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**).

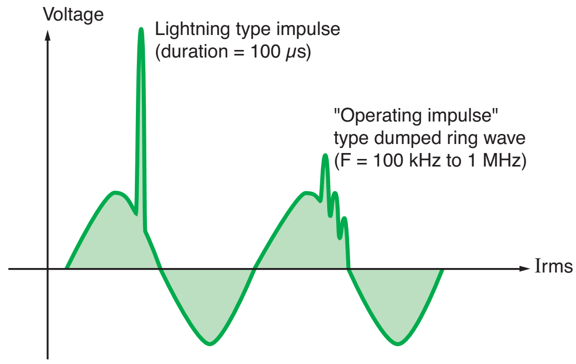


Fig. J1 : Voltage surge examples

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.

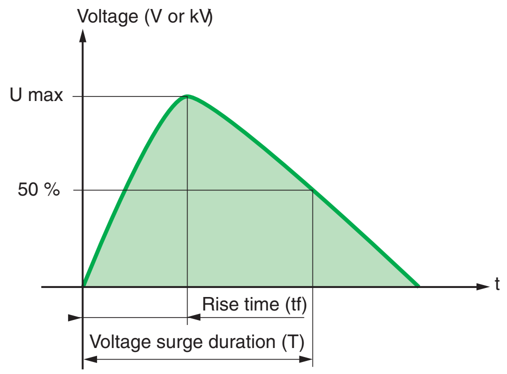


Fig. J2 : Main overvoltage characteristics

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

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.

- 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.

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.

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.

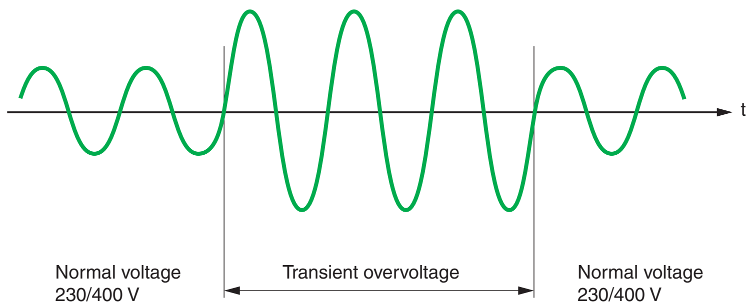


Fig. J4 : Transient overvoltage at industrial frequency

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

1.4 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.

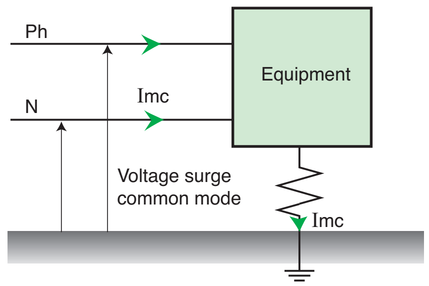


Fig. J6 : Common mode

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.

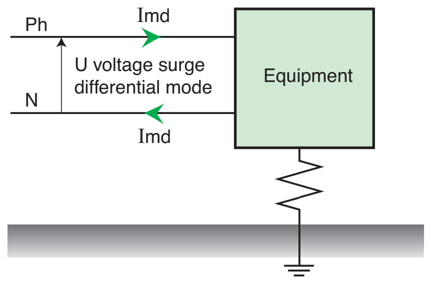


Fig. J7 : Differential mode

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**).

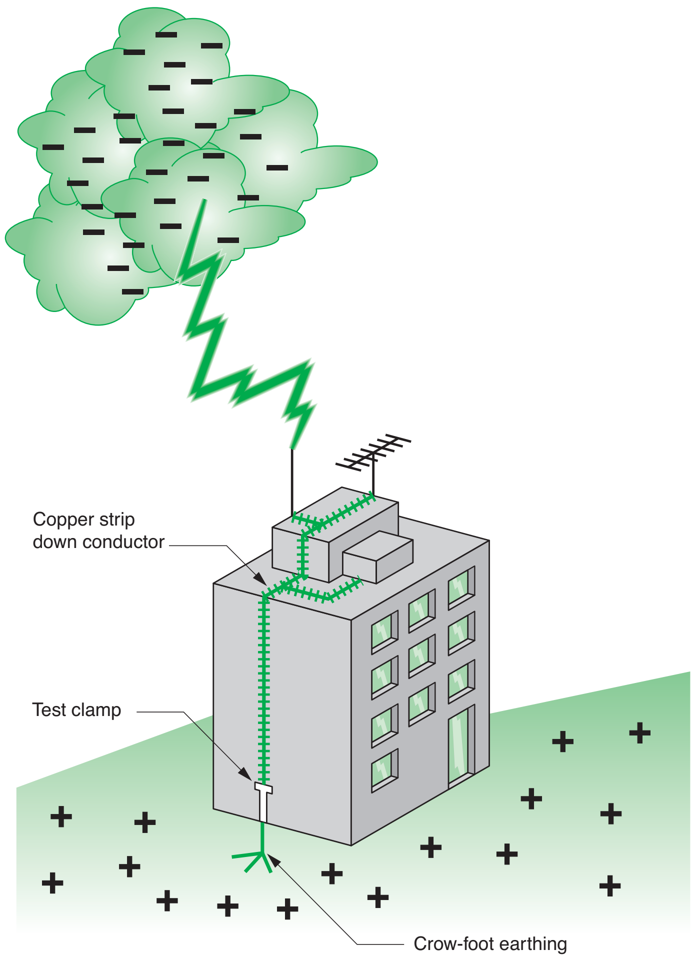


Fig. J8 : Example of protection using a lightning conductor

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**).

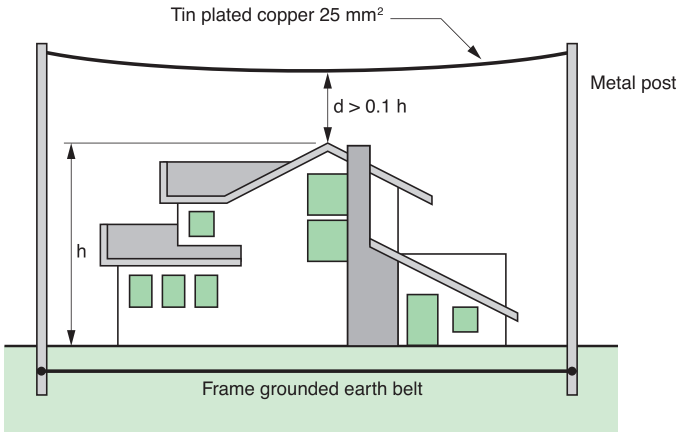


Fig. J9 : Example of lightning protection using overhead earth wires

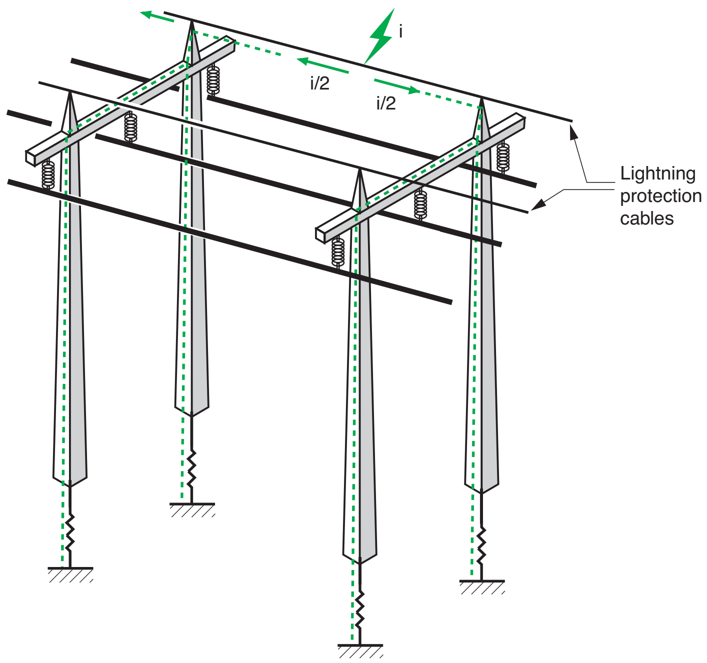


Fig. J10 : Lightning protection wires

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.

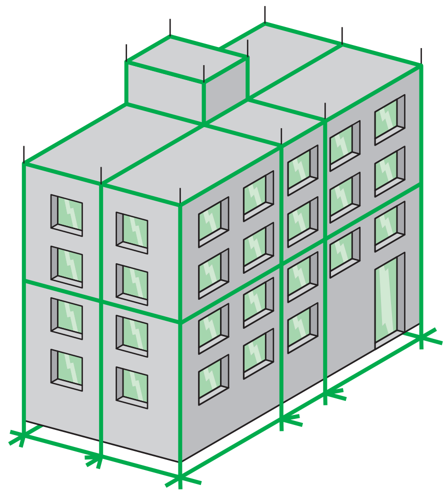


Fig. J11 : Example of protection using the meshed cage (Faraday cage) principle

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**).

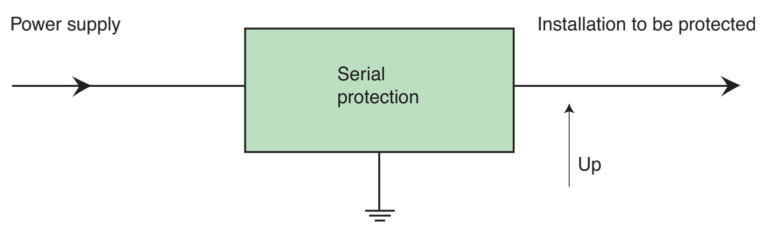


Fig. J12 : Serial protection principle

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.

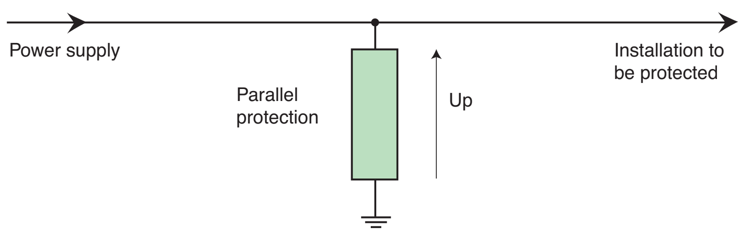


Fig. J13 : Parallel protection principle

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**).

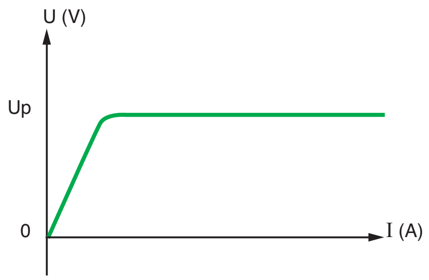


Fig. J14 : Typical U/I curve of the ideal protection device

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**)

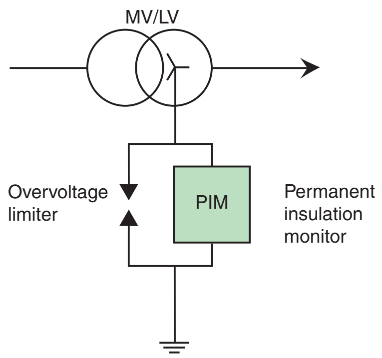


Fig. J15 : Voltage limiter

■ 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 Standards

3.1 Surge Protective Device description

A Surge Protective Device 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 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 Product standards

International standard IEC 61643-1

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

This recent standard (2002) is based on 3 product standards VDE 0675, NF C 61740/95, and UL1449. 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
- 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).

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

3.3 Surge Protective Device data according to the 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.
- **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.

3 Standards

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**)

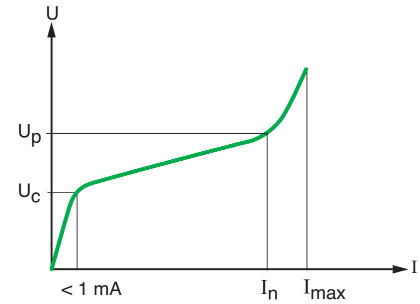


Fig. J16 : Voltage/current characteristics

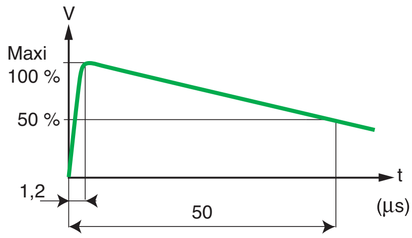


Fig. J17 : 1.2/50 µs wave

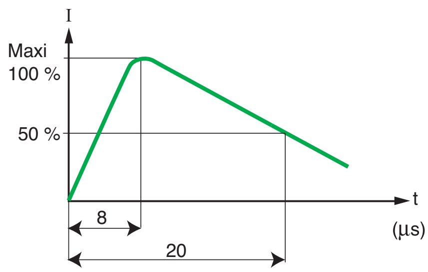


Fig. J18 : 8/20 µs wave

□ 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.

3.4 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
230/440[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

□ IEC 60364-5-534: choosing and implementing electrical equipment
This section describes surge arrester installation conditions:

- **According to earthing systems**: permanent operating full withstand voltage Uc for a surge arrester must not be lower than the maximum real operating voltage on its terminals.
In TT systems, if the surge arrester is on the load side of RCD, Uc must be at least equal to 1.5 Uo (Uo: Line-to-neutral voltage).
In TN and TT systems, if the surge arrester is on the supply side of RCD, Uc must be at least equal to 1.1 Uo.
In IT systems, Uc must be at least equal to phase to phase voltage U.
In large IT systems, the highest Uc values may be needed.

- **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.

- **In the presence of lightning conductors**: if a surge arrester is installed, additional specifications for surge arresters must be applied (see IEC 61024-1 and IEC 61312-1).

(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).

4 Choosing a protection device

4.1 Assessing the overvoltage risk for the installation to be protected

To determine the type of overvoltage protection required by an electrical installation, we suggest the following risk assessment method.
It takes into account the criteria specific to the site on the one hand, and the characteristics of the loads within the installation to be protected on the other hand.

General principle

The following elements should be considered when assessing the risks:

- The risk of the area being struck by lightning
- The type of power distribution or telephone network
- The topography of the area
- Whether there is a lightning conductor
- The type of equipment to be protected
- Operating voltage surges

Two diagnoses can be established using these elements: a diagnosis of the loads to to be protected and a diagnosis of the site to be protected.

Diagnosis of the loads to be protected

This is given in the following formula:

R = S + C + I (see **Fig. J20**)

Where
R: load risk
S: equipment sensitivity
C: equipment cost
I: unavailability of equipment and consequences

Equipment sensitivity

It is due to the impulse withstand voltage of the equipment to be protected (Ui):

S = 1	S = 2	S = 3
High impulse withstand (4 kV) equipment	Normal impulse withstand (2.5 kV) equipment	Low impulse withstand (1.5 kV) equipment
Distribution cabinets power point sockets, motors, transformers...	All household electrical appliances dishwasher, refrigerators, ovens, portable tools	Electronic circuit equipment, televisions, HIFI systems video recorders, alarms, computers and telecommunications

Equipment cost

C = 1	C = 2	C = 3
Low cost	Average cost	High cost
< 2 kUS$	2 to 20 kUS$	> 20 kUS$

Unavailability of equipment and consequences

You accept:

I = 1	I = 2	I = 3
Total interruption of operations (low financial consequences)	Partial interruption of operations (acceptable financial consequences)	No interruption of operations (unacceptable financial consequences)

Fig. J20 : Calculation of load risk, R = S + C + I

4 Choosing a protection device

Diagnosis of the site to be protected

This is given in the following formula:

E = Ng (1 + LV + MV + d) (see **Fig. J21**)

Where

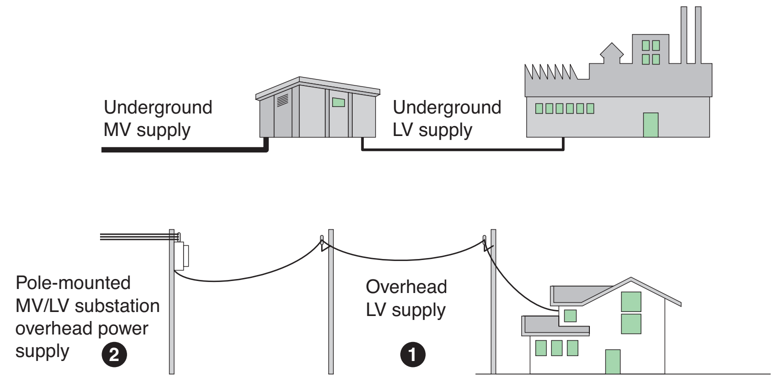
Ng: Lightning strike density (number of impacts/km^2/year).

This can be obtained by consulting a map which shows the specialised weather service network. If you only find the Keraunic (Nk) Level figure (number of days a year when thunder is audible), you can obtain the lightning strike density rate Ng = Nk/20

LV: The length in kilometres of the bare or twisted overhead low voltage power lines supplying the installation.

MV: Parameter depending on the MV network supplying the MV/LV substation.

d: Coefficient taking into account the location of the overhead line and the installation.



LV: The length in kilometres of the bare or twisted overhead low voltage power lines supplying the installation

LV = 0	LV = 0.2	LV = 0.4	LV = 0.6	LV = 0.8	LV = 1
Under-ground or twisted cables	L = 100 to 199 m	L = 200 to 299 m	L = 300 to 399 m	L = 400 to 499 m	L > 500 m
		Length of the overhead low voltage line ❶			

MV: Parameter depending on the MV network supplying the MV/LV substation

MV = 0	MV = 1
Underground MV/LV substation power supply	Overhead or mainly overhead MV/LV substation power supply ❷

d: Coefficient taking into account the location of the overhead line and the installation

d	d = 0	d = 0.5	d = 0.75	d = 1
Building, MV, LV or telephone line location	Entirely surrounded by structures	Several nearby structures	Open or flat land	On a peak, near water in a mountainous area, near a lightning conductor

Fig. J21 : LV supply network structure, E = Ng (1 + LV + MV + d)

Operating voltage surges

Surge protective device installation designed to protect from atmospheric voltage surges also allows for protection against operating voltage surges.

Lightning conductor

The risk of voltage surges on the site is increased if there is a lightning conductor up to 50 metres high on a building or in the surrounding area.

Note: A structure which is 20 metres high such as a factory chimney, a tree, a pole, has the same effect as a lightning conductor; Standard EN 61024-1 requires the installation of a surge arrester on the main energy system if the site to be protected includes a lightning conductor.

4.2 Choosing surge protective device maximum discharge current (LV network)

After having conducted load (R) and site (E) risk studies, the maximum discharge current Imax (8/20 wave) for LV surge arresters is to be determined:

■ **Incoming protection** (see **Fig. J22**)

■ **Secondary protection**

In both of the following cases, a secondary protection surge arrester is needed:

□ If the level of protection (Up) is too high in relation to the impulse withstand voltage (Ui) of the installation's equipment

□ If sensitive equipment is too far from the incoming surge arrester d ⩾ 30 m.

A surge arrester of 8 kA is to be installed in another sub-distribution enclosure and near sensitive loads.

	I =1	I =2	I = 3
R = 8 or 9	30- 40 kA	65 kA	65 kA
R = 6 or 7	15 kA[1]	30-40 kA	65 kA
R ≤ 5	15 kA[1]	15 kA[1]	30-40 kA

Fig. J22 : Choosing surge protective device maximum discharge current

4.3 Choosing surge protective device in function of earthing system (see **Fig. J23**)

Earthing systems	TT	TN-S	TN-C	IT
Uc value in the common mode (phase-earth, neutral-earth protection)	⩾ 1.5 Uo	⩾ 1.1 Uo	⩾ 1.1 Uo	⩾ 1.732 Uo
Uc value in the differential mode (phase-neutral protection)	⩾ 1.1 Uo 15 kA (1)	⩾ 1.1 Uo 30-40 kA		⩾ 1.1 Uo

Uo: phase-to-neutral voltage
Uc: maximum continous operating voltage

Fig. J23 : Uc value according to the international standard IEC 60364-5-534

Choosing surge protective device in function of earting systems
Offer: PRD-PF-PE

Earthing systems		TT	TN-S	TN-C	IT distributed neutral	IT non distributed neutral
Uc (network) Full voltage		345/360 V	345/264 V	253/264 V	380/415 V	380/415 V
Withdrawable surge protective device PRD	CM Uc = 275 V			1P		
	CM Uc = 440 V			3P		3P
	CM/DM Uc = 440/275 V	1P + N 3P + N	1P + N 3P + N		1P + N 3P + N	
Fixed surge protective device						
PF30-65 kA	CM Uc = 440 V	1P + N 3P + N	1P + N 3P + N		1P + N 3P + N	
PF8-15 kA	CM/DM Uc = 440/275 V	1P + N 3P + N	1P + N 3P + N		1P + N 3P + N	
PE	CM Uc = 440 V			1P 3 x 1P		3 x 1P

Complete your choice with the following elements:

■ remote indication of surge protective device status if necessary

■ disconnection circuit-breaker

(1) The risk is low, however if the installation of a surge protective device is desired, the model with an Imax of 15 kA is recommended.

4.4 Choosing a disconnection circuit-breaker

(see **Fig. J24**)

After having chosen the surge protective device(s) needed to protect the installation, the appropriate disconnection circuit-breaker is to be chosen from the table below:

- Its breaking capacity must be compatible with the installation's short-circuit current
- Each live conductor must be protected, for example: a surge arrester 1P+N must be associated with a 2-pole disconnection circuit-breaker (2 protected poles).

Maximum discharge current for surge protective device	Disconnection circuit-breaker	
	Rating	Trip curve
8-15-30-40 kA	20 A	C
65 kA	50 A	C

Fig. J24 : Choosing a disconnection circuit-breaker