Chapter J
Protection against voltage surges in LV

Contents

1 General

1.1 What is a voltage surge?

A voltage surge is a voltage impulse or wave which is superposed on the rated network voltage (see **Fig. J1**).

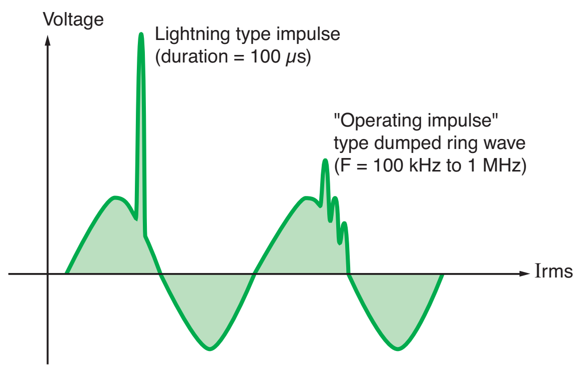


Fig. J1 : Voltage surge examples

This type of voltage surge is characterised by (see **Fig. J2**):
- The rise time (tf) measured in μs
- The gradient S measured in kV/μs

A voltage surge disturbs equipment and causes electromagnetic radiation. Furthermore, the duration of the voltage surge (T) causes a surge of energy in the electrical circuits which is likely to destroy the equipment.

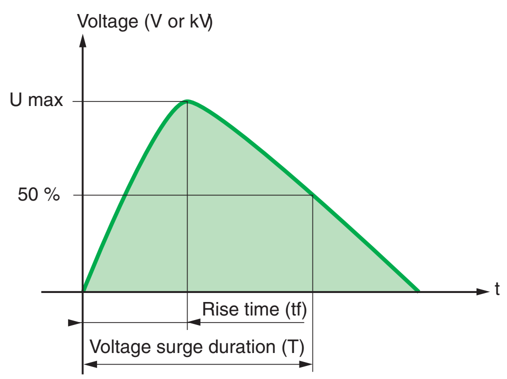


Fig. J2 : Main overvoltage characteristics

1.2 The four voltage surge types

There are four types of voltage surges which may disturb electrical installations and loads:
- Atmospheric voltage surges
- Operating voltage surges
- Transient overvoltage at industrial frequency
- Voltage surges caused by electrostatic discharge

Atmospheric voltage surges

Lightning risk – a few figures

Between 2,000 and 5,000 storms are constantly forming around the earth. These storms are accompanied by lightning which constitutes a serious risk for both people and equipment. Strokes of lightning hit the ground at a rate of 30 to 100 strokes per second. Every year, the earth is struck by about 3 billion strokes of lightning.

1 General

- Throughout the world, every year, thousands of people are struck by lightning and countless animals are killed
- Lightning also causes a large number of fires, most of which break out on farms (destroying buildings or putting them out of use)
- Lightning also affects transformers, electricity meters, household appliances, and all electrical and electronic installations in the residential sector and in industry.
- Tall buildings are the ones most often struck by lightning
- The cost of repairing damage caused by lightning is very high
- It is difficult to evaluate the consequences of disturbance caused to computer or telecommunications networks, faults in PLC cycles and faults in regulation systems.

Furthermore, the losses caused by a machine being put out of use can have financial consequences rising above the cost of the equipment destroyed by the lightning.

Characteristics of lightning discharge

Figure J3 shows the values given by the lighting protection committee (Technical Committee 81) of the I.E.C. As can be seen, 50 % of lightning strokes are of a force greater than 33 kA and 5 % are greater than 85 kA. The energy forces involved are thus very high.

Beyond peak probability P%	Current peak I (kA)	Gradient S (kA/µs)	Total duration T (s)	Number of discharges n
95	7	9.1	0.001	1
50	33	24	0.01	2
5	85	65	1.1	6

Fig. J3 : Lightning discharge values given by the IEC lightning protection committee

It is important to define the probability of adequate protection when protecting a site. Furthermore, a lightning current is a high frequency (HF) impulse current reaching roughly a megahertz.

Lightning comes from the discharge of electrical charges accumulated in the cumulo-nimbus clouds which form a capacitor with the ground. Storm phenomena cause serious damage. Lightning is a high frequency electrical phenomenon which produces voltage surges on all conductive elements, and especially on electrical loads and wires.

The effects of lightning

A lightning current is therefore a high frequency electrical current. As well as considerable induction and voltage surge effects, it causes the same effects as any other low frequency current on a conductor:

- Thermal effects: fusion at the lightning impact points and joule effect, due to the circulation of the current, causing fires
- Electrodynamic effects: when the lightning currents circulate in parallel conductors, they provoke attraction or repulsion forces between the wires, causing breaks or mechanical deformations (crushed or flattened wires)
- Combustion effects: lightning can cause the air to expand and create overpressure which stretches over a distance of a dozen metres or so. A blast effect breaks windows or partitions and can project animals or people several metres away from their original position. This shock wave is at the same time transformed into a sound wave: thunder
- Voltage surges conducted after an impact on overhead electrical or telephone lines
- Voltage surges induced by the electromagnetic radiation effect of the lightning channel which acts as an antenna over several kilometres and is crossed by a considerable impulse current
- The elevation of the earth potential by the circulation of the lightning current in the ground. This explains indirect strokes of lightning by step voltage and the breakdown of equipment

Operating voltage surges

A sudden change in the established operating conditions in an electrical network causes transient phenomena to occur. These are generally high frequency or damped oscillation voltage surge waves (see Fig. J1).
They are said to have a slow gradient: their frequency varies from several ten to several hundred kilohertz.

Operating voltage surges may be created by:

- The opening of protection devices (fuse, circuit-breaker), and the opening or closing of control devices (relays, contactors, etc.)
- Inductive circuits due to motors starting and stopping, or the opening of transformers such as MV/LV substations
- Capacitive circuits due to the connection of capacitor banks to the network
- All devices that contain a coil, a capacitor or a transformer at the power supply inlet: relays, contactors, television sets, printers, computers, electric ovens, filters, etc.

1 General

Transient overvoltages at industrial frequency (see **Fig. J4**)

These overvoltages have the same frequency as the network (50, 60 or 400 Hz); and can be caused by:

■ Phase/frame or phase/earth insulating faults on a network with an insulated or impedant neutral, or by the breakdown of the neutral conductor. When this happens, single phase devices will be supplied in 400 V instead of 230 V.

■ A cable breakdown. For example, a medium voltage cable which falls on a low voltage line.

■ The arcing of a high or medium voltage protective spark-gap causing a rise in earth potential during the action of the protection devices. These protection devices follow automatic switching cycles which will recreate a fault if it persists.

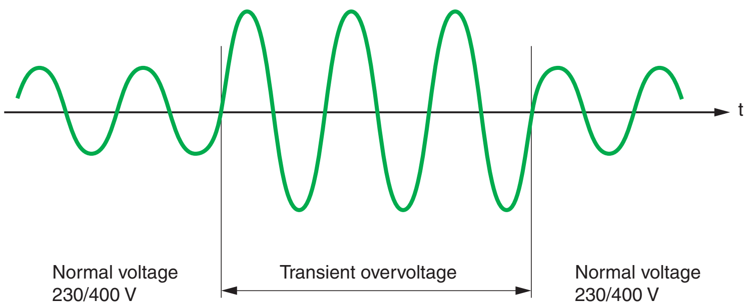


Fig. J4 : Transient overvoltage at industrial frequency

Voltage surges caused by electrical discharge

In a dry environment, electrical charges accumulate and create a very strong electrostatic field. For example, a person walking on carpet with insulating soles will become electrically charged to a voltage of several kilovolts. If the person walks close to a conductive structure, he will give off an electrical discharge of several amperes in a very short rise time of a few nanoseconds. If the structure contains sensitive electronics, a computer for example, its components or circuit boards may be damaged.

Three points must be kept in mind:
■ A direct or indirect lightning stroke may have destructive consequences on electrical installations several kilometres away from where it falls
■ Industrial or operating voltage surges also cause considerable damage
■ The fact that a site installation is underground in no way protects it although it does limit the risk of a direct strike

1.3 Main characteristics of voltage surges

Figure J5 below sums up the main characteristics of voltage surges.

Type of voltage surge	Voltage surge coefficient	Duration	Front gradient or frequency
Industrial frequency (insulation fault)	⩽ 1.7	Long 30 to 1,000 ms	Industrial frequency (50-60-400 Hz)
Operation	2 to 4	Short 1 to 100 ms	Average 1 to 200 kHz
Atmospheric	> 4	Very short 1 to 100 µs	Very high 1 to 1,000 kV/µs

Fig. J5 : Main characteristics of voltage surges

1 General

1.4 Different propagation modes

Common mode

Common mode voltage surges occur between the live parts and the earth: phase/earth or neutral/earth (see **Fig. J6**).
They are especially dangerous for devices whose frame is earthed due to the risk of dielectric breakdown.

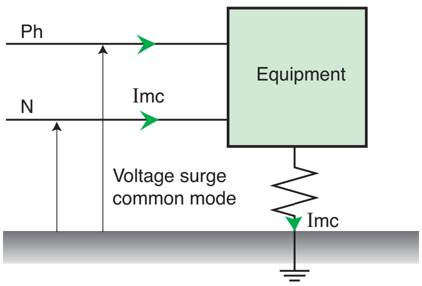


Fig. J6 : Common mode

Differential mode

Differential mode voltage surges circulate between live conductors: Phase to phase or phase to neutral (see **Fig. J7**). They are especially dangerous for electronic equipment, sensitive computer equipment, etc.

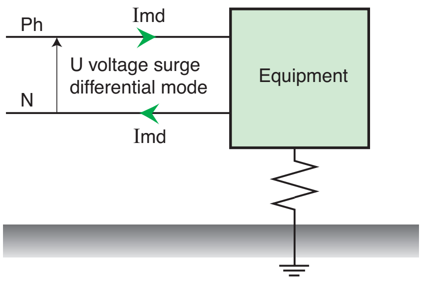


Fig. J7 : Differential mode

2 Overvoltage protection devices

Two major types of protection devices are used to suppress or limit voltage surges: they are referred to as primary protection devices and secondary protection devices.

2.1 Primary protection devices (protection of installations against lightning)

The purpose of primary protection devices is to protect installations against direct strokes of lightning. They catch and run the lightning current into the ground. The principle is based on a protection area determined by a structure which is higher than the rest.

The same applies to any peak effect produced by a pole, building or very high metallic structure.

There are three types of primary protection:
- Lightning conductors, which are the oldest and best known lightning protection device
- Overhead earth wires
- The meshed cage or Faraday cage

The lightning conductor

The lightning conductor is a tapered rod placed on top of the building. It is earthed by one or more conductors (often copper strips) (see **Fig. J8**).

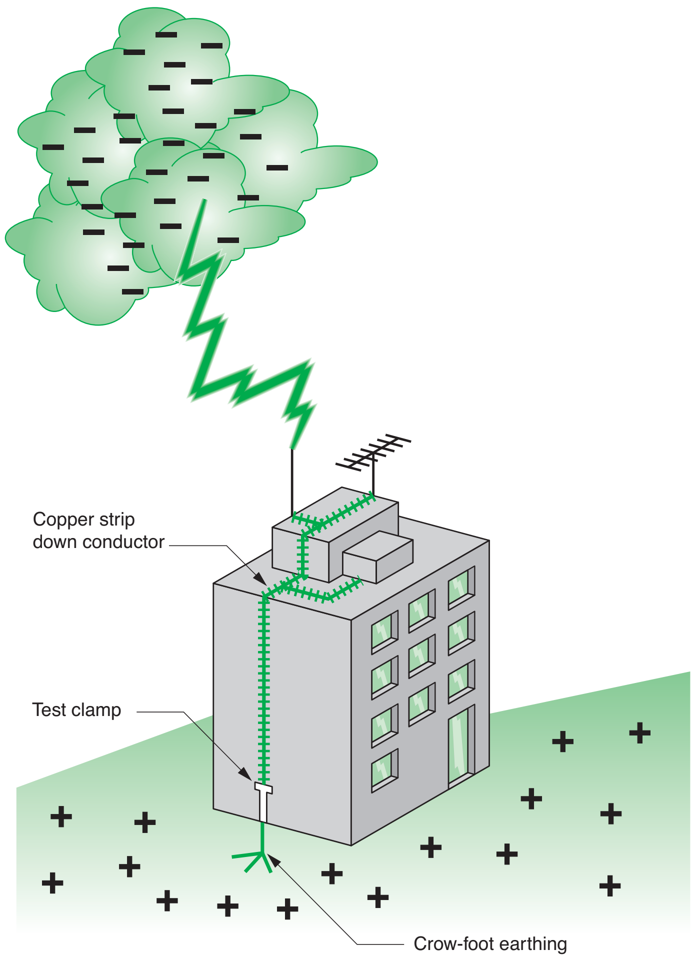


Fig. J8 : Example of protection using a lightning conductor

2 Overvoltage protection devices

The design and installation of a lightning conductor is the job of a specialist.

Attention must be paid to the copper strip paths, the test clamps, the crow-foot earthing to help high frequency lightning currents run to the ground, and the distances in relation to the wiring system (gas, water, etc.).

Furthermore, the flow of the lightning current to the ground will induce voltage surges, by electromagnetic radiation, in the electrical circuits and buildings to be protected. These may reach several dozen kilovolts. It is therefore necessary to symmetrically split the down conductor currents in two, four or more, in order to minimise electromagnetic effects.

Overhead earth wires

These wires are stretched over the structure to be protected (see **Fig. J9**). They are used for special structures: rocket launch pads, military applications and lightning protection cables for overhead high voltage power lines (see **Fig. J10**).

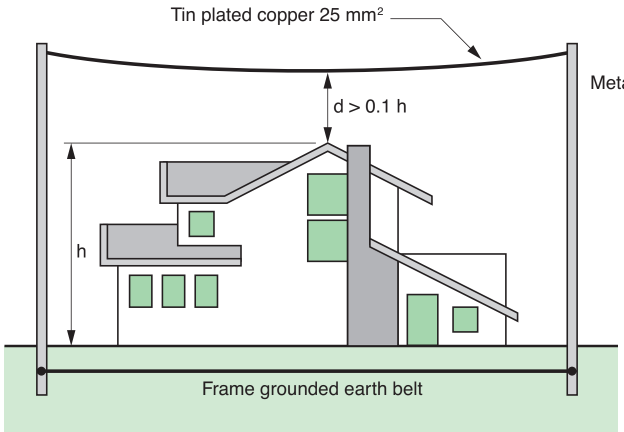


Fig. J9 : Example of lightning protection using overhead earth wires

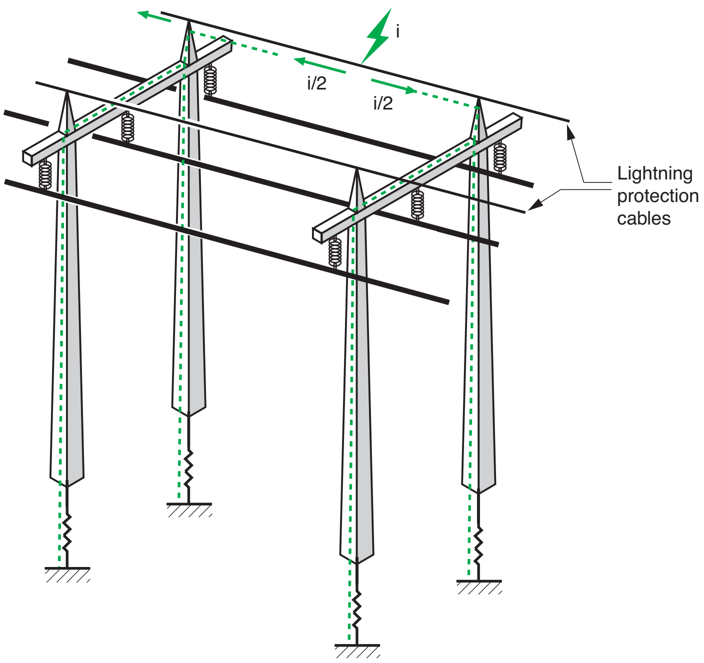


Fig. J10 : Lightning protection wires

2 Overvoltage protection devices

Primary lightning conductor protection devices such as a meshed cage or overhead earth wires are used to protect against direct strokes of lighting. These protection devices do not prevent destructive secondary effects on equipment from occurring. For example, rises in earth potential and electromagnetic induction which are due to currents flowing to the earth. To reduce secondary effects, LV surge arresters must be added on telephone and electrical power networks.

The meshed cage (Faraday cage)

This principle is used for very sensitive buildings housing computer or integrated circuit production equipment. It consists in symmetrically multiplying the number of down strips outside the building. Horizontal links are added if the building is high; for example every two floors (see **Fig. J11**). The down conductors are earthed by frog's foot earthing connections. The result is a series of interconnected 15 x 15 m or 10 x 10 m meshes. This produces better equipotential bonding of the building and splits lightning currents, thus greatly reducing electromagnetic fields and induction.

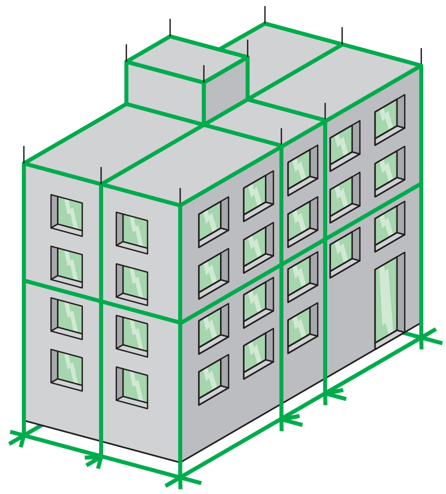


Fig. J11 : Example of protection using the meshed cage (Faraday cage) principle

Secondary protection devices are classed in two categories: Serial protection and parallel protection devices.
Serial protection devices are specific to a system or application.
Parallel protection devices are used for: Power supply network, telephone network, switching network (bus).

2.2 Secondary protection devices (protection of internal installations against lightning)

These handle the effects of atmospheric, operating or industrial frequency voltage surges. They can be classified according to the way they are connected in an installation: serial or parallel protection.

Serial protection device

This is connected in series to the power supply wires of the system to be protected (see **Fig. J12**).

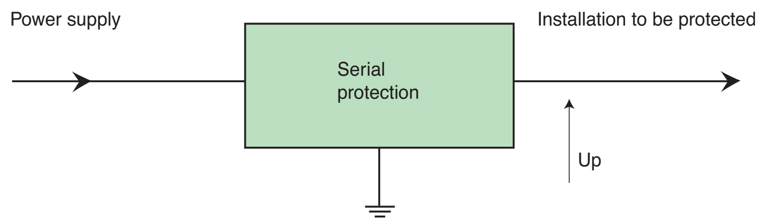


Fig. J12 : Serial protection principle

Transformers
They reduce voltage surges by inductor effect and make certain harmonics disappear by coupling. This protection is not very effective.

Filters
Based on components such as resistors, inductance coils and capacitors they are suitable for voltage surges caused by industrial and operation disturbance corresponding to a clearly defined frequency band. This protection device is not suitable for atmospheric disturbance.

2 Overvoltage protection devices

Wave absorbers
They are essentially made up of air inductance coils which limit the voltage surges, and surge arresters which absorb the currents. They are extremely suitable for protecting sensitive electronic and computing equipment. They only act against voltage surges. They are nonetheless extremely cumbersome and expensive.

Network conditioners and static uninterrupted power supplies (UPS)
These devices are essentially used to protect highly sensitive equipment, such as computer equipment, which requires a high quality electrical power supply. They can be used to regulate the voltage and frequency, stop interference and ensure a continuous electrical power supply even in the event of a mains power failure (for the UPS). On the other hand, they are not protected against large, atmospheric type voltage surges against which it is still necessary to use surge arresters.

Parallel protection device

The principle
The parallel protection is adapted to any installation power level (see **Fig. J13**). This type of overvoltage protection is the most commonly used.

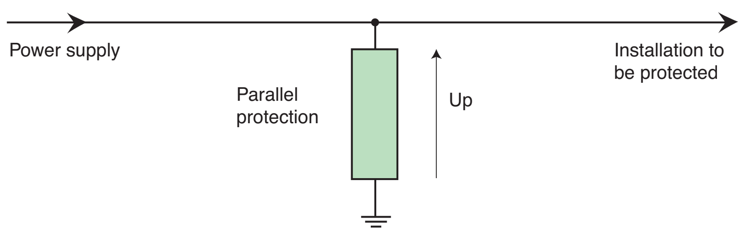


Fig. J13 : Parallel protection principle

Main characteristics
- The rated voltage of the protection device must correspond to the network voltage at the installation terminals
- When there is no voltage surge, a leakage current should not go through the protection device which is on standby
- When a voltage surge above the allowable voltage threshold of the installation to be protected occurs, the protection device abruptly conducts the voltage surge current to the earth by limiting the voltage to the desired protection level Up (see **Fig. J14**).

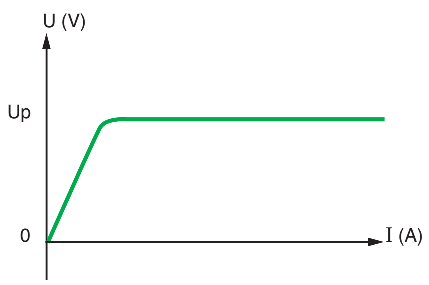


Fig. J14 : Typical U/I curve of the ideal protection device

When the voltage surge disappears, the protection device stops conducting and returns to standby without a holding current. This is the ideal U/I characteristic curve:
- The protection device response time (tr) must be as short as possible to protect the installation as quickly as possible
- The protection device must have the capacity to be able to conduct the energy caused by the foreseeable voltage surge on the site to be protected
- The surge arrester protection device must be able to withstand the rated current In.

2 Overvoltage protection devices

The products used

■ Voltage limiters
They are used in MV/LV substations at the transformer output, in IT earthing scheme. They can run voltage surges to the earth, especially industrial frequency surges (see **Fig. J15**)

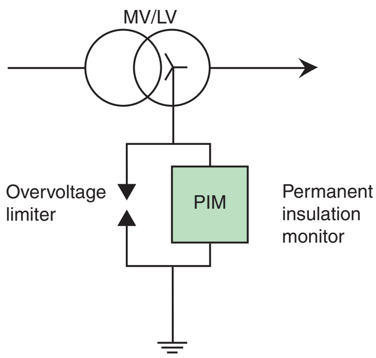


Fig. J15 : Voltage limiter

■ LV surge arresters
This term designates very different devices as far as technology and use are concerned. Low voltage surge arresters come in the form of modules to be installed inside LV switchboard. There are also plug-in types and those that protect power outlets. They ensure secondary protection of nearby elements but have a small flow capacity. Some are even built into loads although they cannot protect against strong voltage surges

■ Low current surge arresters or overvoltage protectors
These protect telephone or switching networks against voltage surges from the outside (lightning), as well as from the inside (polluting equipment, switchgear switching, etc.)
Low current voltage surge arresters are also installed in distribution boxes or built into loads.

3 Protection against voltage surges in LV

3.1 Surge protective device description

A surge protective device (SDP) is a device that limits transient voltage surges and runs current waves to ground to limit the amplitude of the voltage surge to a safe level for electrical installations and equipment.

The surge protective device includes one or several non linear components.

The surge protective device eliminates voltage surges:

- In common mode: Phase to earth or neutral to earth
- In differential mode: Phase to phase or phase to neutral

When a voltage surge exceeds the Uc threshold, the surge protective device (SDP) conducts the energy to earth in common mode. In differential mode the diverted energy is directed to another active conductor.

The surge protective device has an internal thermal protection device which protects against burnout at its end of life. Gradually, over normal use after withstanding several voltage surges, the Surge Protective Device degrades into a conductive device. An indicator informs the user when end-of-life is close.

Some surge protective devices have a remote indication.

In addition, protection against short-circuits is ensured by an external circuit-breaker.

3.2 Surge protective device standards

International standard IEC 61643-1 ed. 02/2005

Surge protective devices connected to low-voltage power distribution systems.

Three test classes are defined:

- Class I tests: They are conducted using nominal discharge current (In), voltage impulse with 1.2/50 µs waveshape and impulse current Iimp.
The class I tests is intended to simulate partial conducted lightning current impulses. SPDs subjected to class I test methods are generally recommended for locations at points of high exposure, e.g., line entrances to buildings protected by lightning protection systems.
- Class II tests: They are conducted using nominal discharge current (In), voltage impulse with 1.2/50 µs waveshape
- Class III tests: They are conducted using the combination waveform (1.2/50 and 8/20 µs).

SPDs tested to class II or III test methods are subjected to impulses of shorter duration. These SPDs are generally recommended for locations with lesser exposure.

These 3 test classes cannot be compared, since each originates in a country and each has its own specificities. Moreover, each builder can refer to one of the 3 test classes.

European standard EN 61643-11 2002

Some requirements as per IEC 61643-1. Moreover SPDs are classified in three categories:

Type 1: SPD tested to Class I

Type 2: SPD tested to Class II

Type 3: SPD tested to Class III

3.3 Surge protective device data according to IEC 61643-1 standard

- **Surge protective device** (SPD): A device that is intended to limit transient overvoltages and divert surge currents. It contains at least one nonlinear component.
- **Test classes**: Surge arrester test classification.
- **In**: Nominal discharge current; the crest value of the current through the SPD having a current waveshape of 8/20. This is used for the classification of the SPD for the class II test and also for preconditioning of the SPD for class I and II tests.
- **Imax**: Maximum discharge current for class II test; crest value of a current through the SPD having an 8/20 waveshape and magnitude according to the test sequence of the class II operating duty test. Imax is greater than In.
- **Ic**: Continuous operating current; current that flows in an SPD when supplied at its permament full withstand operating voltage (Uc) for each mode. Ic corresponds to the sum of the currents that flow in the SPD's protection component and in all the internal circuits connected in parallel.

3 Protection against voltage surges in LV

■ **Iimp**: Impulse current, it is defined by a current peak value Ipeak and the charge Q. Tested according to the test sequence of the operating duty test. This is used for the classification of the SPD for class I test.

■ **Un**: Rated network voltage.

■ **Uc**: Maximum continuous operating voltage; the maximum r.m.s. or d.c. voltage which may be continuously applied to the SPDs mode of protection. This is equal to the rated voltage.

■ **Up**: Voltage protection level; a parameter that characterizes the performance of the SPD in limiting the voltage across its terminals, which is selected from a list of preferred values. This value shall be greater than the highest value of the measured limiting voltages.

The most common values for a **230/400 V** network are:
1 kV - 1.2 kV - 1.5 kV - 1.8 kV - 2 kV - 2.5 kV.

■ **Ures**: Residual voltage, the peak value of the voltage that appears between the terminals of an SPD due to the passage of discharge current.

The SPD is characterised by Uc, Up, In and Imax (see **Fig. J16**)

■ To test the surge arrester, standardized voltage and current waves have been defined that are specific to each country:

□ Voltage wave
e.g. 1.2/50 µs (see **Fig. J17**)

□ Current wave
Example 8/20 µs (see **Fig. J18**)

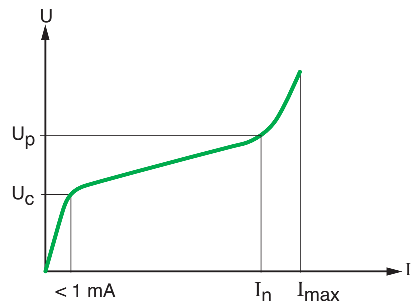


Fig. J16 : Voltage/current characteristics

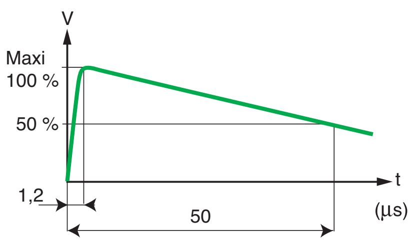


Fig. J17 : 1.2/50 µs wave

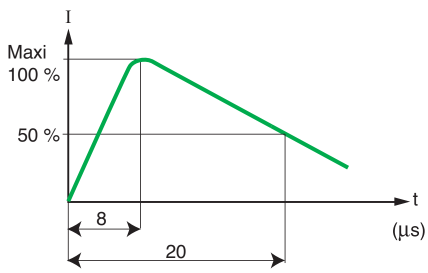


Fig. J18 : 8/20 µs wave

□ Other possible wave characteristics:
4/10 µs, 10/1000 µs, 30/60 µs, 10/350 µs...
Comparison between different surge protective devices must be carried out using the same wave characteristics, in order to get relevant results.

3 Protection against voltage surges in LV

3.4 Lightning protection standards

The IEC 62305 series (part 1 to 5) restructures and updates the publications of IEC 61024 series, IEC 61312 series and IEC 61663 series.
The need for protection, the economic benefits of installing protection measures and the selection of adequate protection measures should be determined in terms of risk management. Risk management is the subject of IEC 62305-2.
The criteria for design, installation and maintenance of lightning protection measures are considered in three separate groups:

- The first group concerning protection measures to reduce physical damage and life hazard in a structure is given in IEC 62305-3.
- The second group concerning protection measures to reduce failures of electrical and electronic systems in a structure is given in IEC 62305-4.
- The third group concerning protection measures to reduce physical damage and failures of services connected to a structure (mainly electrical and telecommunication lines) is given in IEC 62305-5.

3.5 Surge arrester installation standards

- **International**: IEC 61643-12 selection and application principles
- **International**: IEC 60364 Electrical installations of buildings
  - IEC 60364-4-443: protection for safety
    When an installation is supplied by, or includes, an overhead line, a protection device against atmospheric overvoltages **must be** foreseen if the keraunic level of the site being considered corresponds to the external influences condition AQ 1 (more than 25 days per year with thunderstorms).
  - IEC 60364-4-443-4: selection of equipment in the installation.
    This section helps with the choice of the protection level Up for the surge arrester in function of the loads to be protected.
    Rated residual voltage of protection devices must not be higher than the value in the voltage impulse withstand category II (see **Fig. J19**):

Nominal voltage of the installation(1) V		Required impulse withstand voltage for kV			
Three-phase systems(2)	Single-phase systems with middle point	Equipment at the origin of the installation (impulse withstand category IV)	Equipment of distribution and final circuits (impulse withstand category III)	Appliances (impulse withstand category II)	Specially protected equipment (impulse withstand category I)
	120-240	4	2.5	1.5	0.8
230/400(2) 277/480(2)	-	6	4	2.5	1.5
400/690	-	8	6	4	2.5
1,000	-	Values subject to system engineers			

Fig. J19 : Choosing equipment for the installation according to IEC 60364

(1) According to IEC 60038
(2) In Canada and USA for voltages to earth higher than 300 V, the impulse withstand voltage corresponding to the next higher voltage in column one applies.
Category I is addressed to particular equipment engineering.
Category II is addressed to product committees for equipment for connection to the mains.
Category III is addressed to product committees of installation material and some special product committees.
Category IV is addressed to supply authorities and system engineers (see also 443.2.2).

3 Protection against voltage surges in LV

□ IEC 60364-5-534: choosing and implementing electrical equipment
This section describes surge arrester installation conditions:
- **According to earthing systems:** The maximum continuous operating voltage Uc of SPDs shall be equal to or higher than shown in **Fig. J20**.

SPDs connected between	System configuration of distribution network				
	TT	TN-C	TN-S	IT with distributed neutral	IT without distributed neutral
Line conductor and neutral conductor	1.1 Uo	NA	1.1 Uo	1.1 Uo	NA
Each line conductor and PE conductor	1.1 Uo	NA	1.1 Uo	$\sqrt{3}$ Uo(1)	Line-to-line voltage (1)
Neutral conductor and PE conductor	Uo(1)	NA	Uo(1)	Uo(1)	NA
Each line conductor and PEN conductor	NA	1.1 Uo	NA	NA	NA

NA: not applicable
NOTE 1: Uo is the line-to-neutral voltage of the low-voltage system.
NOTE 2: This table is based on IEC 61643-1 amendment 1.

Fig. J20 : Minimum required Uc of the SPD dependent on supply system configuration

- **At the origin of the installation:** if the surge arrester is installed at the source of an electrical installation supplied by the utility distribution network, its rated discharge current may be lower than 5 kA.
If a surge arrester is installed downstream from an earth leakage protection device, an RCD of the s type, with immunity to impulse currents of less than 3 kA (8/20 µs), must be used.
- **Protection against overcurrent at 50 Hz** and consequences of a SPD failure: protection against SPDs short-circuits is provided by the overcurrent protective devices F2 which are to be selected according to the maximum recommended rating for the overcurrent protective device given in the manufacturer's SPD instructions.
- **In the presence of lightning conductors**: a surge arrester must be installed, additional specifications for surge arresters must be applied (see IEC 62305 part 4).

(1) These values are related to worst case fault conditions, therefore the tolerance of 10 % is not taken into account

4 Choosing a protection device

When installing surge arresters, several elements must be considered, such as:
- Cascading
- Positioning with respect to residual current devices
- The choice of disconnection circuit breakers

The earthing system must also be taken into account.

4.1 Protection devices according to the earthing system

- Common mode overvoltage: basic protection involves the installation of a common mode surge arrester between phase and PE or phase and PEN, whatever type of earthing system is used.
- Differential mode overvoltage: in the TT and TN-S earthing systems, earthing the neutral leads to dissymmetry due to earthing impedances, which causes differential mode voltages to appear, whereas the overvoltage induced by a lightning strike is a common mode voltage.

For example, let us consider a TT earthing system. A two-pole surge arrester is installed in common mode to protect the installation (see **Fig. J21**).

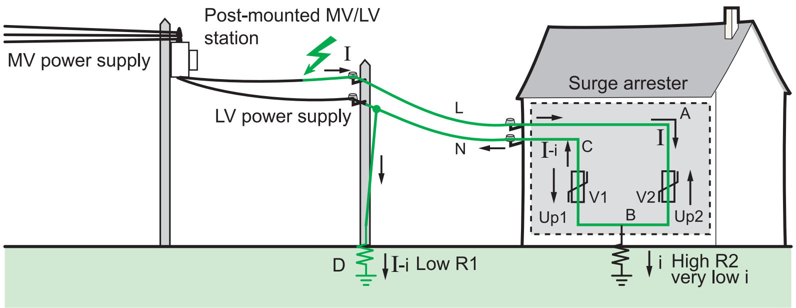


Fig. J21 : Common mode protection only

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 residual voltage of the surge arrester (Up1 + Up2) to appear at the terminals of A and C at the entrance to the installation in extreme cases.

To protect the loads between Ph and N effectively, the differential mode voltage (between A and C) must be reduced.
Another earthing system is therefore used (see **Fig. J22**).
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 surge arrester (Up2).

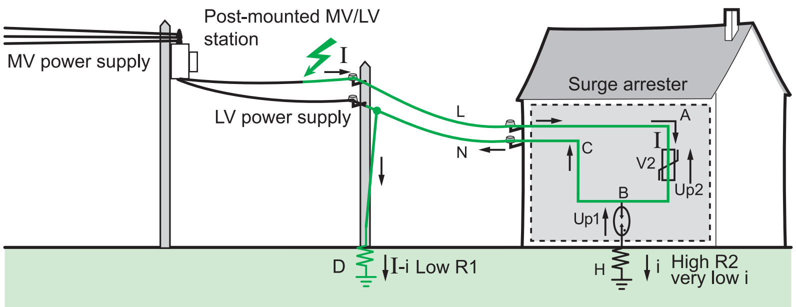


Fig. J22 : Common + differentiel mode protection

4 Choosing a protection device

Mode	Between	TT	TN-S	TN-C	IT
Differential	phase and neutral	yes	yes	-	-
Common	phase and earth	yes	yes	yes	yes
	phase and earth	yes	yes	-	yes (if distributed neutral)

Fig. J23 : Connections to be made according to the earthing systems used, in the case of atmospheric overvoltages

4.2 Internal architecture of surge arresters

■ 2P, 3P, 4P surge arresters (see **Fig. J24**):
□ They provide protection against common-mode overvoltages only
□ They are appropriate for TN-C and IT earthing systems.

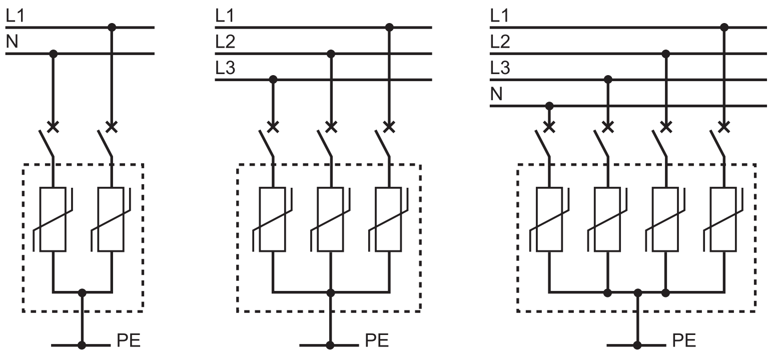


Fig. J24 : 2P, 3P, 4P surge arresters

■ 1P+N, 3P+N surge arresters (see **Fig. J25**):
□ They provide protection against common-mode and differential-mode overvoltages
□ They are appropriate for TT, TN-S, and IT earthing systems.

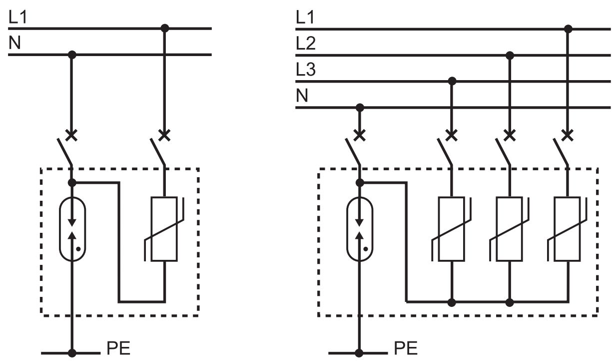


Fig. J25 : 1P+N, 3P+N surge arresters

■ Single-pole (1P) surge arresters (see **Fig. J26**):
□ They are used to satisfy the demand of different assemblies (according to the manufacturer's instructions) by supplying only one product.
However, special dimensioning will be required for N - PE protection (for example 1+N and 3P+N)
□ The assembly must be validated by means of the tests specified in EN 61643-11.

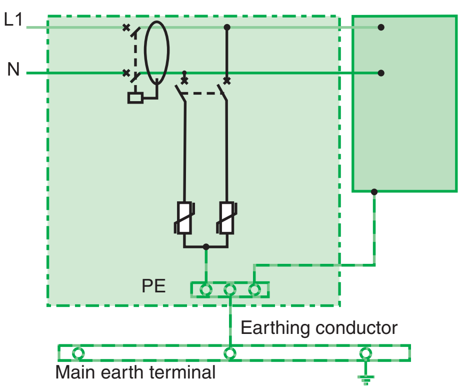


Fig. J26 : Connection example

4 Choosing a protection device

Cascading protection requires a minimum distance of at least 10 m between the two protection devices.
This is valid, whatever the field of application: domestic, tertiary or industrial.

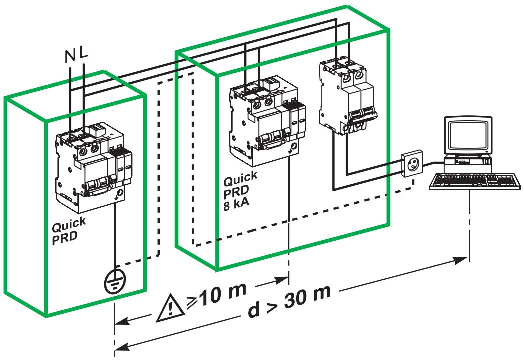


Fig. J27 : Cascading of surge arresters

4.3 Coordination of surge arresters

The overvoltage protection study of an installation may show that the site is highly exposed and that the equipment to be protected is sensitive. The surge arrester must be able to discharge high currents and have a low level of protection. This dual constraint cannot always be handled by a single surge arrester. A second one will therefore be required (see **Fig. J27**).

The first device, P1 (incoming protection) will be placed at the incoming end of the installation.
Its purpose will be to discharge the maximum amount of energy to earth with a level of protection ⩽ 2000 V that can be withstood by the electrotechnical equipment (contactors, motors, etc.).
The second device (fine protection) will be placed in a distribution enclosure, as close as possible to the sensitive loads. It will have a low discharge capacity and a low level of protection that will limit overvoltages significantly and therefore protect sensitive loads (⩽ 1500 V).

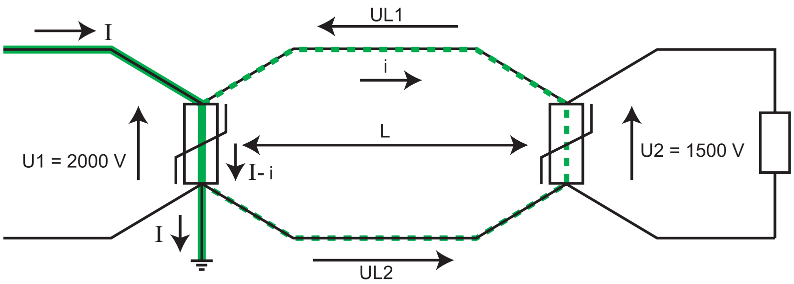


Fig. J28 : Coordination of surge arresters

The fine-protection device P2 is installed in parallel with the incoming protection device P1.
If the distance L is too small, at the incoming overvoltage, P2 with a protection level of U2 = 1500 V will operate before P1 with a level of U1 = 2000 V. P2 will not withstand an excessively high current. The protection devices must therefore be coordinated to ensure that P1 activates before P2. To do this, we shall experiment with the length L of the cable, i.e. the value of the self-inductance between the two protection devices. This self-inductance will block the current flow to P2 and cause a certain delay, which will force P1 to operate before P2. A metre of cable gives a self-inductance of approximately 1µH.

The rule $\Delta U = \frac{Ldi}{dt}$ causes a voltage drop of approximately 100 V/m/kA, 8/20 µs wave.

For L = 10 m, we get UL1 = UL2 ≈ 1000 V.
To ensure that P2 operates with a level of protection of 1500 V requires
U1 = UL1 + UL2 + U2 = 1000 + 1000 + 1500 V = 3500 V.
Consequently, P1 operates before 2000 V and therefore protects P2.

Note: if the distance between the surge arrester at the incoming end of the installation and the equipment to be protected exceeds 30 m, cascading the surge arresters is recommended, as the residual voltage of the surge arrester may rise to double the residual voltage at the terminals of the incoming surge arrester; as in the above example, the fine protection surge arrester must be placed as close as possible to the loads to be protected.

Installation rules (see page Q12).

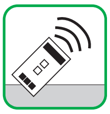
4.4 Selection guide

Estimate the value of the equipment to be protected

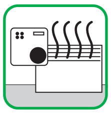
To estimate its value, consider:

- The cost of the equipment in financial terms
- The economic impact if the equipment goes down.

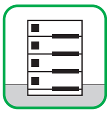
- Domestic equipment:
  - audio-video, computers
  - household appliances
  - burglar alarm.



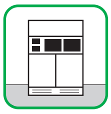
- Sensitive equipment:
  - burglar alarm
  - fire alarm
  - access control
  - video surveillance.



- Building equipment:
  - automated heating or air-conditioning
  - lift.



- Professional equipment:
  - programmable machine
  - computer server
  - sound or light control system.



- Heavy equipment:
  - medical infrastructure
  - production infrastructure
  - heavy computer processing.

Determine the electrical architecture of buildings

Lightning protection can be calculated for an entire building or for part of a building that is electrically independent

Depending on the size of the building and the extent of its electrical system, one or more surge arresters must be used in the various switchboards in the installation.

- Detached house.
- Apartment, small semi-detached house.
- Communal part of a building.
- Professional premises.
- Tertiary and industrial buildings:
  - single switchboard, main switchboard
  - distribution board
  - sensitive equipment more than 30 m from the switchboard.

Understand the risk of the impact of lightning on the site

Lightning is attracted by high points that conduct electricity. They can be:

- Natural: tall trees, mountain crest, wet areas, ferrous soil
- Artificial: chimney, aerial, pylon, lightning conductor.

Indirect effects can be incurred within a fifty metre radius around the point of impact.

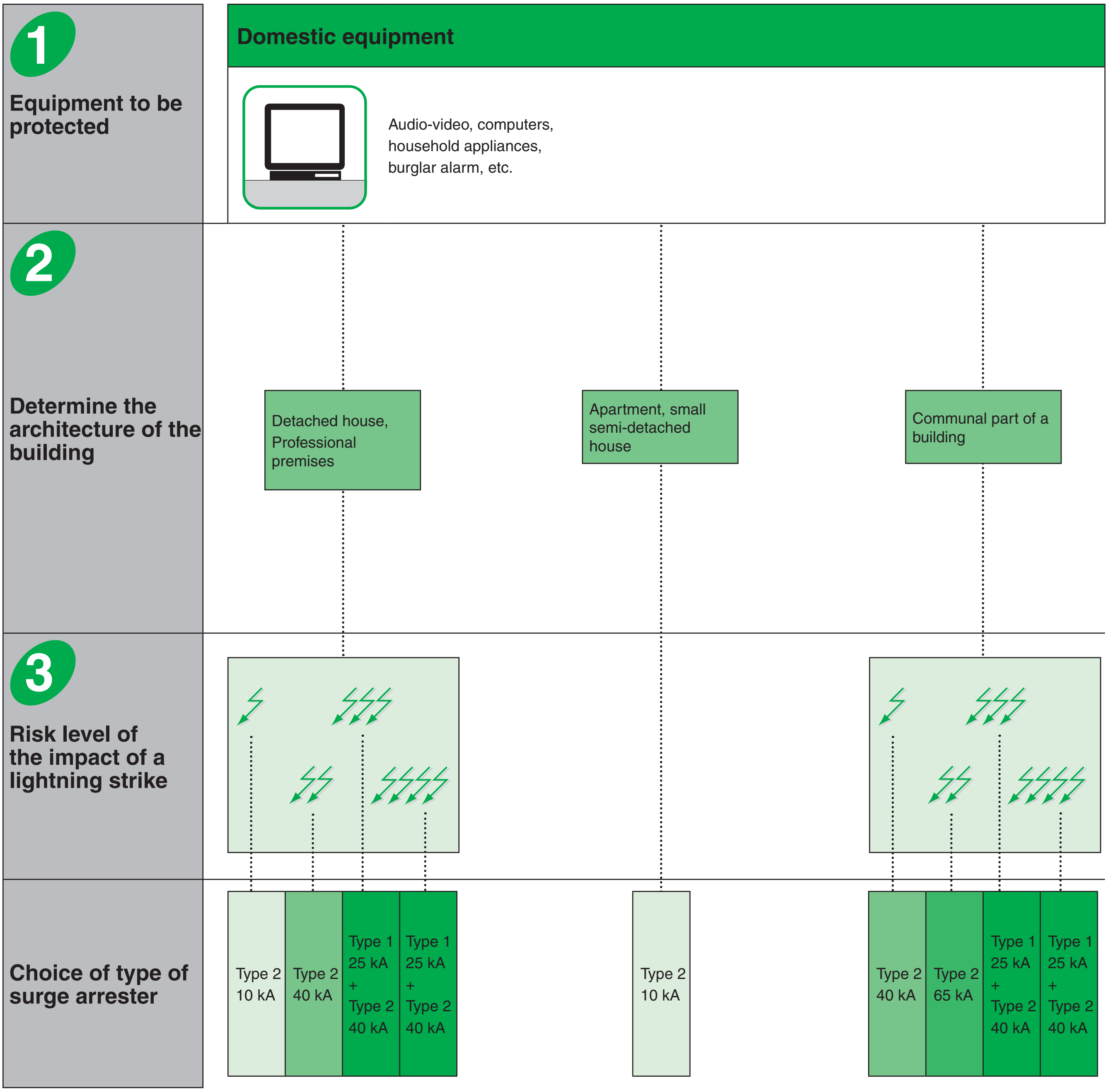
Location of the building

In an urban, peri-urban, grouped housing area.

In an area where there is a particular hazard (pylon, tree, mountainous region, mountain crest, wet area or pond).

In flat open country.

In an exceptionally exposed area (lightning conductor on a building less than 50 metres away).



Note:
Type 1: very high discharge capacity surge arrester used with a lightning conductor with an impact level of and .
Type 2: surge arrester used in cascade behind a type 1 surge arrester or alone in zone and .

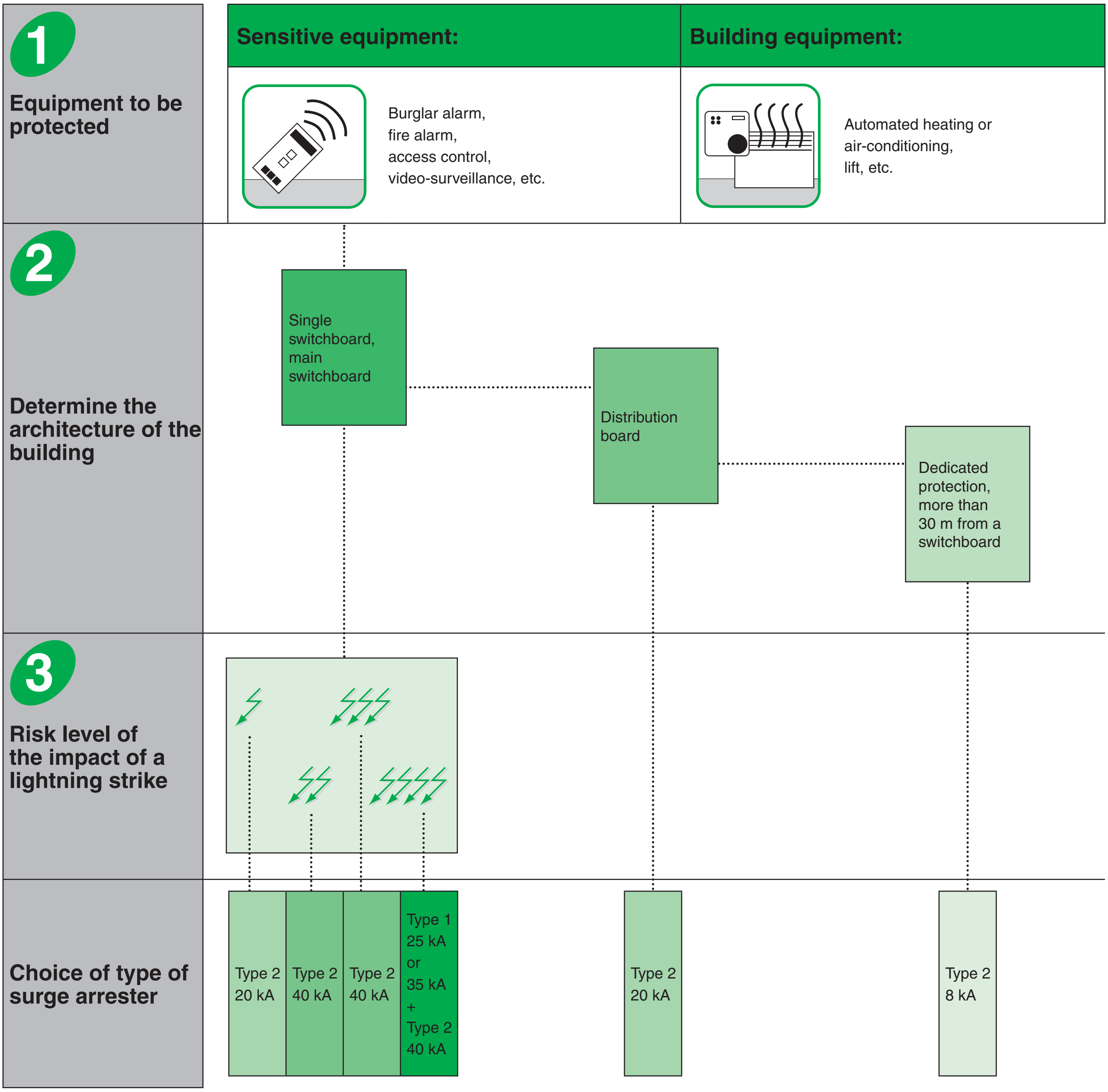
Fig. J32 : Domestic equipment

Lightning also propagates through telecommunications networks.
It can damage all the equipment connected to these networks.

Protection of telecommunications equipment

Choice of surge arresters	PRC
Analogue telephone networks < 200 V	■

4 Choosing a protection device

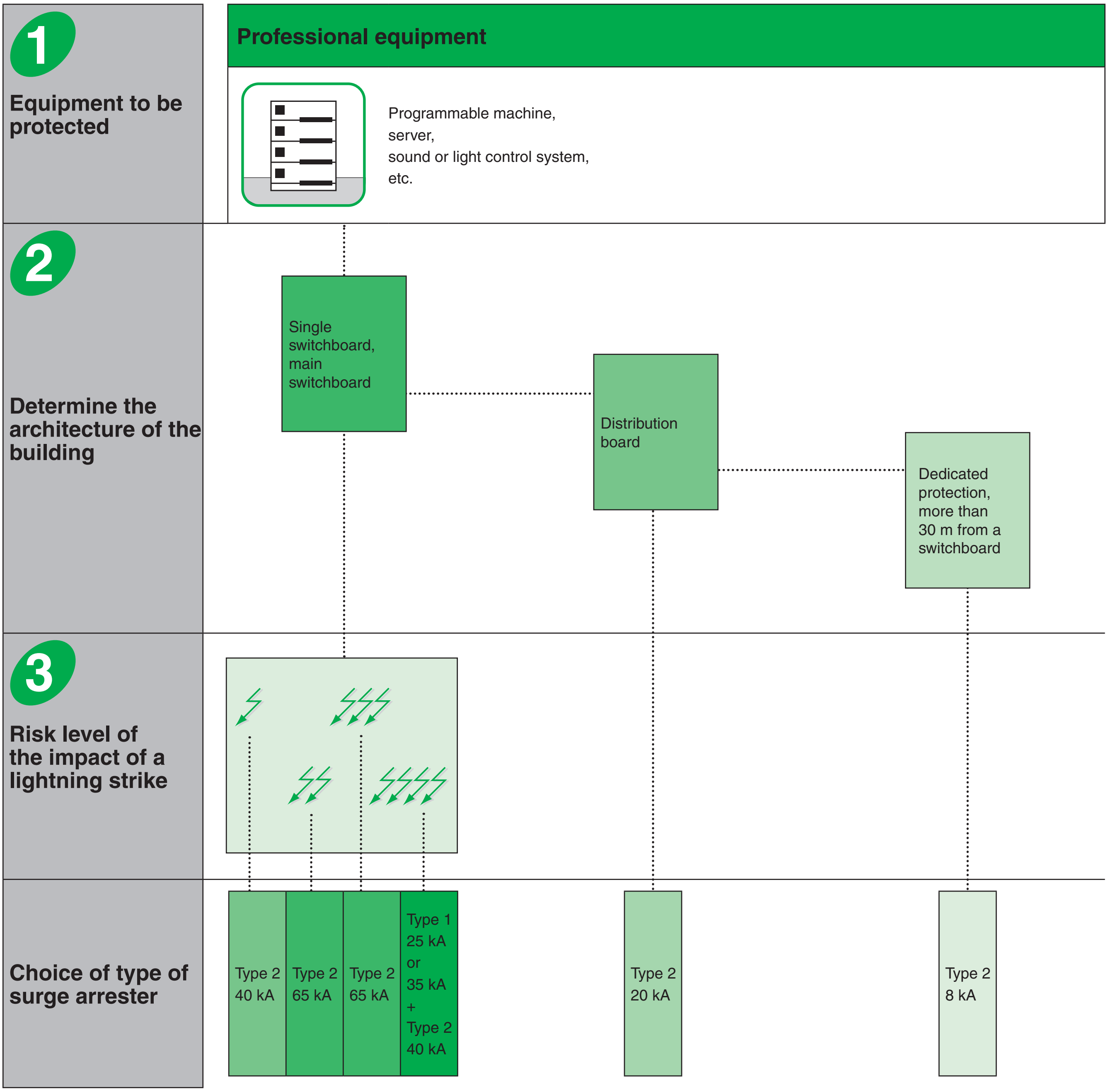


Note:
Type 1: very high discharge capacity surge arrester used with a lightning conductor with an impact level of and .

Type 2: surge arrester used in cascade behind a type 1 surge arrester or alone in zone and .

Fig. J33 : Sensitive equipment, Building equipment

4 Choosing a protection device

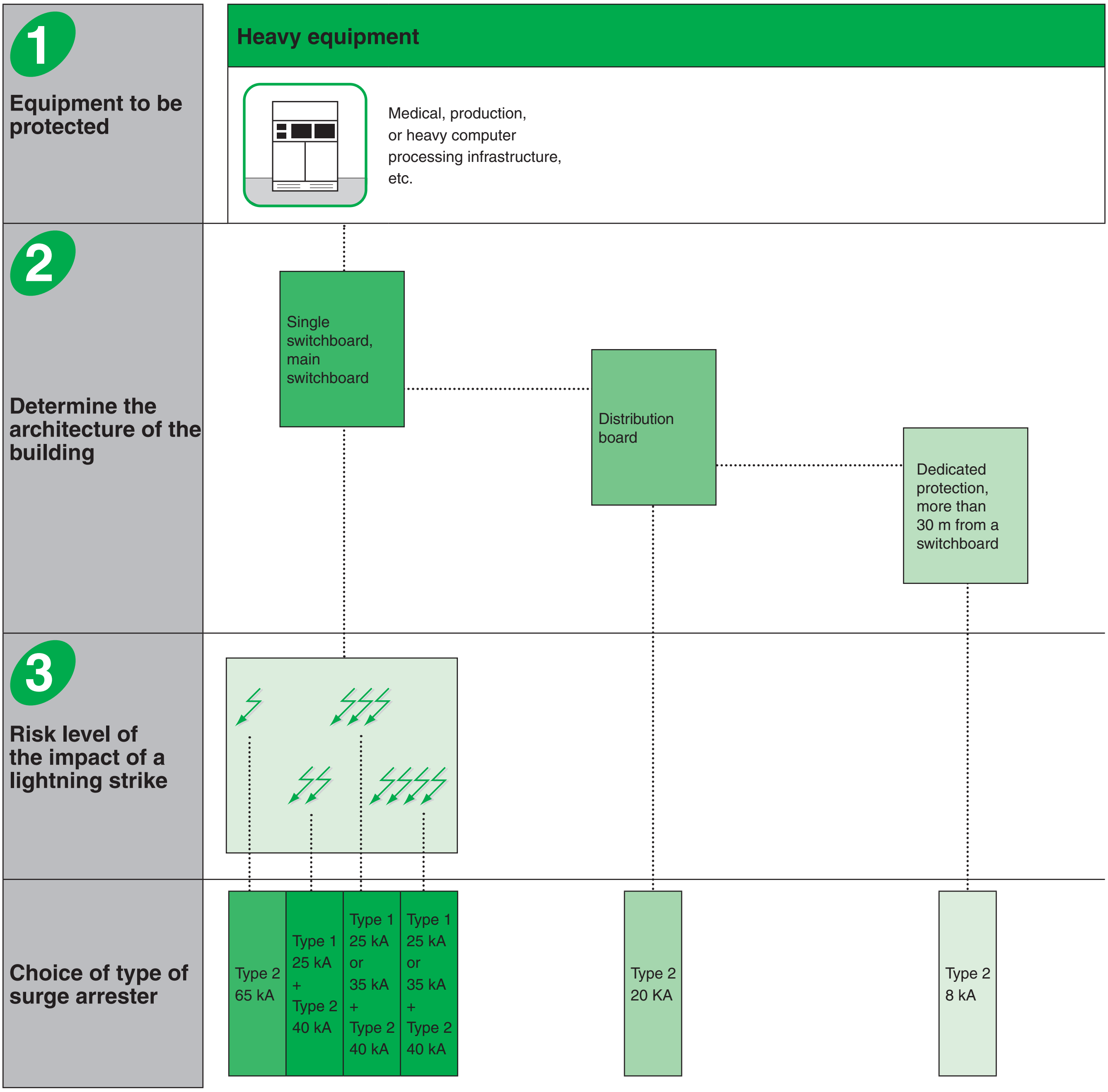


Note:
Type 1: very high discharge capacity surge arrester used with a lightning conductor with an impact level of and .

Type 2: surge arrester used in cascade behind a type 1 surge arrester or alone in zone and .

Fig. J34 : Professional equipment

4 Choosing a protection device



Note:
Type 1: very high discharge capacity surge arrester used with a lightning conductor with an impact level of (3 lightning bolts) and (4 lightning bolts).

Type 2: surge arrester used in cascade behind a type 1 surge arrester or alone in zone (1 lightning bolt) and (2 lightning bolts).

Fig. J35 : Heavy equipment

Lightning can also propagate through telecommunications and computer networks. It can damage all the equipment connected to these networks: telephones, modems, computers, servers, etc.

Protection of telecommunications and computer equipment

Choice of surge arresters	PRC	PRI
Analogue telephone networks < 200 V	■	
Digital networks, analogue lines < 48 V		■
Digital networks, analogue lines < 6 V VLV load supply < 48 V		■

4.5 Choice of disconnector

The disconnector is necessary to ensure the safety of the installation

■ One of the surge arrester parameters is the maximum current (Imax 8/20 µs wave) that it can withstand without degradation. If this current is exceeded, the surge arrester will be destroyed; it will be permanently short circuited and it is essential to replace it.

The fault current must therefore be eliminated by an external disconnector installed upstream.

The disconnector provides the complete protection required by a surge arrester installation, i.e.:

□ It must be able to withstand standard test waves:

- it must not trip at 20 impulses at In
- it can trip at Imax without being destroyed

□ the surge arrester disconnects if it short-circuits.

■ The ready-to-cable surge arresters with an integrated disconnection circuit breaker are:

□ Combi PRF1

□ Quick PF

□ Quick PRD.

Surge arrester / disconnection circuit breaker correspondence table

Types	Surge arrester names	Isc Imax or Iimp	6 kA	10 kA	15 kA	25 kA	36 kA	50 kA	70 kA	100 kA
Type 1	PRF1 Master	**35 kA(1)**	Compact NSX160B 160A				Compact NSX160F 160A	Compact NSX160N 160A		
	PRD1 Master	**25 kA(1)**	NG 125 N C 80A				NG 125L C 80A			
	PRD1 25r		NG 125 N C 80A				NG 125L C 80A			
	PRF1		D125 D curve							
	Combi PRF1		Integrated							
	PRF1 12,5 r	**12,5 kA(1)**	NG 125 N C 80A				NG 125L C 80A			
Type 2	PF 65/ PRD 65r	**65 kA(2)**	C60N 50A C curve		C60H 50A C curve	NG125L 50A C curve	Fuse NH 50A gL/gG			
	PF 40 / PRD 40r	**40 kA(2)**	C60N 40A C curve		C60H 40A C curve	NG125L 40A C curve	Fuse 22x58 40A gL/gG			
	Quick PRD 40r		Integrated				Contact us			
	PF 20/ PRD 20r	**20 kA(2)**	C60N 25A C curve		C60H 25A C curve	NG125L 25A C curve	Fuse 22x58 25A gL/gG			
	Quick PRD 20r		Integrated				Contact us			
	Quick PF 10	**10 kA(2)**	Integrated							
	PF 8/ PRD 8r	**8 kA(2)**	C60N 20A C curve		C60H 20A C curve	NG125L 20A C curve				
	Quick PRD 8 r		Integrated				Contact us			

Isc: prospective short-circuit current at the point of installation.
(1) Iimp.
(2) Imax.

Fig. J36 : Coordination table between SPD and its disconnector

4.6 End-of-life indication of the surge arrester

Various indication devices are provided to warn the user that the loads are no longer protected against atmospheric overvoltages.

Type 1 surge arresters (with gas filled spark gap)

PRF1 1P 260 V, Combi 1P+N and 3P+N and PRF1 Master

These surge arresters have a light indicating that the module is in good working order. This indicator light requires a minimum operating voltage of 120 V AC.

■ The light does not come on:

□ if the operating voltage is ⩽ 120 V AC

□ if there is no network voltage

□ if the spark-over electronics are defective.

Type 2 surge arresters (varistor, varistor + gas filled spark gap)

PF, PRD

At end of life, the surge arrester or the cartridge are destroyed.

■ This can occur in two ways:

□ internal end-of-life disconnection: the accumulated electric shocks cause the varistors to age, resulting in an increase in leakage current.
Above 1 mA, a thermal runaway occurs and the surge arrester disconnects.

□ external end-of-life disconnection: this occurs in the event of an excessive overvoltage (direct lightning strike on the line); above the discharge capacity of the surge arrester, the varistor(s) are dead short-circuited to earth (or possibly between phase and neutral). This short-circuit is eliminated when the mandatory associated disconnection circuit breaker opens.

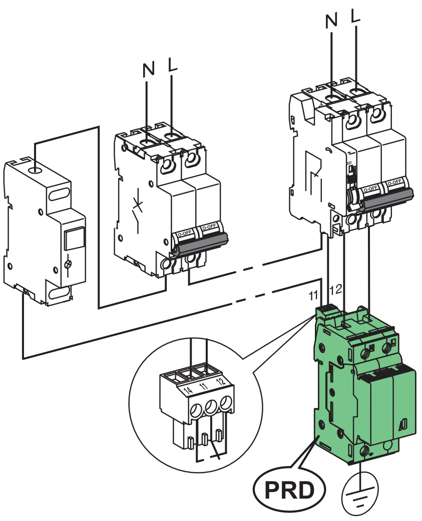


Fig. J37 : Example of indication for PRD

Quick PRD and Quick PF

Whatever the hazards of the power supply network, Quick PRD and Quick PF incorporate a perfectly coordinated disconnector.

■ In the event of lightning strikes < Imax: like all surge arresters, they have internal anti-ageing protection.

■ In the event of a lightning strike > Imax: Quick PRD and Quick PF are self-protected by their integrated disconnector.

■ In the event of neutral disconnection or phase-neutral reversal occurring on the power supply:
Quick PRD and Quick PF are self-protected by their integrated disconnector.
To simplify maintenance work, Quick PRD is fitted with local indicators and draw-out cartridges that are mechanically combined with the disconnector.

Quick PRD has indicator lights on the cartridges and on the integrated disconnector, so that the work to be carried out can quickly be located.
For safety reasons, the disconnector opens automatically when a cartridge is removed. It cannot be set until the cartridge is plugged in.
When changing the cartridge, a phase/neutral failsafe system ensures that it can be plugged in safely.

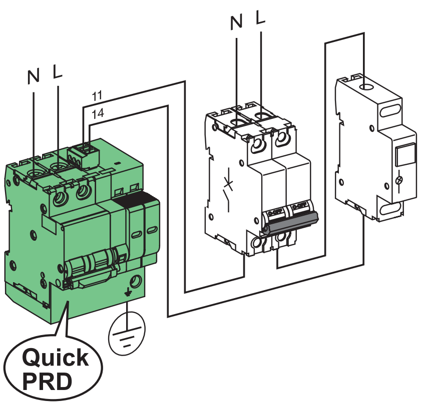


Fig. J39 : Example of indication for Quick PRD

Operating state continuous display

Quick PRD has an integrated reporting contact to send information about the operating state of the surge arrester from a remote location.
Monitoring the surge arresters installed throughout the installation makes it possible to be continuously aware of their operating state and to ensure that the protection devices are always in good working order.

■ A reporting contact gives the alert:

□ at end of life of a cartridge

□ if a cartridge is missing, as soon as it has been removed

□ if a fault occurs on the line (short-circuit, neutral disconnection, phase-neutral reversal)

□ in the event of local manual operation (handle down).

Quick PF has an optional indication reporting auxiliary (SR) that sends information about the operating state of the surge arrester from a remote location.

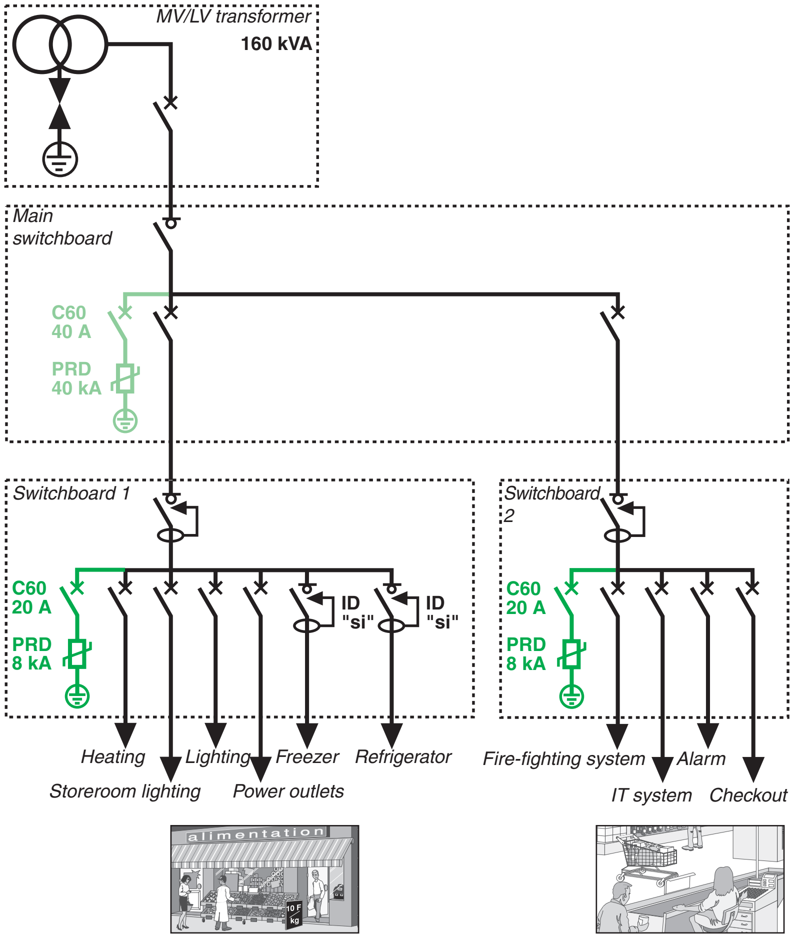


Fig. J39 : *Application example : supermarket*

4.7 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.

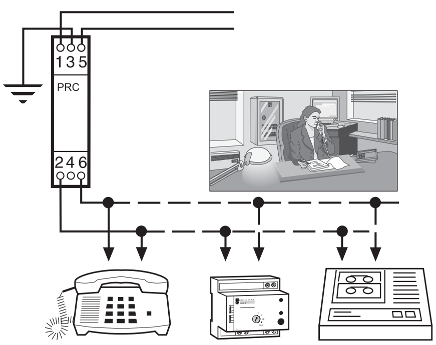


Fig. J40 : *Telecommunications network*

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 A.