

ASCENDANCY OF SURGE ARRESTOR ON POWER SYSTEM

Gawade Sudarshan Dilip

Department-of-Electrical-and-Electronics-Engineering

sudarshangawade12345@gmail.com

Abstract— This paper presents an overview of how the lightning strikes and their acts on power distribution systems can be modeled. Each piece of electrical equipment in an electrical system needs to be protected from voltage surges. To prevent damage to electrical equipment, surge protection considerations are paramount to a well-designed electrical system. Modern metal oxide arresters provide exceptional overvoltage protection of equipment connected to the power system. The development of the Metal Oxide Varistor (MOV), which is the heart of the modern surge arrester, did not happen overnight. There were many characters and many breakthroughs that made it possible. The MOV arrester was also the beginning of the end for the two giants in surge protection: The priority you give to surge protection depends on your willingness to take risks! Perhaps you think "it'll never happen to

me". Then you won't have lost anything, but will have gained only very little. However, the subject of overvoltage is then a daily worry for you. But if you wish to be on the safe side, you should include surge protection in your corporate strategy.

Index terms- Lighting , mov(metal oxide varistor), overvoltage , residual voltage .

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 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 . 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. Surge protection is an important aspect of electromagnetic compatibility and is required by law. There have been many technical improvements in the field of surge protection over the years. The quality and quantity of surge protection systems have increased. This is also revealed by the statistics of the umbrella organisation for the German insurance industry: the annual total damages for the insurance of electronic equipment has fallen slightly despite the fact that more electronic equipment is almost certainly being used and electrical and electronic systems are becoming increasingly complex with the degree of integration ever higher. Nevertheless, each year in Germany about 450,000 claims are registered across the whole electronic spectrum. The total loss in Germany for 2005 amounted to 230 mio. €. It is estimated that about one-third of these are due to overvoltages.

II. ELECTROMAGNETIC COMPATIBILITY

EMC – electromagnetic compatibility – means the trouble-free interaction between electrical and electronic systems and devices without mutual interference. In this respect, any electrical item can act both as transmitter (source of interference) and receiver (potentially susceptible device) simultaneously.

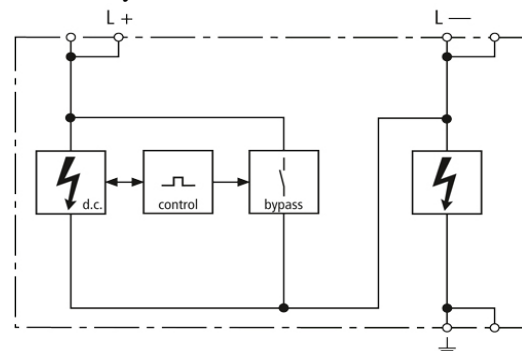


Fig.(a)-emc law & directives

There are a multitude of standards and statutory requirements

aimed at controlling mutual interference-free operation. As the

Single European Market was set up in 1989, an EEC directive

covering electromagnetic compatibility was passed and subsequently ratified by the governments of the member states.

In Germany this is covered by the Electromagnetic Compatibility

Act, passed on 9 November 1992. There was a period of transition

in which the 1992 Act, the Radio Interference Act of 1979 and the High-Frequency Equipment Act of 1949 were all valid.

However, since 1 January 1996 only the 1992 Act has been valid. The second amendment to the Act has been in force since

25 September 1998. Electromagnetic influences can be caused

by natural processes, e.g. a lightning strike, and also technical

processes, e.g. high-speed changes in the status of currents and voltages.

We distinguish between periodic interference (system hum, RF irradiation), transient interference (brief, often high-energy pulses) and noise (broad distribution of interference energy across the frequency range). However, the arrangement of various electrical systems within a complex plant or in a room and the many lines for power supplies, inputs and outputs to controls and bus systems give rise to diverse potential influences. Surges can be introduced by lightning, switching operations, etc. via the various coupling paths. This can lead to the following effects:

- reduced functionality
- malfunctions
- failure of functions
- damage

These last two functional interferences result in stoppages for entire production facilities and cause high breakdown costs. The following points must be taken into account in order to achieve a system or plant that operates according to EMC guidelines:

- cable shielding
- panel construction
- sensors and actuators
- transmitters and receivers
- frequency converters.
- lightning protection
- earthing
- routing of cables
- bus and field devices

III. WHAT ARE SURGES?

Surges are extremely high voltages that damage or even completely destroy insulation and hence impair or completely disrupt the function of electrical and electronic components of all kinds. Every electrical component is provided with

insulation to isolate the electrical voltage from earth or other voltage-carrying parts. The insulation strength is dependent on the rated voltage and the type of electrical component, as stipulated by the IEC/VDE regulations. It is tested by applying the prescribed voltages for a defined period of time. If the test voltage is exceeded in operation, the safety effect of the insulation is no longer guaranteed. The component can be damaged or completely ruined. Surges are the voltage pulses that are higher than the test voltage and therefore could have a detrimental effect on the respective electrical component or system. This means that components with a high rated voltage may be capable of withstanding a surge voltage. But components with a lower rated voltage would be very much at risk from the same surge. An overvoltage allowable in an electric motor can spell disaster for an electronic circuit! Permanently higher voltages also occur with the 50/60 Hz mains frequency. These voltages can be coupled or may occur as a result of faulty switching operations. The resulting continuous interference voltages are then another case for overvoltage protection. Individual surge pulses, which have a high frequency because of their physical formation, have a current rise that is about ten thousand times steeper compared with 50 Hz voltage. If the current rise time in the 50/60 Hz range is 5 ms, then for an overvoltage it is around 1 μ s. These surges are designated as "transient" voltages.

IV. HOW DO WE ACHIEVE SURGE PROTECTION?

We have to consider surge protection from two points of view:

- General protective measures during the planning and construction of buildings and electrical installations.
- Special protective measures realised by the installation of additional surge protection component.

A. Planning buildings and electrical installations-

Much can be done to prevent damage due to overvoltages through the careful planning and construction of buildings and electrical/electronic systems. Although these measures provide only basic protection, they can amount to cost-savings in an effective, complete protection concept. It is vital to include an adequately dimensioned earthing system right from the very first construction phase. Only this guarantees full equipotential bonding in the event of interference. When planning the electrical installation, care must be taken to ensure that electrical systems with dissimilar rated voltages are kept separate. Corresponding protection zones can then be set up and this leads to cost-savings for the surge protection. Furthermore, the physical separation or shielding of lines that can influence each other is a good way to achieve maximum electrical isolation. Another good option is to split up the individual phases of three-phase systems corresponding to their functions, e.g. one phase only for the supply to instrumentation and control systems. Of course, all these primary measures do not achieve complete protection. To do this, you must install additional protective components.

V. COMPONENTS FOR SURGE PROTECTION :

There is no ideal component that can fulfil all the technical requirements of surge protection equally effectively. Instead, we use a variety of components whose different physical methods of operation complement each other; these possess distinct protective effects. Super-fast reaction time, high current-carrying capacity, low residual voltage and long service life cannot be found in one single component. In practice we use three principal components:

1. sparkover gaps
2. varistors
3. suppression diodes

Therefore, to optimise the surge protection, carefully matched groups of these components are often combined in one protective module.

A. Sparkover gaps :



Fig (b)-

Sparkover gaps.

The name says it all. High voltages are discharged to earth via a spark gap (e.g. gas discharge tube) that has been fired. The discharge capacity of sparkover gaps is very high – up to 100 kA depending on type.

Gas sparkover gaps are incorporated in insulating glass or ceramic (aluminium oxide) housings. The electrodes of the sparkover gap are made from a special alloy and placed in housings which are vacuum sealed and filled with a noble gas such as argon or neon. They are aligned with respect to shape and clearance distance, so that the applied voltage produces a distribution of

field strengths. This results in a fairly precise voltage value for the complete ignition of the spark gap. The housings are vacuumtight and filled with an inert gas such as argon or neon. The spark gap has a bipolar function. The ignition voltage value,

however, is dependent on the steepness of the applied surge voltage. The ignition characteristic curve for gas-filled spark gaps reveals that the ignition voltages increase for those surge voltages which climb more steeply. The consequence is that, for very steep surge voltages, the ignition voltage (that is, the protection level) is relatively high and can be well in excess of the rated voltage for the spark gap (approx. 600–800 V). The problematic quenching behaviour of the fired sparkover gap can be a disadvantage. The arc has a very low voltage and is only extinguished when the value drops below this. Therefore,

when designing the geometry of a sparkover gap, care is taken to ensure that – through long distances and also through cooling – the voltage of

the arc remains as high as possible and so

is quenched relatively quickly. Nevertheless, a longer follow current can ensue. This can draw its energy, in addition, from the incoming supply of the circuit to be protected. One effective solution is to wire a sparkover gap and a fast-acting fusible link

in series.

B. Varistors :



Fig(c)- Varistor

C. Suppression diodes :



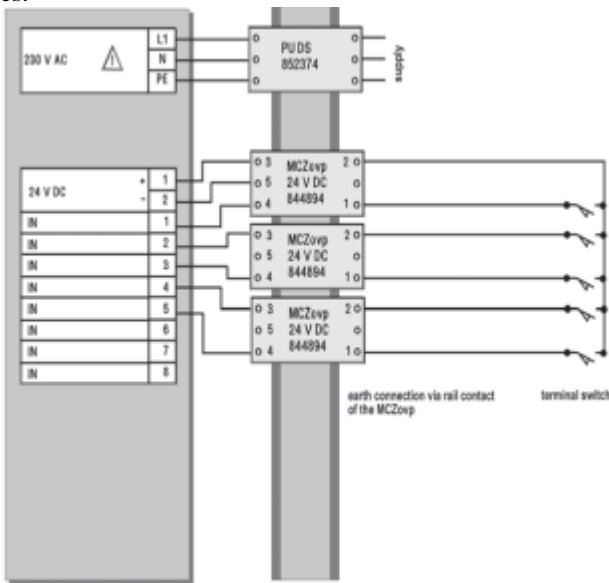
Fig (d)- Suppression diodes

The varistors used with surge protection (MOV-Metal Oxide Varistors) have resistance which depends on the voltage. This is implemented with metal-oxide (zinc-oxide) discs. There is a low ohm resistance in the range above the rated voltage. The surge voltage is limited since a current flows through the varistor. The varistor works bi-directionally. Depending on the type, varistors have either a middle or high discharging capacity. It is in the range from 40 kA to 80 kA. The response time is less than 25 ns. However there are also disadvantages when using varistors. Two factors that must be taken into account are the relatively high capacitance and the aging characteristics. Leakage currents occur over time, depending on the frequency of the triggering, because individual resistance elements break down. This can cause temperature

rise or even destroy them completely. The high capacitance of varistors causes problems in circuits with high frequencies. Attenuation of the signals must be reckoned with for frequencies above about 100 kHz. Therefore, varistors are not recommended for use in data transmission systems.

VI. APPLICATIONS IN INSTRUMENTATION AND CONTROL ENGINEERING BINARY SIGNALS.

Limit switches are used for monitoring the positions of moving machine parts in plants with marsh operating conditions, e.g. drives whose direction of rotation is reversed after the limit switch has been actuated. Surge protection in the form of a modular terminal, **MCZ OVP SL 24 Vdc 0.5 A**, can protect two switching signals at the input of a controller. The discharge to earth of the coupled energy is achieved via gas discharge tube, varistor and high-speed suppression diode in each earth line. The **PU DS 852374** is installed in the supply voltage so that the controller is protected from the mains side. The PU II 230V is installed in the power supply so the controller is protected from the mains side. However, the PU III series must always be installed together with the PU II series.

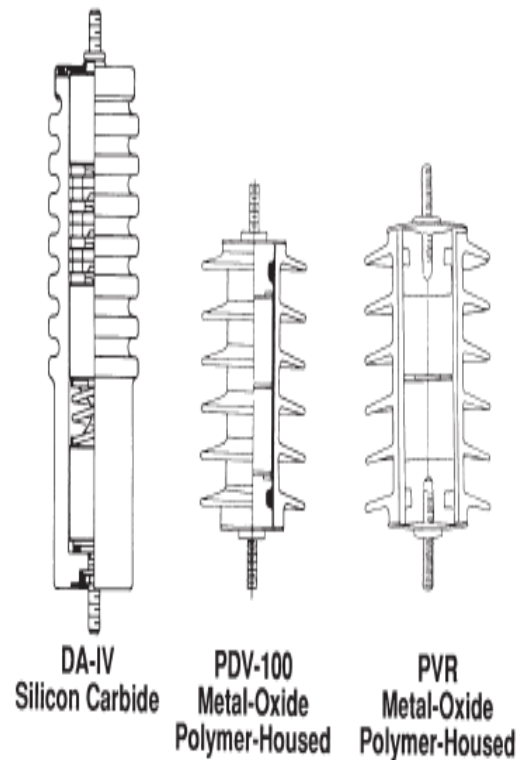


Fig(e)-monitoring control system

VII. 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(f):- Distribution surge arrester

VIII. 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 siliconcarbide designs.

IX. 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.

B. Protection of Traction System:- Damages of Electric locomotives frequently occur if no over voltage protection is provided.

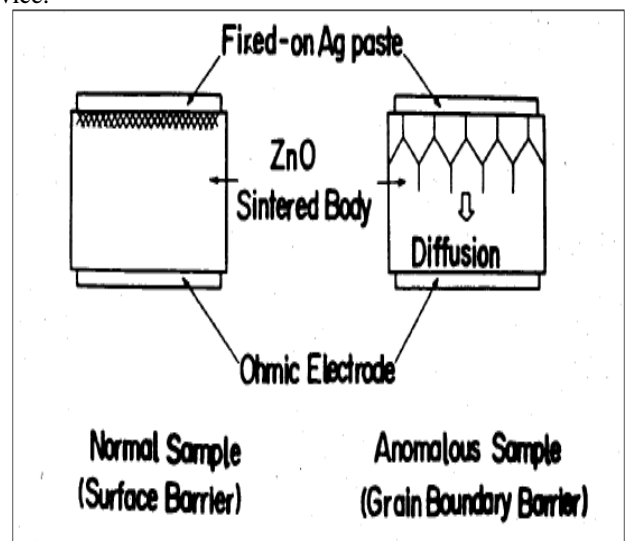
Protection of surge arrester on Electric locomotives is used for a long time. When the risk of a breaking porcelain housing in case of an arrester overhead.

X. HISTORY OF ARRESTERS ON POWER SYSTEMS 1965 – PRESENT:

Soon after that in Japan, the Matsushita Electric Company, which later became known as Panasonic, introduced their first transistor radio to the industry. By the end of 1965, they had become a significant competitor in the semiconductor industry and had their own R&D group.

Also by 1965 it had become obvious to those involved in surge protection of the semiconductor components that Silicon Carbide Varistors were no longer capable of protecting the sensitive low voltage Shockley type junctions. The SiC technology that had successfully been used to protect vacuum tubes just could not take care of this emerging technology. In November of that year, one of Matsushita’s young scientists named Michio Matsuoka, was assigned the task of improving surge protection of semiconductors. Thus the start of the development of a new varistor.

Research for a new varistor proceeded along a path that they were familiar with, which was to create a nonlinear junction using a ceramic and non-ohmic electrode. It was anticipated that the interface between the ceramic and electrode would result in a Shockley junction that was non conductive at lower voltages, but when a voltage threshold was met, it would become conductive. Based on numerous experiments between 1965 and 1967, the material choice was Zinc Oxide for the ceramic and Silver Oxide along with a glass frit for the electrodes. By March 1967, they had achieved the goal of producing a Shockley barrier type varistor, but the threshold voltage was much to low to be useful. They knew they had to increase the turn-on voltage level of the device to use it as a surge protector. They then proceeded to run a series of experiments to discover a means of producing a higher voltage device.



Fig(g)- Contrast of Surface and Grain Boundaries Barrier

XI. THE SiC TO MOV TECHNOLOGY TRANSITION

The transition from gapped silicon carbide arresters to MOV type gapless arresters was rapid. All the US manufacturers of surge arrester could see that the future of the business lay in investment in zinc oxide technology and production of this new semi-conductor. The transition was positive for some and not so for others. McGraw Edison chose the development path, and in the late 1970's they developed their own zinc oxide formula. They were the first in the US to produce a MOV type arrester for the distribution systems. The Kearney Co. attempted to produce their own version of the MOV arrester, but by 1990, they had failed and were out of the surge arrester business. The Ohio Brass company licensed the technology from Toshiba in the early 1980's and their strong station arrester market presence carried them through to the next paradigm shift. The Joslyn manufacturing company held strong and with some technology licensing, they made the transition from SiC to MOV.



Fig(h)- Silicon Carbide Varistor and Zinc Oxide Varistor based Arrester Comparison

XII. 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 meaningful 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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