SURGE ARRESTER FOR PROTECTION AGAINST OVERVOLTAGE OF HIGH VOLTAGE NETWORKS

DESCĂRCĂTOARE PENTRU PROTECŢIA LA SUPRATENSIUNI A REŢELELOR DE ÎNALTĂ TENSIUNE

Alina VIIȘOREANU-RĂCHIȚEANU[1], Alexandru-Marius VIIŞOREANU[2]

Abstract: *The paper presents the main elements of surge arresters used in high voltage electrical networks. A comparison is made between the main characteristics of surge arresters, both in terms of the construction elements and in terms of the technical and functional characteristics of surge arresters.*

Keywords: overvoltage, surge arrester, high voltage network, protection.

Rezumat: *În lucrare se prezintă elementele principale privind descărcătoarele pentru protecţia la supratensiuni, folosite în reţelele electrice de înaltă tensiune. Se face o comparaţie între principalele caracteristici ale acestor descărcătoare, atât în ceea ce priveşte elementele constructive, cât şi în ceea ce priveşte caracteristicile tehnice şi funcţionale ale acestor descărcătoare.*

Cuvinte cheie: supratensiune, descărcător, reţea de înaltă tensiune, protecţie.

1. Introduction

Phase-to-earth or phase-to-phase surges occurring in electrical networks due to atmospheric discharges of a microsecond duration represent the lightning surge.

Electrical installations operate at a utilization voltage as defined in IEC 60038. This involves a dielectric stress through the electric field to which the insulating material is subjected, this stress being produced by the amplitude value of the nominal voltage. When a surge occurs in an installation, the electrical field created by it exceeds the value produced by the amplitude of the nominal voltage and there is a risk of breakdown the insulation.The problem that arises is how the insulation of electrical equipment and installations can be sized to withstand the demands of atmospheric or switching surges. Surges, depending on their type, have amplitude values in a very wide range.

[1] PhD., Dept.of Electrical Engineering, University POLITEHNICA of Bucharest, Romania, e- mail: alina.rachiteanu92@yahoo.com

[2] PhD., Dept.of Electrical Engineering, University POLITEHNICA of Bucharest, Romania, e- mail: alex.viisoreanu@yahoo.ro

Excessive oversizing of the insulation of equipment and installations is not economical and also impossible to achieve for the whole range of surges, especially those of atmospheric origin. Electrical demands require the coordination of insulation by the defining elements, namely the overvoltage factor, the type of atmospheric overvoltage, the level of protection and the voltage withstand.

Due to technological development and increasing dependence on technology, the effects of atmospheric or switching surges are increasing. In Fig. 1, a fault statistic is presented, resulting from the analysis of more than 9600 cases of damages, caused by various causes such as: lightning or switching surges, damaged or aged insulation, negligence of operation or maintenance, fires, floods, vandalism or thefts.

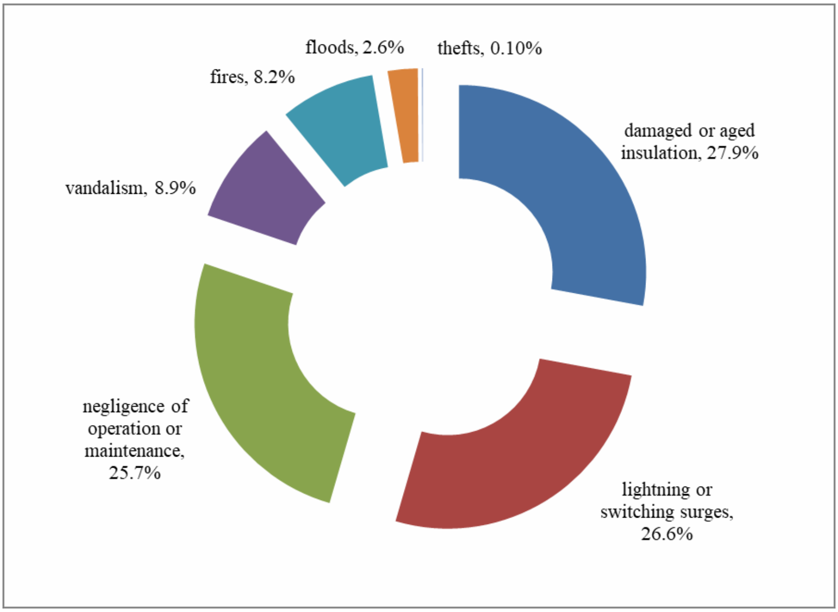


Figure 1. Analysis of the causes of defects [1]

1. Protection of electrical installations against lightning surge waves

The protection of electrical installations against lightning surge waves propagating on overhead power lines shall comply with the level of insulation withstand. The level of insulation retention or coordination of the insulation is the choice of the insulating distance so that the electrical grid operates with a minimum risk of defect [2].

The following are the basic protective measures applied to the power stations, as well as the additional protection measures on the overhead power lines, at the entrance to the electric station.

Basic protection shall ensure that equipment in the installation is protected from lightning surges that propagate from the line to the electric station as a result of lightning strikes in the line. For this purpose, various types of surge arresters are used. Additional protective measures on overhead power lines at the entrance to the electric station are the use of earthwire and lightning rods.

The type of protective measures used shall be determined on the basis of the nominal voltage of the network, the keraunic index of the area where the installation is located and the operating mode of the network.

It is also possible to determine the keraunic index of the installation area of the surge arresters, which is the number of stormy days with electrical discharges during a year, according to weather data over a period of 10 years or more.

In an power station up to and including 400 kV, the protection scheme shall be applied so that there is a safety margin between the maximum voltage for each equipment in the station and the lightning pulse withstand voltage.

2. Types of surge arresters used in electrical networks

Surge arresters (or lightning arrester or surge diverter) for high voltage electrical networks are classified into two categories:

- Surge arrester with metal oxide without priming spark gaps (Fig. 2.a);
- Silicon carbide surge arrester with priming spark gaps and shunt resistors (variable resistance) (Fig. 2.b).

a. *b.*

Figure 2. Types of surge arresters

The differences between the two types of surge arresters, from a constructive point of view, are the following:

- Variable resistance surge arresters have columns of spark gaps, their number depending strictly on the rated voltage of the network, and high value shunt resistors that ensure the distribution of the surge evenly on the primar spark gaps.

- Metal oxide surge arrester is formed by putting several disks made of metallic oxide in series (90% ZnO Bi2O3 - bismuth trioxide);

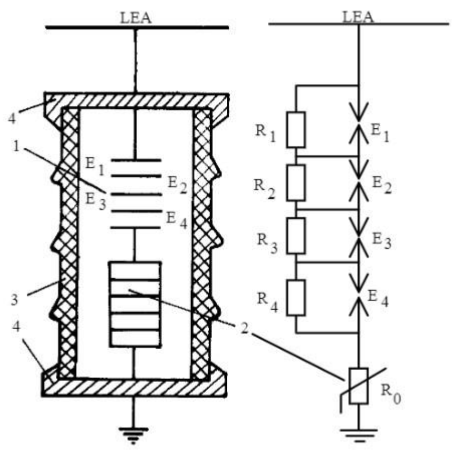
3.1 Surge arrester with variable resistance and shunt resistor

The variable resistor surge arrester reduces the value of the overvoltages by the non-linear resistors, voltage dependent, to a value equal to the protection level.

The main components of the variable resistor surge arrester are the spark gaps which ensure, in normal operating mode, the galvanic separation of the variable resistors from the phase conductor in order to limit the current absorbed by the surge arrester to a negligible value relative to the nominal current of the main current path. In turn, the spark gaps are of several types, classic spark gaps and spark gaps with force extinguishing (self-blowing, magnetic blowing, etc.) [4].

Another component of the variable resistance surge arrester is a resistor formed from silicon carbide (SiC) or metal oxide (90% ZnO Bi2O3 - bismuth trioxide). Nonlinear resistors have a very low value so that they provide a low value of the residual voltage in the overload discharge process. The utilization voltage may vary over time, and for this reason, a continuous operating voltage *Uc*, representing that value of the voltage which can be applied to the surge arrester for a period of time in which it does not intervene.

The construction of a variable resistor surge arrester and the principle electrical scheme are shown in Fig. 3. The active part of the surge arrester is formed by the spark gaps 1 and the variable resistors in series 2. These are composed of several silicon carbide disks, of special construction and of suitable composition [5]. The entire construction is protected by the porcelain case 3, and the metal front covers 4 have the role of sealing the construction and at the same time have the role of connection terminals.



a. *b.*

Figure 3. Construction of variable resistor surge arrester (a) and principle electrical scheme (b) [5]

The shunt resistors, *R1, R2, R3, R4*, are an integral part of the silicon carbide surge arrester with priming spark gaps and have a very high value, ensuring that the surge voltage is distributed evenly on the surge arrester's priming spark gaps.

Defects of the variable resistance surge arrester (Tab.1) occur during operation and therefore it is advisable to carry out periodic checks such as measuring the priming voltage at industrial frequency and measuring the conduction current.

Following these measurements, the following can be seen[4]:

- Moisture in the surge arrester due to tightness indicates values below the permissible limit of the priming voltage at industrial frequency;
- Wrong sizing of the spark gaps, the interruption of the shunting resistors or the unequal distribution of potentials show values above the permissible limit of the priming voltage at industrial frequency;
- Due to the mechanical shocks, the chain of non-linear shunting resistors can be interrupted, thus values under the permissible limit of the conduction currents will be observed at measurements;
- Short circuiting elements in the surge arrester, such as shunt resistors or spark gaps, indicate high values of conduction currents.

*Table1.***The main defects that can occur during operatio n at variable resistance surge arresters [4]**

Variable resistance surge arresters		
No.	**Common faults that may occur during operation**	**Repair of the defect**
1	Increase of the conduction current over the permissible limits	Checking / replacing the surge arrester;
2	Interrupting network or ground connections	The damaged links are restored;
3	Reduction of the priming voltage at the industrial frequency below the permissible limits	Checking / replacing the surge arrester;
4	Moving the distribution rings	Bring the reinforcement to the position provided by the supplier;
5	Case cracks	Replace the defective surge arrester with a suitable one;
6	The defect of the insulating case coating	;The damaged surface is covered with electropaste;
7	Intense case pollution	The case is cleaned and treated with silicone grease;

3.2 Metal oxides surge arrester

The metal oxide surge arrester by the non-linear voltage-current characteristic limits the overvoltage.

The initial concept regarding the role of the surge arresters was the protection against atmospheric discharges. With the development of the thermal capacity, the surge arresters have the nominal withstand voltage higher than the voltage level caused by the grounding of a phase, and the protective voltage belongs to the level of the switching and atmospheric overvoltages.

The installation of the surge arresters in the electrical networks is done between the neutral of the transformer and the ground, between the overhead power line and the ground (in the transformer stations), at the connection of an overhead power line with a transformer station or at the cable connection of an electric motor [6].

This model of surge arrester is made up of a column of resistors with non-linear resistance with a coefficient of nonlinearity much higher in comparison with the resistors of silicon carbide. The coefficient of nonlinearity thus determined the elimination of the spark gaps from the surge arrester structure. The surge discharge is done in a very short time, in matter of nanoseconds.

Fig. 4 shows the section of the sealing device and the protection of the surge arrester [5].

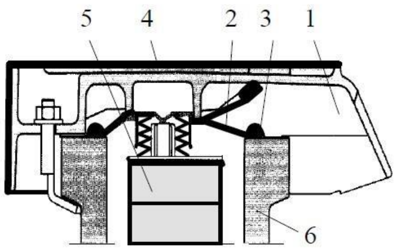


Figure 4. The sealing and protection device of the metal oxide surge arrester [5]

The porcelain case 6 is hermetically sealed by the force exerted by the sealing plate 2 on the flange 4 and the rubber ring gasket 3. Overvoltage protection is achieved by the sealing plate 2. As a result of the surge arrester, the ionized gas accumulated in the case, is released through the ventilation channel 1.

The main advantages of metal oxide surge arresters are the following:

- From a constructive point of view, they have a smaller dimensions and high reliability by giving up the spark gaps and the shunt resistors;
- The voltage-time protection feature of the surge arresters is stable;

- The degree of protection is about 20% lower than in the case of classical construction technology.

Due to these qualities, this type of surge arrester will completely replace the surge arresters with spark gaps.

The main parameters that are taken into account when choosing the metal oxide surge arresters are the following:

- Continuous operating voltage of the surge arrester *Uc*;
- The amplitude and duration of the temporary surges in the network;
- The level of protection provided at the switching and lightning impulse waves;
- Withstand levels of protective equipment;
- The absorption capacity of the discharged energy;
- Pressure limiter class.

An important aspect is the grounding of the surge arresters with conductor or grouding plate having a minimum cross-section of 16 mm^2.

One of the auxiliary equipments that is mounted on the ground connection of the surge arrester is the electric discharge meter. It counts the number of operations. The minimum starting current of the metering is 200 A at a lightning pulse wave of 8/20 µs. One of the important functions of the electric discharge meter is the measurement of the residual leakage current to the ground. [6]

Maintenance of metal oxide surge arresters during operation is very important and the defects or damages presented below in Table 2 can be avoided.

The figure below gives an example of a defect by breaking the porcelain casing, which appeared as a result of aging and overloading of the surge arrester. Thus, the defect is repaired by replacing the surge arrester.

Figure 5. Cracking of the metal oxide surge arrester case [8]

Following the checks of the surge arresters with metallic oxides, values can be ascertained above the permissible limit of the resistive component and the total conduction current.

Table 2. **The main defects that can occur during operation at the metal oxide surge arresters[4]**

Metal oxide surge arresters		
No.	**Common faults that may occur during operation**	**Repair of the defect**
1	Increase of resistive component or total current and its components (peak value and 3rd harmonic)	Replacing the surge arrester;
2	Deterioration of porcelain insulators or external insulation of composite material (breaking or occurring corrosion or electric arc traces, etc.)	Replacing the surge arrester;
3	Insulation blackening at the top of the insulators or at the upper element in the case of multi-element surge arresters	Verification of the assembly of the distribution rings and compliance with the manufacturer's installation instructions
4	Loose connections to the live part or to the ground	Restore of the damaged links
5	Damage due to breakage, cracking or damping of insulators at the base of the surge arrester, with wires or vegetation	Replacing damaged insulators or cleaning deposits from the base of the surge arrester

The most common causes that increase the value of the resistive component and the total conduction current are [4]:

- Electric overload of the surge arrester;
- Moisture due to tightness of the surge arrester;
- Deterioration of the support insulators;
- The effects of pollution on the external insulation of the surge arrester.

According to the operating requirements of the surge arrester, their failure rate is 0.005% / year.

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3. Conclusions

Surge arresters for the protection of electrical networks and of the main consumers connected to these networks are essential elements of an energy system. They must ensure the operational safety of these networks for a relatively long time and also comply with the norms or regulations elaborated by the main beneficiary of these networks.

Initially, these surge arresters were designed to protect electrical networks against overvoltages of atmospheric origin but also against single or multiple reflections of surge waves at points where the electrical network changes its characteristic impedance. At present, these surge arresters also have a sufficiently high thermal capacity so that they can withstand the internal switching surges.

In the absence of the surge arrester, the overvoltage at the network terminals can reach much higher values, even doubling its value in the most unfavorable situations [7].

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