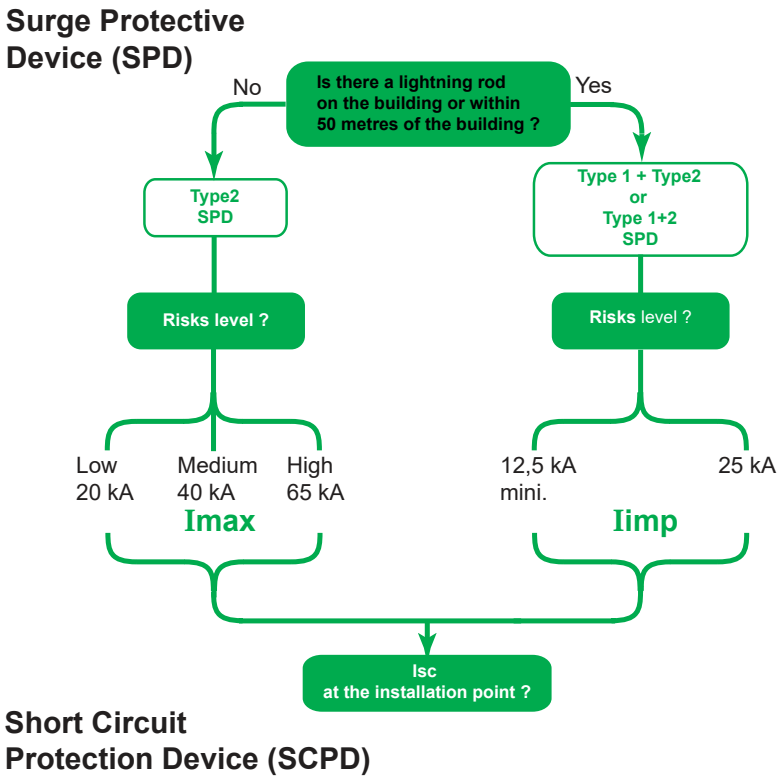


***Fig. J20** : Logic diagram for selection of a protection system*

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.

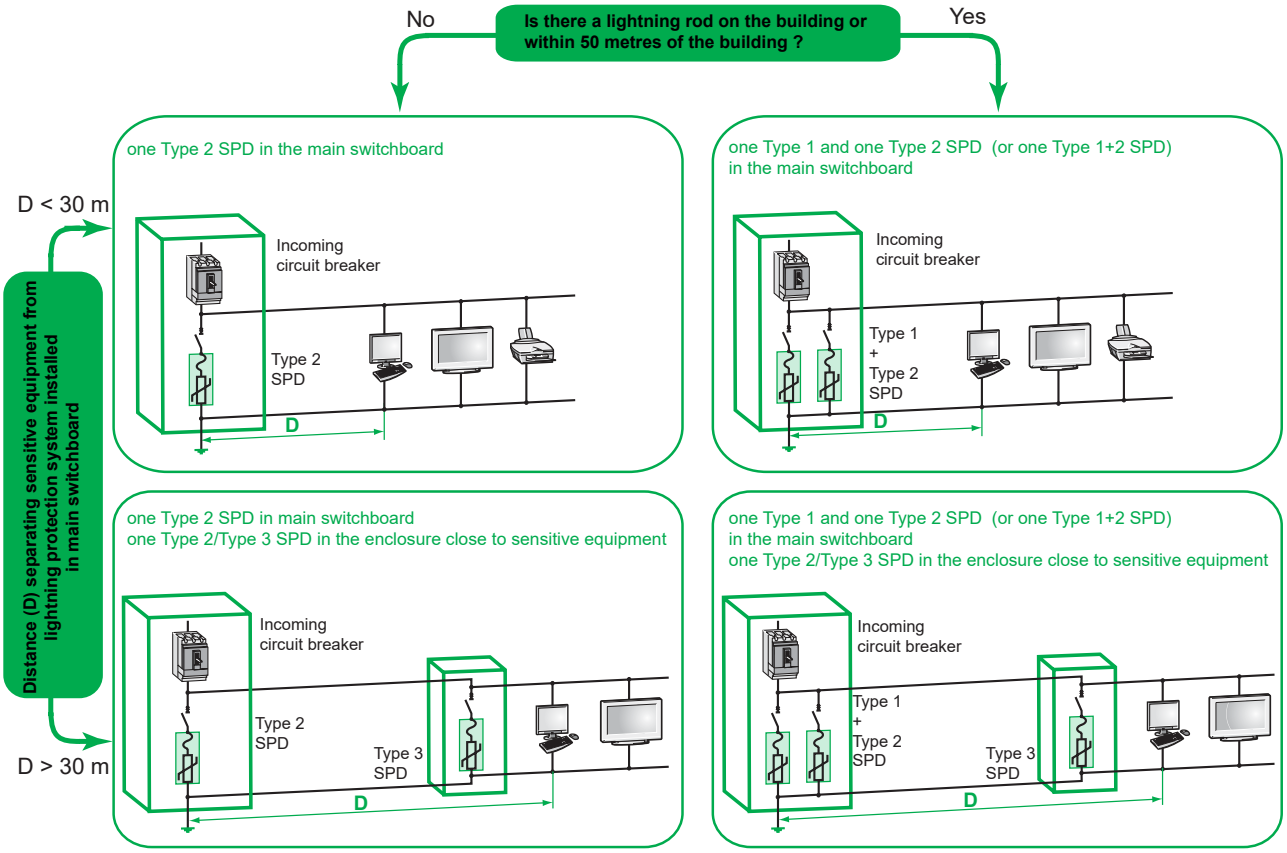


Fig. J21 : The 4 cases of SPD implementation
Note : The Type 1 SPD is installed in the electrical switchboard connected to the earth lead of the lightning protection system.