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**)

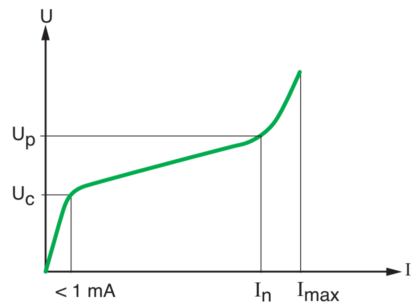


Fig. J16 : Voltage/current characteristics

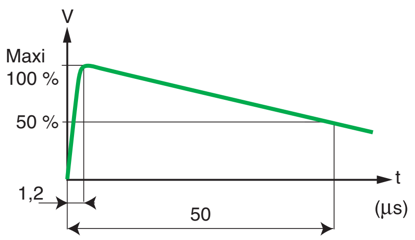


Fig. J17 : 1.2/50 µs wave

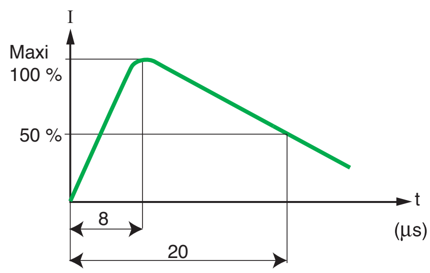


Fig. J18 : 8/20 µs wave

□ 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).

J14

(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**).

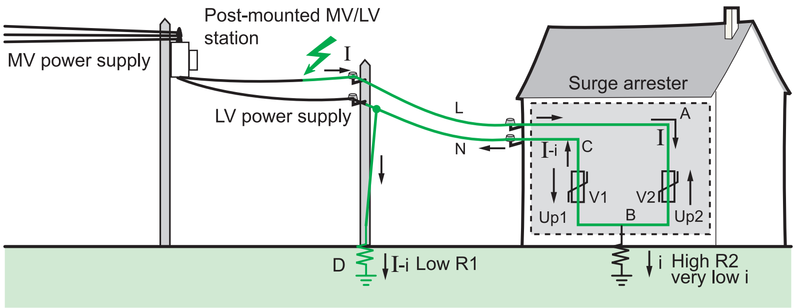


Fig. J21 : Common mode protection only

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).

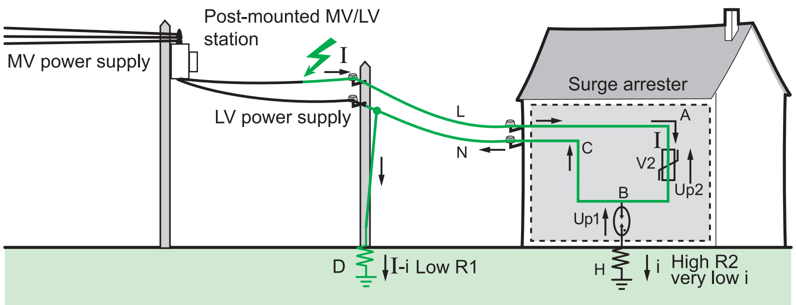


Fig. J22 : Common + differentiel mode protection

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.

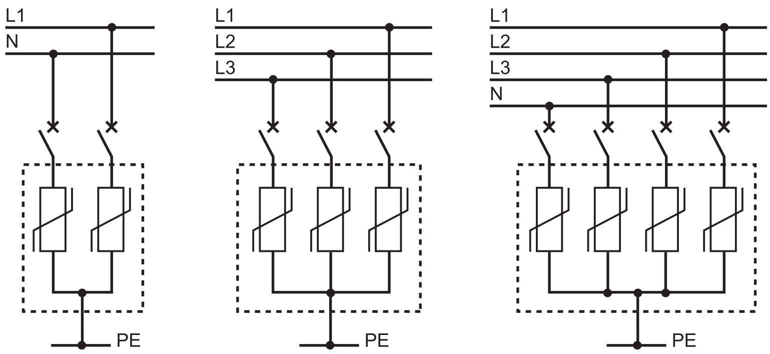


Fig. J24 : 2P, 3P, 4P surge arresters

■ 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.

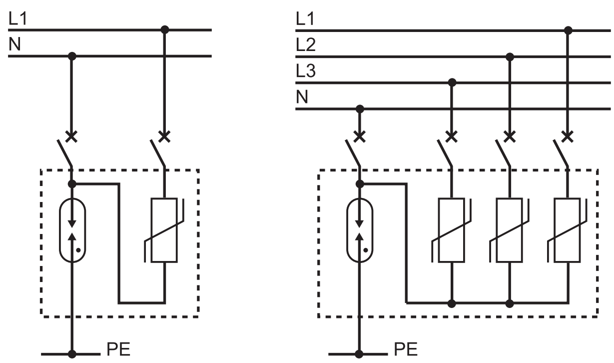


Fig. J25 : 1P+N, 3P+N surge arresters

■ 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.

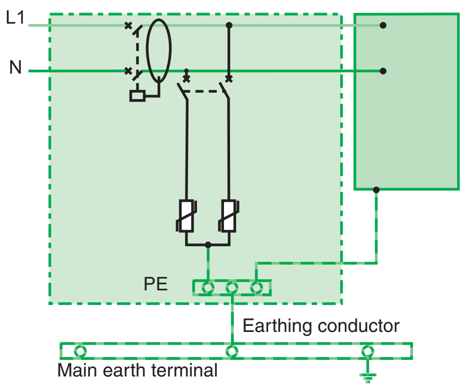


Fig. J26 : Connection example

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.

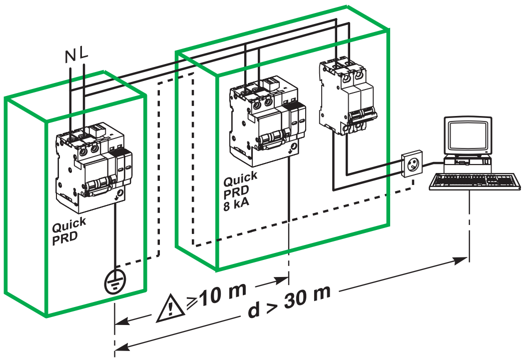


Fig. J27 : Cascading of surge arresters

4.3 Installation rules

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).

Coordination of surge arresters

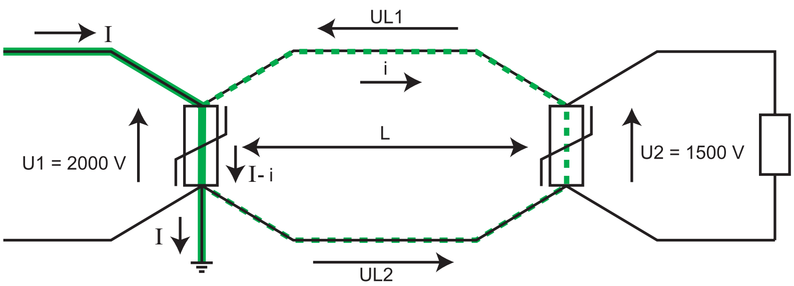


Fig. J28 : Coordination of surge arresters

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.

The first rule to be observed is to ensure that the connection between the surge arrester and its disconnection circuit breaker does not exceed 50 cm.

4 Choosing a protection device

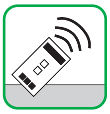
4.4 Selection guide

Estimate the value of the equipment to be protected

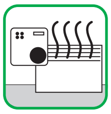
To estimate its value, consider:

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

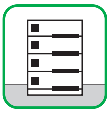
■ Domestic equipment:
□ audio-video, computers
□ household appliances
□ burglar alarm.



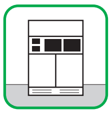
■ Sensitive equipment:
□ burglar alarm
□ fire alarm
□ access control
□ video surveillance.



■ 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

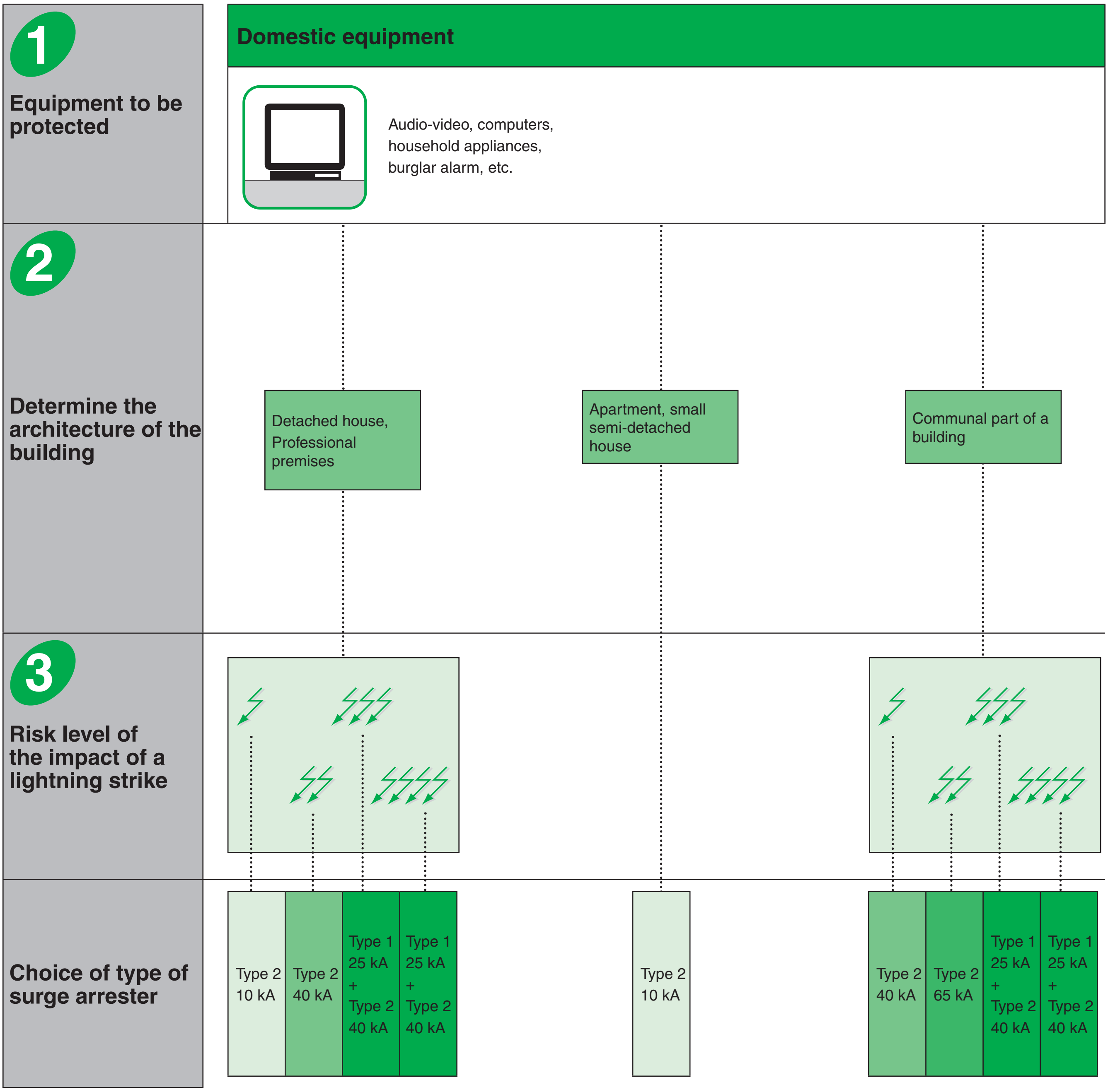
In an urban, peri-urban, grouped housing area.

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).

4 Choosing a protection device



Note:

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

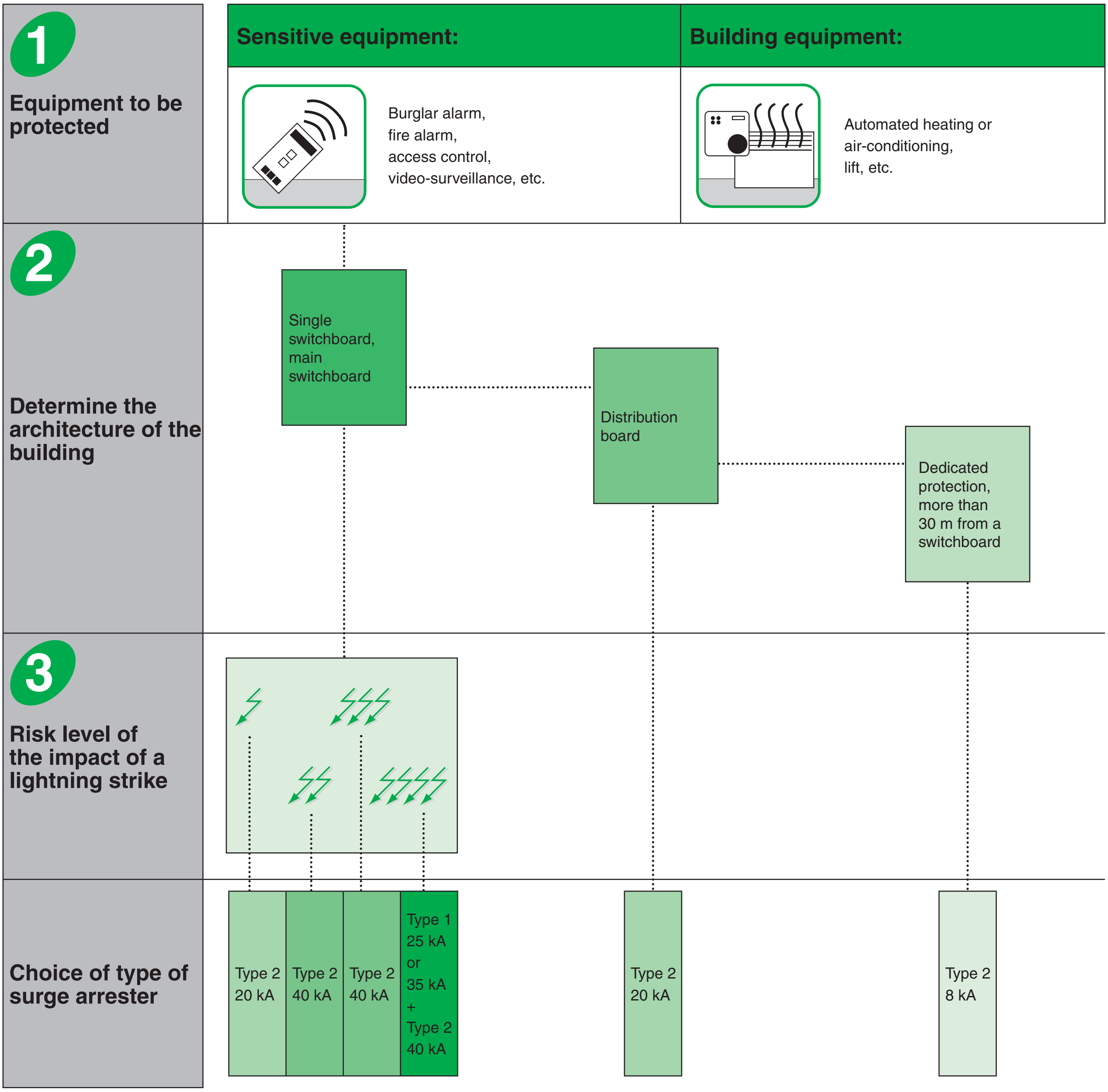
Type 2: surge arrester used in cascade behind a type 1 surge arrester or alone in zone ϟ and ϟϟ.

Fig. J32 : Domestic equipment

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

Protection of telecommunications equipment

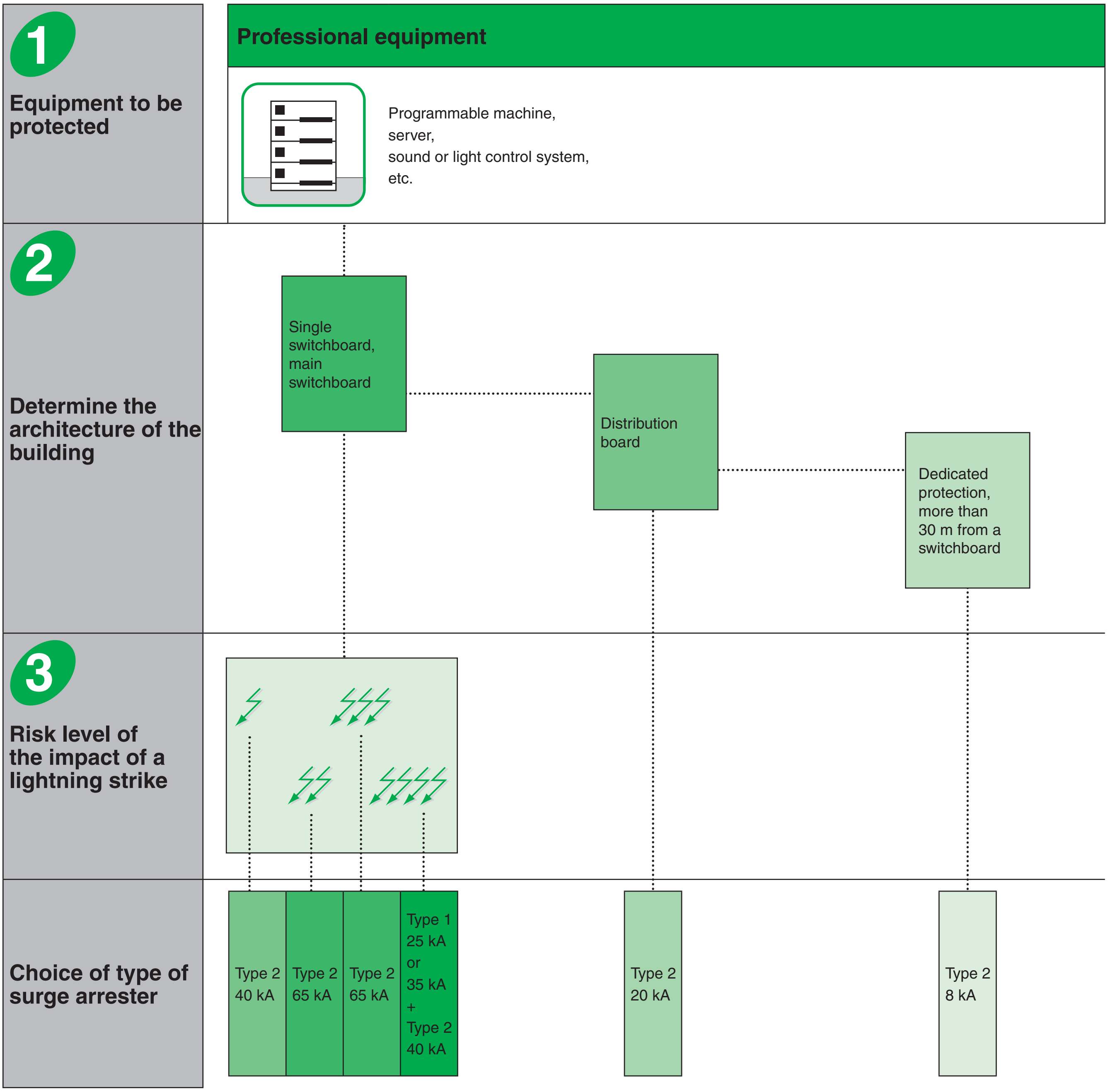
Choice of surge arresters	PRC
Analogue telephone networks < 200 V	■



Note:
Type 1: very high discharge capacity surge arrester used with a lightning conductor with an impact level of [3 lightning symbols] and [4 lightning symbols].
Type 2: surge arrester used in cascade behind a type 1 surge arrester or alone in zone [1 lightning symbol] and [2 lightning symbols].

Fig. J33 : Sensitive equipment, Building equipment

4 Choosing a protection device



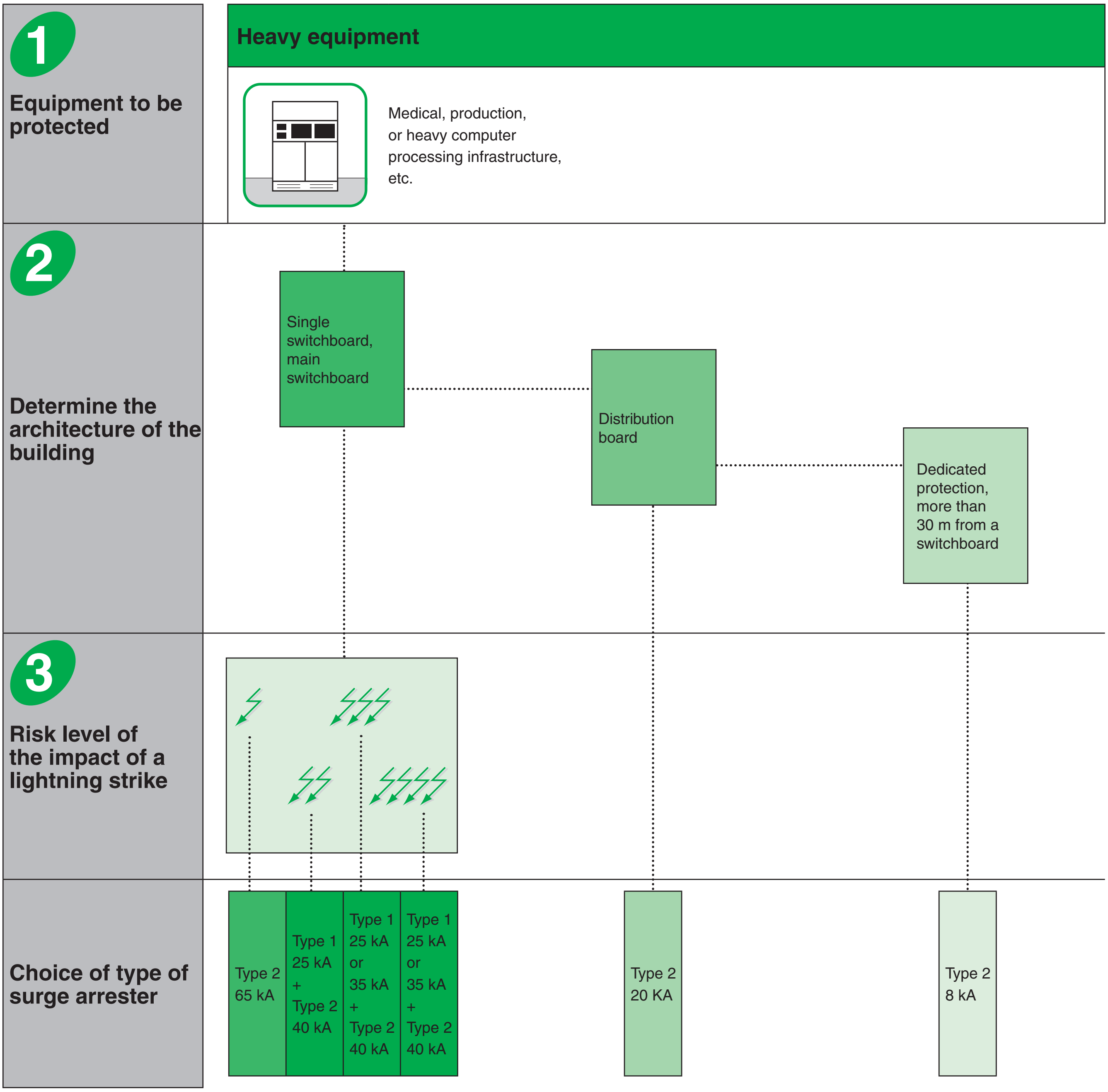
Note:

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 and .

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

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	Isc	Surge arresters	6 kA	10 kA	15 kA	25 kA	36 kA	50 kA	70 kA
Type 1	35 kA (1)	PRF1 Master	NH 160 A gL/gG fuse						
			NS160N 160 A					NS160H 160 A	
	25 kA (1)	PRF1	D125	NH 125 A gL/gG fuse					
Type 2	65 kA (2)	PF65, PRD65	C60N 50 A Curve C		C60H 50 A Curve C	Contact us			
	40 kA (2)	PF40, PRD40	C60N 40 A Curve C		C60H 40 A Curve C	Contact us			
	20 kA (2)	PF20, PRD20	C60N 25 A Curve C		C60H 25 A Curve C	Contact us			
	8 kA (2)		C60N 20 A Curve C		C60H 20 A Curve C				

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

Fig. J36 : Correspondence between surge arrester / disconnection circuit breaker

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.

4 Choosing a protection device

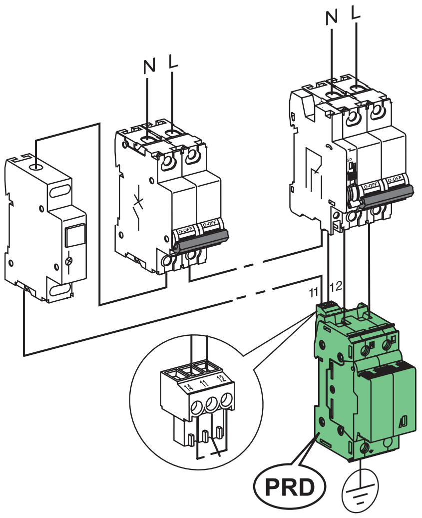


Fig. J37 : Example of indication for PRD

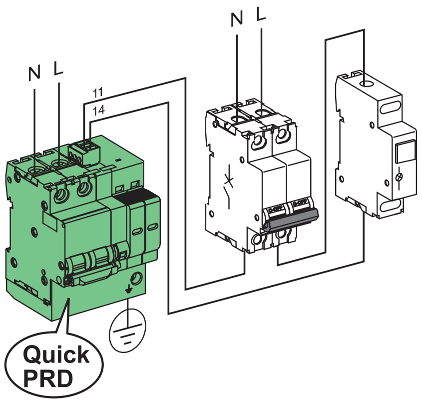


Fig. J39 : Example of indication for Quick PRD

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.

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.

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.

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.

4 Choosing a protection device

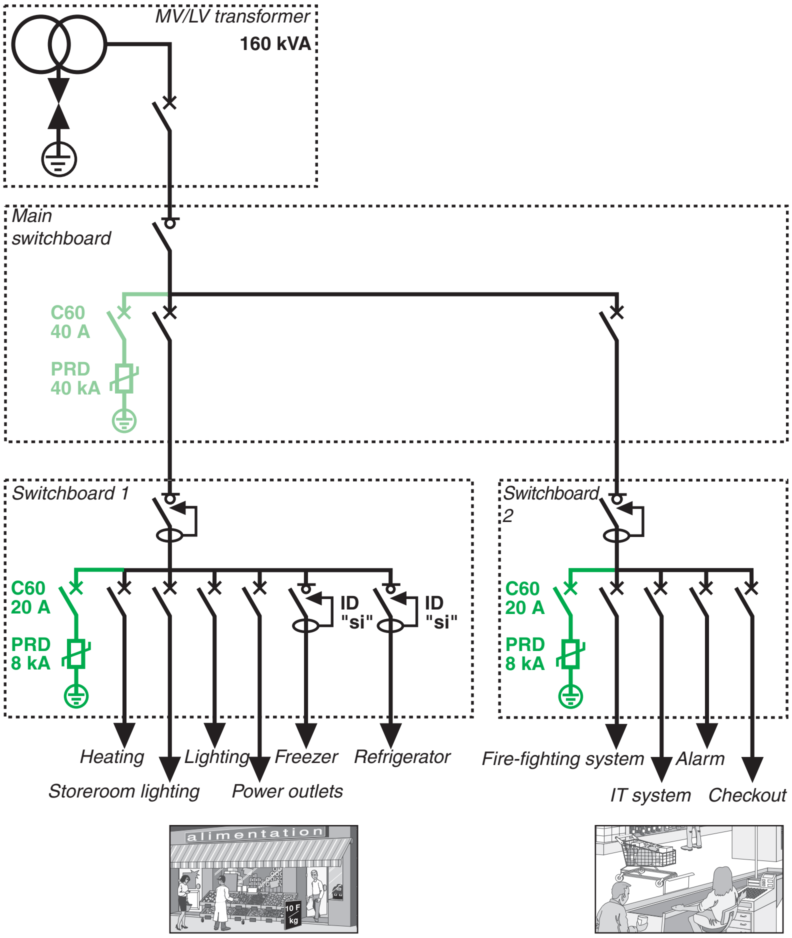


Fig. J39 : Application example : supermarket

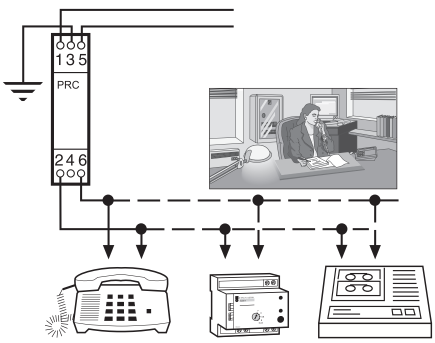


Fig. J40 : Telecommunications network

Function of the surge arrester protection

■ Conduct the lightning current to earth, ensuring a level of protection Up compatible with the electrical equipment to be protected.
■ Limit the rise in earth potential and the magnetic field induced.

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.