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- White Paper on the selection and classification of MV Surge Arresters -

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Abstract

During day to day operations, a company's sales department is required to quote customers on surge arrester-based protection, to be incorporated into Medium Voltage switchgear and(or) other system solutions at distribution level; protecting the clients' "end-user reticulation infrastructure." This paper serves to define the classifications and applications of surge arresters, as well as to define an adequate "standard offering specification" to quote to prospective clients. It is critical that such standard offerings be suitable across a broad spectrum of varying solution scheme characteristics. This ensures system protection in the event that no specifications are provided by the client/their affiliated engineer(s), which is currently a concern of many sales department in terms of offering the most technically correct solution.

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Introduction to the Surge Arrester

What is a Surge Arrester?

A *Surge Arrester* is defined as an electrical protective device, that is used to protect various electrical equipment from over-voltage transients caused by either:

1. External system events (e.g. Lightning);
2. Internal system events (e.g. Switching).

A surge arrester can also be defined as a **SVD** (Surge Protection Device) or **TVSS** (Transient Voltage Surge Suppressor).

Further, it should be noted that technically, a Surge Arrester/SVD/TVSS, refers to a piece of protection equipment to be implemented in equipment in power transmission and distribution systems. For low voltage applications, protecting the end-user's electrical system, the device is referred to as a Secondary Surge Protector.

Why are Surge Arresters Required?

When it comes to lightning, geographical areas are classified with an isokeraunic level:

An isokeraunic map (which plots the keraunic level of different areas), in laymen terms defines the probability of lightning strikes occurring in a given area (days per year).

Lightning strikes cause voltage surges in a system which can damage equipment, or catastrophically, cause loss of life. Surge arresters essentially provide a path for this over-voltage to be dissipated from an electrical system, without causing calamitous failure or fatality to the end-user(s) of the system(s).

Generally, you get two types of lighting surges:

1. Direct Strike;
2. Indirect Strike.

A direct Strike is when a "lightning bolt" strikes the affected equipment directly, usually via the supply conductors feeding a substation.

An indirect Strike occurs when electrostatically induced charges are presented on distribution conductors due to charge clouds. A charge cloud, in laymen terms can be seen as an "inrush of electrons" on a circuits path of current flow.

Surge arresters, depending on their position within a distribution system, will obviously assist in the dissipation of the additional energy "seen" when a lightning strike occurs. But the "biggest impact" of a lightning strike is usually mitigated by implementing the following into a substation's design:

1. Earthing Screens (e.g. connection to an earth mat/building lightning conductors);
2. Overhead Ground Wires (e.g. OPGW at HV level).

Surge arresters act as the last point of mitigation for lightning strikes – it is crucial that a surge arrester is selected; designed to handle the vindication of lightning strikes.

However, lightning is not the only source of voltage transients. Transient voltages are more often experienced by a system when:

1. Capacitors are switched;
2. General systems are switched;

3. Insulation Failure (e.g. a dead short/equipment failure);
4. Arcing ground;
5. Resonance (when impedance = resistance and the power factor is at unity);
6. Discharges by adjacent surge arresters connected to the same distribution infrastructure as the system under consideration.

Generally, a surge, when unprotected, can cause mechanical failure on equipment such as cracked bushings and so on, leading to a catastrophic failure.

Types of Surge Arrester

There are four types of surge arrester classifications that exist in the electrical industry:

1. Station Class Surge Arrester;
2. Intermediate Class Surge Arrester;
3. Distribution Class Surge Arrester;
4. Secondary Class Surge Arrester.

The above list, in order, is ranked in terms of protection, capability and cost. I.e. a Station Class Surge Arrester is the most effective in delivering protection, but is costly. A Secondary Class Surge Arrester, offers minimal protection within a more-feasible economic bracket; pending the application of protection required.

There seems to be significant confusion on the actual difference between the above listed surge arresters. Each surge arrester can, briefly, be defined as follows:

Station Class	These units are typically used in power/sub stations at HV level, other HV applications are also covered. This unit is designed to handle lightning and “other” types of electrical surges; where the system has more current flowing within it than the rating for which the system was designed. Station class arresters typically have greater energy absorption capabilities, with low discharge voltages along with high pressure relief capability. When un-interrupted service is desired on critical supplies, station class arresters should be used. ***DESIGNED TO PROTECT EQUIPMENT >= 20mVA. BUT CAN ALSO BE APPLIED TO 5 >= mVA >= 20 SYSTEMS, DEPENDING ON REDUNDANCY REQUIREMENTS.***
Intermediate Class	These units are specifically designed to be used in MV applications. They protect against lightning as well as over-voltage conditions. They are typically utilized in MV substations, transformers and other substation related equipment. ***DESIGNED TO PROTECT EQUIPMENT 1 <= Mva <= 20.***
Distribution Class	These arresters are utilized in MV applications, but for a specific application. They are commonly used in conjunction with dry and oil type transformers at distribution level usually when exposed lines are used. One can see this application characteristic solely by their design, where an additional 90° bushing is incorporated onto the arrester to allow for easy pole mounting.
Secondary Class	These are surge arresters that are most commonly found in LV installations. They provide the least amount of protection. These arrestors, when activated, cause high over-voltages to ground – they do not however short all transients to ground. Typically, these surge arresters do not provide critical protection to very sensitive electrical equipment.

1: Different Surge Arrester Classes

Further to the above definitions, surge arresters are also split into class rankings. I.e. you can get a Station Class Surge Arrester rated at Class 1. The additional class rankings are defined as follows:

Class 1	Class 1 is to be specified when the probability of direct lightning strikes is very high. These surge arresters are critical when the earth mat of the substation is shared with an additional lightning protection system (LPS) on-site such as lightning conductors. These surge arresters conform to IEC61643-11 to handle an impulse injection current for 10/350 µs. This ensures full simulation of a lightning strike. Laymen's version; these surge arresters are very powerful.
Class 2	Class 2 is to be specified at the origin of the installation (e.g. main substation), **HOWEVER** it is not recommended to utilize class 2 surge arresters on systems that share an earth mat with a LPS. This class, too conforms with IEC61643-11, but is subjected to an impulse injection current for 8/20 µs.
Class 3	When very sensitive equipment is used, an additional set of surge arresters will be required. These are typically referred to as 'low energy devices.' These are usually class 2 or class 3. These also conform to the IEC61643-11 standard, and are subjected to a combination waveform (1,2/50 µs – 8/20 µs) impulse injection current.

2: Different Additional Surge Arrester Class Rankings

Design Characteristics of a Surge Arrester

As a general reminder, remember that the maximum continuous operating voltage (MCOV) refers to your line-neutral voltage, and not the system voltage.

Due the fact that our surge arresters will typically be mounted in our switchgear panels, we need to consider the possibility of arrester failure and/or pressure relief:

A metal-oxide varistor (MOV) typically used in most surge arresters, can crack or puncture (i.e. damage the housing of the surge arrester), when the rating of the arrester is exceeded. The internal resistance of the arrester is directly impacted when this occurs.

This will limit the arrester's ability to survive future system transients, but will not negate the basic insulation protection rating of the system. Design characteristics however, of the linking components utilized in the surge arrester assembly (e.g. earth busbar) should be considered, to prevent "dangling wires" etc.

A pressure relief device is a crucial feature that HAS TO BE PRESENT on the surge arresters we use. Why? In the event of a complete arrester failure, an arcing ground condition will occur. This in turn leads to a pressure build up in the arrester housing.

A pressure relief device, will safely dissipate this pressure build-up, provided that the fault current is within the pressure relief fault rating of the surge arrester. Thus, if our panels are rated at 25kA, it is best to use this as a minimum value on the surge arrester to not only ensure uniformity, but equality on our offered fault level rating of the switchgear assembly.

Laymen terms: We cannot offer a 25kA fault level rated system, however our weakest point is a 10kA surge arrester. REMEMBER, it is not only lightning strikes but other transients too. If our system can handle transient faults up to 25kA, clearly offered during the tendering process, it is no good that we put in a surge arrester that can only hand transient faults up to 10kA.

You cannot rely on the probability of a transient fault >= 10kA never occurring. What if it does? Our product and reputation will be disregarded for future business opportunities. Assumptions rarely turn into facts – in engineering, do not make assumptions unless you have all of the facts regarding the "new" system being designed/offered. If you do make assumptions (not lower than 25kA though) clearly define, in detail, all assumptions for any legal disputes that may occur later on.

Do not be negative, but ensure that in the event of a catastrophic failure, we are indemnified. You never anticipate a fault beyond our control, or more importantly, outside our scope of works.

Once an arrester has safely dissipated the pressure build up, IT WILL NO LONGER function normally. I.e. it cannot withstand another fault. It then needs to be replaced immediately. This in essence means that you need to have a basic off-the-shelf counter/warning device that indicates whether the surge arrester is healthy or not. This, for example, can be achieved using a standard LED pilot light on the front of our panel.

The above being said, a contingency should be factored into the system to allow for future expansion/changes. Based on the typical fault levels experienced in urban South Africa (between 18.5 – 21.5 kA), a 25kA arrester can provide between 26% and 14% contingency, which is more than sufficient.

The placement of the surge arrester is also critical. In our application, placing the surge arresters nearest to the terminals of the equipment/system requiring protection is ideal. The surge arresters should also follow the shortest path to ground to dissipate faults.

In most switchgear applications, sufficient application is provided at the up-stream transformer substation (i.e. the substation that is feeding the substation provided by us). When the transformer is adequately protected, the magnitude of a fault experienced by the substation offered by us, is usually not considered as a concern.

Considering the status of our current HV/MV reticulation grid within South Africa, negate this school of thought completely for the next 2-8 years, as this is another assumption which could bring disrepute to our company's designs/solutions.

EXTREMELY IMPORTANT:

NEVER offer a surge arrester solution that is not located within our equipment.

When surge arresters are located away from the primary point of the system being protected (i.e. our switchgear), the transient voltage wave reflects with a positive nature at the primary point of the system (i.e. our switchgear). This basically means that the magnitude of the transient voltages on the system WILL ALWAYS be higher than the discharge voltage rating of the surge arrester.

Why you ask? If an arrester is located away from the equipment being protected, the cable linking the surge arrester to the equipment being protected, cannot handle the impedance ("capacity") of the fault being fed to the arrester for dissipation. If an open circuit condition occurs, the voltage fed to the arrester, will be approximately double that of the surge arresters rating, negating the actual protective function of the arrester.

The closer the arrester is to protected system, the better the reflected surge in terms of the arresters discharge capability, implying better protection on the system being protected.

However, in the event we provide additional equipment with low BIL apparatus such as dry type transformers, it is crucial to apply another/set of surge arrester(s) at the input termination to this equipment.

Surge Arrester Housings

Surge arrester are typically housed as follows:

1. Porcelain Housings;
2. Silicone-Rubber Housings;
3. Metal Enclosure Housings.

In general, MV applications, stay away from oil-cooled surge arresters, these are predominantly for specific applications in HV/MV, and are usually used outdoors.

Keeping this consideration simple:

We should veer away from porcelain insulated arresters. When a surge arrester fails or "relieves pressure" for any reason, a porcelain arrester can typically only handle one "venting." Thereafter, should another fault be experienced, a breaker's protection system will kick in, resulting in the breaker trying to reclose AT LEAST ONCE, into the fault caused by the surge arrester. Worst case scenario, this "extended exposure" on the "used arrester" could cause the arrester to explode. A porcelain arrester could also collapse, mechanically, due to thermal conditions.

If a porcelain-based arrester is utilized within busbar chambers or as busbar supports, this could lead to catastrophic failure of equipment within the substation.

Silicone Rubber housed surge arresters are the "most-up-to-date" technology available. Firstly, their mechanical design allows for auto-reclose of a breaker onto the system to occur several times before any catastrophic failure occurs.

Further, for a porcelain arrester to successfully "relieve pressure" after a fault, the internal arc caused by the fault, needs to dissipate outside of the arrester housing. On porcelain arresters, multiple pressure relief "directional ports" are utilized to achieve this. However, after many years of practical application, it has been shown that there is a significant time delay in the dissipation of this internal arc fault.

In short, the silicon rubber-based housings, instantaneously relieve the pressure caused by the fault – significantly mitigating the possibility of a catastrophic failure from occurring. This is a specific mechanical design feature, which we do not need to go into great detail on. A chemical and mechanical engineer would have to explain this in depth, enough for us to have a true understanding of the operating philosophy of this design. Common sense however prevails, the easiest path of resistance (electrical and/or mechanical) in design, for pressure to be relieved from the arrester housing., will occur.

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Practical Application Example

Let us look at a practical exmpale; Discovery Sandton Substation. The site entails two substations:

1. Primary Distribution;
2. Secondary Distribution, dedicated to a Data Centre.

Thus, station class surge arresters should be applied to both substations. Class 1 at the primary point, and Class 3 at the secondary point (defined under classes).

How do we specify Surge Arresters?

Everyone will always have their own opination, but in my professional opinion, these are the key characteristics to consider when supplying and(or) considering the implementation of a surge arrester for a specific application:

Type	Station/Intermediate/Distribution/Secondary
Discharge Class	1/2/3
System Frequency:	e.g. 50Hz
Operating Voltage	e.g. 11kV
MCOV	e.g. 10.2kV
Pressure Relief Class	e.g. 63kA
Configuration	Single/Three-Phase
Max Fault Current (Discharge)	25kA – 30kA (Supplier Dependent)
Protection Philosophy	Varistor Based (Our application, always used Varistor Based Tech.)
Additional Features	Remote Monitoring on Arrester Healthy and Trip Counter

3: Key Technical parameters to consider when working with Surge Arresters

Surge Arrester Specification

In general, it is common engineering practice, that <u>when very few details of the OVERALL system have been specified</u>, to use Station Class Surge Arresters. They are the most suitably rated to handle worst case scenario transients.

Based on the fact that day-to-day switchgear suppliers, predominantly supply 11kV MV systems, I suggest the following two surge arresters be supplied as per the practical application guidelines detailed in this white paper:

Primary Substation(s)

Type	Station Class
Discharge Class	1
System Frequency:	50Hz
Operating Voltage	12kV
MCOV	10.2 – 10.8kV
Pressure Relief Class	63 – 65 kA
Configuration	Three-Phase (best, alternatively single-phase design required) – THREE-WIRE
Max Fault Current (Discharge)	25 – 30 kA
Protection Philosophy	Varistor
Additional Features	Trip Counter (incl. counter) Status indicator (incl. indicator)

4: Proposed Standard Performance Specification for Primary Substations

Secondary Substation(s)

Type	Station Class
Discharge Class	3
System Frequency:	50Hz
Operating Voltage	12kV
MCOV	10.2 – 10.8kV
Pressure Relief Class	63 – 65 kA
Configuration	Three-Phase (best, alternatively single-phase design required) – THREE-WIRE
Max Fault Current (Discharge)	25 – 30 kA
Protection Philosophy	Varistor
Additional Features	Trip Counter (incl. counter) Status indicator (incl. indicator)

5: Proposed Standard Performance Specification for Secondary Substations

Conclusion

As discussed in this paper, it would be recommended that two standard specifications be put into place for day-to-day applications as defined in 4: Proposed Standard Performance Specification for Primary Substations and 5: Proposed Standard Performance Specification for Secondary Substations respectively.

I.e. on one sub (so where only one substation is in commission) you use the primary specification set, and on a sub, feeding another sub for critical equipment; use the secondary specification.

However, while this information can be used as a good general rule of thumb, it is always important that in the event that there should there be any special application of surge arresters, you confirm the specification(s) with the duly appointed project engineer; for further technical assistance and confirmation of the(all) applicable performance specification(s) associated with the project concerned.

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