

# Role of Surge Arrestors in Electrical Power Systems

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**ABSTRACT-** This paper presents the study of surge arresters in the transmission & distribution systems. It discussed the surge arresters with their construction where it indicates that surge arresters protect the equipments of power systems from the effects of lightning & switching over voltages. This paper indicates the information about the electrical characteristics & designs of Modern MO surge arresters. Then about the advantages which arresters are combined with other equipment such as post insulators, disconnector or earthing switches.

**Keywords:** Surge arrestors, high voltage, power system, metal-oxide arresters

## I. INTRODUCTION

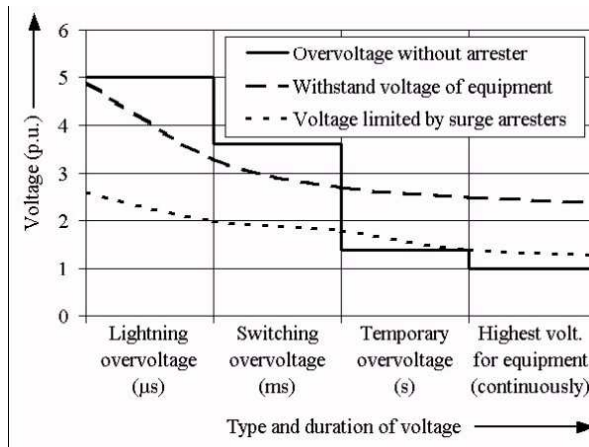
Electric power systems are exposed to overvoltages of different origin which might endanger the equipment such as transformers, instrument transformers or circuit breakers, only to name a few. Fig. 1 summarises the different kinds of overvoltages as a function of their duration in comparison to the highest voltage for equipment. Lightning strokes into the electric power system or its vicinity lead to lightning overvoltages in the range of microseconds, switching action within the system cause switching overvoltages in the range of milliseconds and certain operating conditions due to load flow control cause temporary overvoltages which can last for several seconds.

As can be seen from Figure 1, the equipment is designed to withstand the highest voltage for equipment as well as temporary overvoltages. However, the insulation of the equipment is not capable of withstanding lightning and switching overvoltages. Without countermeasures, occurrences of these overvoltages in the system can lead to breakdown of the equipment insulation and its failure.

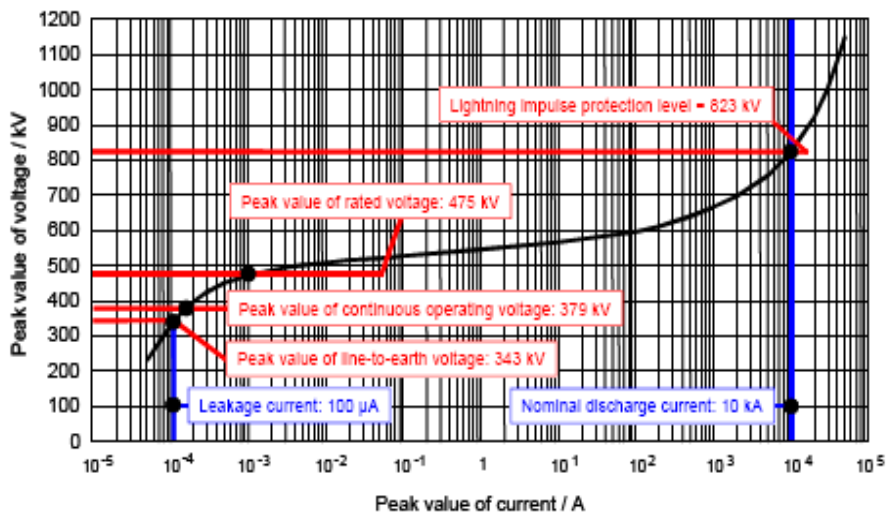
In order to protect electric power system equipment from lightning and switching overvoltages, surge arresters are used within the system as a tool for insulation co-ordination. The purpose of using a surge arrester is to always limit the voltage across the terminals of the equipment to be protected below its insulation withstand voltage.

This is achieved by connecting elements with an extremely non linear voltage current characteristic (varistor) in parallel to the terminals of the equipment. So called metal oxide (MO) surge arresters containing ceramic MO elements mainly made from zinc oxide (ZnO) and bismuth oxide are used nowadays [1]. Due to the high non linearity of the material there is no need for series spark gaps any more as they were used in silicon carbide (SiC) surge arresters.

Per the NEC 2005, a surge arrester is defined as: “A protective device for limiting surge voltages by discharging or bypassing surge current, and it also prevents the flow of follow current while remaining capable of repeating these functions”.



**Figure 1:** Overvoltages in high voltage electric power systems compared to the highest voltage for equipment.



**Figure 2:** V-I Characteristics of a Metal-Oxide Arrester in a solidly earthed neutral 420 KV system

In figure 2, an Example is shown of a typical MO arrester connected between phase and ground in a solidly earthed neutral 420-KV system. On the Ordinate the voltage peak value is depicted linearly, while on the abscissa current peak value are given in a logarithmic scale. In the depiction, the characteristics extends over a current in the range of 50μA to 50kA, that is, over nine decades of magnitude.

The power-frequency voltage, while continuously applied to the arrester, is the highest phase-to-earth voltage of the system. In this case peak value is:-

$$V_m = \sqrt{2} \cdot V_s / \sqrt{3} = \sqrt{2} \cdot 420 \text{ kV} / \sqrt{3} = 343 \text{ kV}$$

At the same time, the so called Leakage current flows through the arrester. This consists of a large capacitive and a considerably smaller, resistive component. The next significant characteristic point is the continuous operating voltage of the arrester. This is Power-frequency voltage which arrester can be operated at, without of any

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restrictions. All properties of the arrester which have been demonstrated in the type tests, are valid, assuming that this arrester is energized at a voltage level equivalent to its continuous operating voltage.

### II. DESIGN OF HIGH VOLTAGE SURGE ARRESTERS

In the past twenty years there were two major changes in the technology of surge arresters. Firstly, the gapped SiC arrester technology was replaced by the gapless metal oxide (MO) arrester technology in the late seventies to early eighties. As a consequence, the protection characteristic was improved, the reliability was dramatically increased to failure rates close to zero and the design became much simpler.

In the late eighties to early nineties, polymeric housings were introduced using fibre reinforced plastic (FRP) tubes with sheds made from silicone rubber or ethylene propylene diene copolymer (EPDM). Since then, porcelain housings have almost been fully replaced by polymer housings in the medium voltage distribution systems for new installations and polymer technology is increasingly used in high voltage power systems even up to 800 kV. The success of polymer housings lies in the versatility of the possible designs and properties which allow a wide range of arresters with respect to mechanical properties, short circuit behaviour and costs. An MO high voltage surge arrester basically consists of a stack of cylindrical MO elements kept together by a supporting structure and a housing.

The general purpose of the housing is to

- protect the MO elements from environmental impacts such as humidity and pollution as well as damages due to transport,
- carry external forces, e.g. by conductor wires, wind or earthquake,
- control the pressure relief behaviour in case of electrically overloading the arrester,
- provide a dielectric strength (withstand voltage) above the protection level of the arrester and to
- keep the stack of MO elements together by maintaining a certain pressure within the stack.

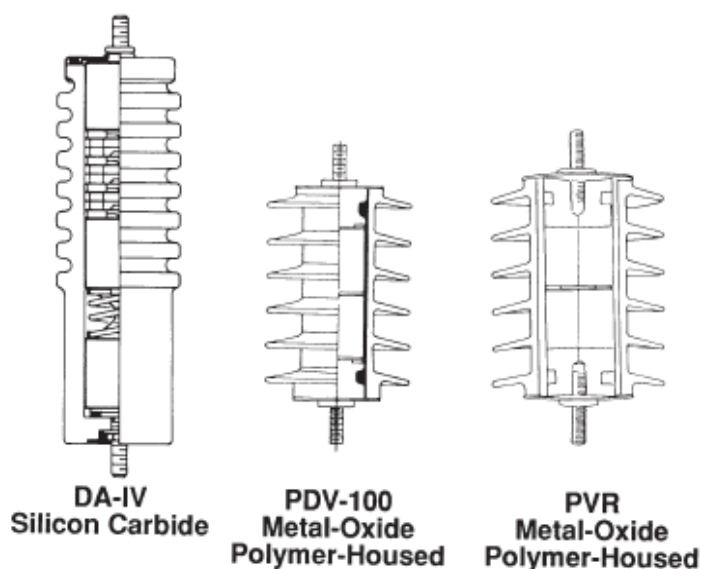


Figure 3 :- Distribution surge arrester

The distribution class surge arrester is the most common type of protective device used on power systems today. Its application typically is limited to systems rated 34.5-kV and lower. The primary function of the distribution surge arrester is to protect the insulation of distribution class oil-filled transformers. Other typical applications include the protection of rotating machines and dry-type transformers. Until recently, the design of the distribution arrester was predicated on the use of a simple multigap connected in series with silicon-carbide valve elements. Under continuous energization, system phase-ground voltage was maintained across the series gap element. The size of the multi-gap was maintained approximately proportional to the system voltage to which the arrester was attached. The gap element sparked over to limit system overvoltages and provided the reseal function after the arrester conducted a half cycle of follow current. The magnitude of the system follow current was limited by the silicon-carbide valve elements connected in series with the multi-gap.

The protection provided to insulation adjacent to the gapped silicon-carbide distribution arrester is a function of both the sparkover characteristic of the arrester gap structure and the discharge voltage characteristic of the silicon-carbide valve elements. The intent of this paper is to examine the improved protection provided for distribution system insulation by polymer-housed metal-oxide surge arresters.

Three types of polymer-housed metal-oxide arresters are available for application on distribution systems. They may be used on overhead lines to improve existing protective margins, or on riser-poles adjacent to underground distribution circuits that cannot be adequately protected by conventional silicon-carbide arresters. One type is a gapless heavy-duty distribution class surge arrester, the DynaVar Type PDV-100, constructed with 40-mm diameter metal-oxide discs. The PDV-100 has lower protective characteristics than the DA-IV heavy-duty gapped silicon-carbide distribution arresters. Because of the excellent energy-absorbing capability of the metal-oxide material, the PDV-100 arrester units are smaller than equivalent sizes of the DA-IV. The normal-duty polymer-housed MOV arrester, PDV-65, is constructed with 32-mm diameter metal-oxide discs. The polymer-housed metal-oxide riser-pole arrester, DynaVar Type PVR, in the study is assembled with larger-diameter 48-mm metal-oxide discs. It has the protective characteristics and durability of an intermediate class arrester. The PVR's protective characteristics are better than those of both conventional silicon-carbide and metal-oxide distribution arresters.



**Figure 4:-** Modern distribution arrester with directly molded silicon rubber housing (left: complete arrester, right: internal design)



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**Figure 5:-** Polymer housed arrester( $V_m=550kV$ ) during seismic testing on a shaking table.

### III. ADVANTAGES OF METAL-OXIDE ARRESTERS OVER CONVENTIONAL SILICON-CARBIDE DISTRIBUTION CLASS ARRESTERS

#### A. Improved Temporary-Overvoltage Capability

When subjected to temporary power-frequency overvoltages, the high-exponent metal-oxide arrester conducts significantly less current than a comparably rated silicon-carbide distribution class arrester. If the silicon-carbide arrester is subjected to an overvoltage condition and simultaneously is forced to spark over, the integrity of the arrester is dependent on the ability of the multi-gap design to successfully interrupt the high power follow currents associated with the overvoltage condition. If the arrester is not able to reseal against the overvoltage condition, failure occurs within a few cycles.

#### B. Improved Surge-Duty Capability

The high-exponent characteristics of the MOSA design allow the arrester to conduct less than one ampere of follow current after an impulse discharge when energized at equivalent rated voltage. In contrast, the silicon-carbide arrester conducts over 100 amperes of follow current when forced to spark over with rated voltage applied. Therefore, the MOV arrester is not subject to restriking failure that the silicon-carbide arrester may experience at normal operating voltages.

#### C. Improved Contamination Performance

This advantage is most prevalent on higher ratings where the silicon-carbide distribution class arrester is most vulnerable to the influences of contamination, which can cause substantial reduction in sparkover. The gapless MOV arrester is immune to internal problems from external contamination.

#### D. Resistance to Leaking and Safe Failure Mode

The major cause of arrester failure is moisture ingress. The Ohio Brass polymer-housed arrester makes it nearly impossible for moisture to enter the unit so failures due to leaking are eliminated.

#### E. Improved Protective Characteristics

The remainder of this paper is concerned with the protective characteristics of polymer-housed metal-oxide arresters compared with equivalently sized silicon-carbide arresters. Specific overhead and underground applications are examined, comparing the standard arrester characteristics and examining the advantages of metal-oxide over silicon-carbide designs.

### IV. APPLICATION EXAMPLES OF ARRESTER IN POWER SYSTEM

The most common application of surge arrester is the protection of transformers. But there are many other fields where these arresters can protect different kind of equipments from the effect of over voltages and thus it may help to improve power supply quality and may reduce maintenance costs in the networks.

Some more selected application examples are given below:

**A. Cable Protection:-** If cables are directly connected to overload lines, it may exposed to lightning overvoltages. This case particularly in Distribution systems. Distribution overhead lines are normally not protected by shield wires, so direct lightning strikes in to the phase conductors are quite common.



**Figure 6 :** 161-kV-tower with 6 cable terminations, protected by suspended polymer housed surge arresters (IEC, Israel)

*B. Protection of Traction System:-* Damages of Electric locomotives frequently occur if no over voltage protection is provided. Protection of surge arrester on Electric locomotives is used for a long time. When the risk of a breaking porcelain housing in case of an arrester overhead.



**Figure 7:** Polymer housed arrester for protection of electric locomotives (High speed train "ICE", Deutsche Bahn, 15 kV/16.7 Hz)

*C. Protection of Thyristors in HVDC application:-* HVDC transmission lines and back-to-back stations are gaining importance world wide to exchange electric energy over long distances by overhead lines. The main components of the converters are thyristors, which have achieved a high degree of technical performance and reliability, but are expensive devices. To protect the thyristors from over voltages, an HVDC converter station where surge arresters are important the valve protection arresters.

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**Figure 8:** Suspended valve tower with polymer housed valve protection arresters (LADWP, California/USA,  $\pm 500$  kV dc)



**Figure 9:- Various Application-** Toshiba 400kV surge arresters can be applied to extra heavy pollution area.

### V. CONCLUSION

All electrical equipment in an electrical system needs to be protected from voltage surges. The rating of the arrester, the class of arrester and the location of the arrester all play a part in the surge protection. Modern metal oxide arresters provide markedly superior protective characteristics and energy absorption capability, compared to previous generation arresters. Surge arresters protect equipment of transmission and distribution systems, worth several magnitudes more than the arresters themselves, from the effects of lightning and switching overvoltages. If properly designed and configured, they are extremely reliable devices, offering decades of service without causing any problems. The benefit can be increased if arresters are combined with other devices, solutions which have been supported by the users' increasing confidence in arrester performance and the possibilities offered by modern arrester technology. The introduction of gapless MO arresters has meaningfully improved the protection characteristics, reliability and the ease of application in general. The use of polymer housings, beginning in the late eighties, has contributed to safety, thus opening new fields of application, for instance in areas of public access, or where there are extreme requirements on mechanical strength. Countless applications exist in which modern arresters help to reduce investment, repair and maintenance costs in systems of electric power supply.

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