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Precautions to be considered for use of surge arresters tested according to Class 1 of IEC 61643-1

Foreword:

The protection products named surge arresters and tested according to Class I of IEC 61643-1 are often wrongly called "Class 1 surge arresters". In actual fact the IEC classes are above all test classes and any product can be placed in one of the three classes

More generally, surge arresters with a high run-off capacity are tested according to Class 1 of IEC 61643-11.

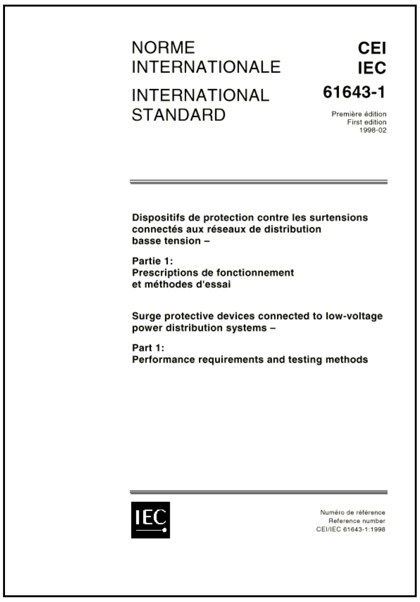
These are the surge arresters dealt with in this document.

A distinction must be made between the various technologies available, as they present different advantages and disadvantages on application.

IEC 61643-1

IEC 61643-1 "Surge protective devices connected to low voltage power distribution systems - part 1: Performance requirements and testing methods" introduces three test classes:

- Class I tests: tests performed under the maximum shock current limp. The specific energy of the W/R surge arrester is determined.
- Class II tests: tests performed under the maximum discharge current Imax in 8 /20 wave
- Class III tests: tests performed with combined wave (1.2/50 – 8/20)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Dispositifs de protection contre les surtensions connectés aux réseaux de distribution basse tension –
Partie 1:
Prescriptions de fonctionnement et méthodes d'essai

Surge protective devices connected to low-voltage power distribution systems –
Part 1:
Performance requirements and testing methods

IEC
Numéro de référence
Reference number
CEI/IEC 61643-1:1998

A few definitions

Holding current: Current delivered by the power system and run off by the surge arrester after flow of the discharge current: this behaviour is characteristic of surge arresters with "spark-gap" technology. The value of the holding current roughly corresponds to the short-circuit current (Isc) of the installation at the point considered. To avoid obvious problems of safety and continuity of supply, spark-gap surge arresters must spontaneously break this current, at least up to a certain value defined by the manufacturer.

Air spark-gap: Device normally made up of 2 electrodes placed opposite one another and between which arcing occurs (follow-up of a holding current) as soon as a surge reaches a certain value. In order to quickly "quench" the holding current, the arc puffing principle is used, which results in expulsion to the exterior of hot gases.

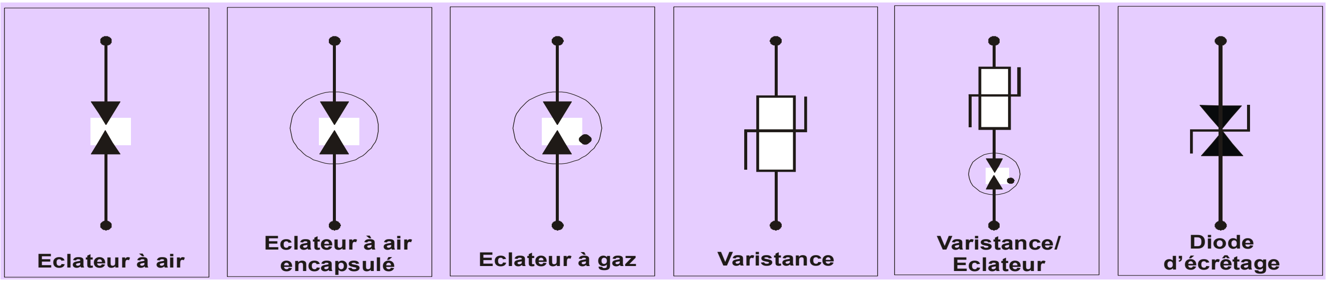
Encapsulated spark-gap: Air spark-gap in which holding current is quenched without expulsion of gases. This is normally to the detriment of the breaking capacity of the holding current.

Gas spark-gap: Spark-gap in a hermetic enclosure, filled with a mixture of rare gases at controlled pressure. This device is ideal for protection of telecommunication networks. Its main feature is its very low leakage current.

Varistor: Non-linear component (Resistance varies as a function of voltage) made of Zinc Oxide (ZnO), used to limit voltage at its terminals: this limiting operation is used to avoid the holding current, thus making this component ideal for the protection of power systems (HV and LV).

Spark-gap/Varistor: Association of a series of components designed to benefit from the advantages of both technologies: no leakage current and low Up (spark-gap) and no holding current (varistor).

Limiting diode: Zener type diode (voltage limitation) equipped with a special structure to optimise its limiting behaviour on transient surges. This component is characterised by a particularly quick response time.



Comparison

Note:
- The values given are for information only and can vary according to product ranges and manufacturers.
- Maximum voltage in steady state (Uc) is 440 V.

Technology	Air spark-gap	Encapsulated spark-gap	Gas spark-gap	Varistor	Spark-gap/ Varistor	Clipping diode
Discharge current (Imax) 8/20	> 100 kA	> 100 kA	10-50 kA	15-100 kA	10-50 kA	100A
Discharge current (limp)	> 50 kA	> 25 kA	> 5 kA	> 3 kA	> 3 kA	< 10A
Level of protection (Up)	> 3 kV	> 3 kV	> 1.5 kV	> 2 kV	> 1.5 kV	< 1 kV
Self-extinguishing on LV network	> 25 kA	> 1.5 kA	> 100 A	not limited	not limited	not limited
Holding current	yes	yes	yes	no	no	no
Leakage current at Uc (If)	<< 0.1 mA	<< 0.1 mA	<< 0.1 mA	< 0.1 mA	<< 0.1 mA	< 0.1 mA
Influence of external conditions	yes	no	no	no	no	no
End of life	open circuit	open circuit	open circuit	thermal racing	thermal racing	short-circuit

Conditions of use:

1- Air spark-gaps must be installed in separate enclosures of the main enclosure to prevent interaction on the other switchboard products. The arc chutes and vents provided to break the arc are used to expulse hot gases in the rear part that must be monitored. **It is thus essential to comply with minimum distances between the surrounding devices and the enclosure.**

2- The spark-gaps used between phase and neutral or phase and earth generate 50 Hz holding currents (local short-circuit current). The spark-gaps said to be self-extinguishing are those whose holding current is broken in less than one halfwave.

3- When the distance between the main spark-gaps and the second-level protective devices is large (a few hundreds of metres), run-off of small transient currents in the second-level varistor generates a voltage over cable length that will cause spark-gap arcing, although its operation is not necessary.
When cumulated with problem number 1, the continuity of supply problem is amplified.

4- Fuses and other devices providing protection against the fault currents located upstream of the spark-gap may stop the power supply to the installation by opening on the holding current even if the latter is limited in time, or by opening on a long waveform used for class 1 tests. In point of fact, the withstand of the fuses and circuit-breakers on this type of aggression is random and in most cases results in opening. Although it is possible to recommend a specific breaking device for the surge arrester, on the other hand the devices provided on the network for the other functions remain vulnerable.
If a specific device can be fitted, it will not be able to withstand long wave high values (test class 1) without opening.

5- Use of spark-gap products (high residual voltage) systematically results in co-ordination with other surge arresters, thus leading to extra expenses when compared with other solutions.

6- Decoupling reactors are required to ensure co-ordination between the spark-gaps and the varistors (or an equivalent distance). They are installed in series on the line and must be sized according to the rated current of the installation, which has drawbacks for operation and leads to high costs.

7- Use of spark-gaps at the front generates brownouts that are tolerated less and less by modern equipment (reduction of voltage to arcing voltage).

8- The profession's experience in the area shows that these solutions are often over-sized in time (waveform) and amplitude. It should not be forgotten that the medium voltage surge arresters used by EDF on overhead networks have a nominal current of 5 kA 8/20 which corresponds to an Imax of 40 kA 8/20 without any particular maintenance problems. In most cases escalation to high discharge current values is at the detriment of residual voltage (which is nevertheless well and truly the main feature for protection, as the discharge current only provides information on product durability and not on its efficiency).

EDF's experience is based on 700 000 surge arresters of In=5kA, Imax=40kA installed on medium voltage network lines. The failure rate observed on this installed base is 0.025% (CIGRE Colloquium 95).

Regarding standards, IEC 60 -099-1 and 60-099-4 recommend 40 or 65 kA Imax for medium voltage and 65kA for high voltage in 8/20 wave.

Standard NFC 61740/95 recommends a max current of 65 kA, i.e. the same value as for medium and high voltage, which is already an ample sizing.

9- These solutions are not advantageous if there is no lightning rod fitted in the installation (probability of finding currents of this amplitude).

10- If a lightning rod is fitted, the maximum current value to be taken into account, recommended by standard UTE C 15443 is In=20kA 8/20 wave.

11- Low leakage currents mean that this protection type is ideal when the aim is to protect the upstream of the incomer circuit-breaker with the TT system, if it can be guaranteed that the end of life of the surge arrester is short-circuited (repeated lightning impulses, temporary surges, etc.).

Note 1: Waveforms are in fact models that are not strictly reproduced in nature (a lightning stroke never has the 8/20 form). These forms are used to characterise and compare products. They exist only because generators exist. Only a few laboratories in Europe are able to perform long wave tests (of the test class 1 type) at high current (greater than 20 kA). These tests are very costly (this can be seen at product level) and are hard of access for European manufacturers.

Note 2: Use of the long wave (test class 1 type) already corresponds to an extreme model in terms of duration. It is not reasonable to cumulate width and extreme amplitude. The long wave (test class 1 type) must be used for ≤ 20kA currents as stipulated in the standard.

A few figures to return to reality…

- A 6kV LV surge arrester, test class 1, has a MTBF of 1700 years if Ng=1 (1 lightning stroke a year and per km2).
- A 25kA LV surge arrester, test class 2, has a MTBF of 33000 years if Ng=1. (direct lightning stroke on the lightning rod)
- A 65kA LV surge arrester, test class 2, has a MTBF of 5000 years if Ng=1. (direct lightning stroke on the lightning rod) - Values of 600 kA (8/20) are found on the market (Ng=1 average value in France.

Conclusion:

- **Test class 1 surge arresters should never be installed unless the building is protected by lightning rods and even in that case only with reservations.**

- **As part of standard NFC 15100 (in France), test class 1 surge arresters with spark-gap are not recommended.** Varistor technologies should preferably be used. The use of Test Class Surge arresters is justified **only** in the TT earthing system when it is authorised to place surge arresters upstream of the circuit-breaker. (This is a special case authorised in Germany)

- Test class 1 surge arresters where Iimp=20kA are more than sufficient: it is pointless and costly to continue kA escalation.

- The other electrical devices electrical installations (circuit-breakers, fuses, etc.) are not sized for the requirements corresponding to Class 1 tests at high amplitude. Yet destruction of these devices due to these phenomena is not observed. This tends to prove that these high 10/350 amplitudes do not exist or if so very rarely.

- It is possible to monitor the behaviour of the surge arrester and its disconnector on this type of aggression, but as the rest of the installation is not monitored, global withstand cannot be obtained.

- A surge arrester must not be over-sized in kA to the detriment of residual voltage.

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