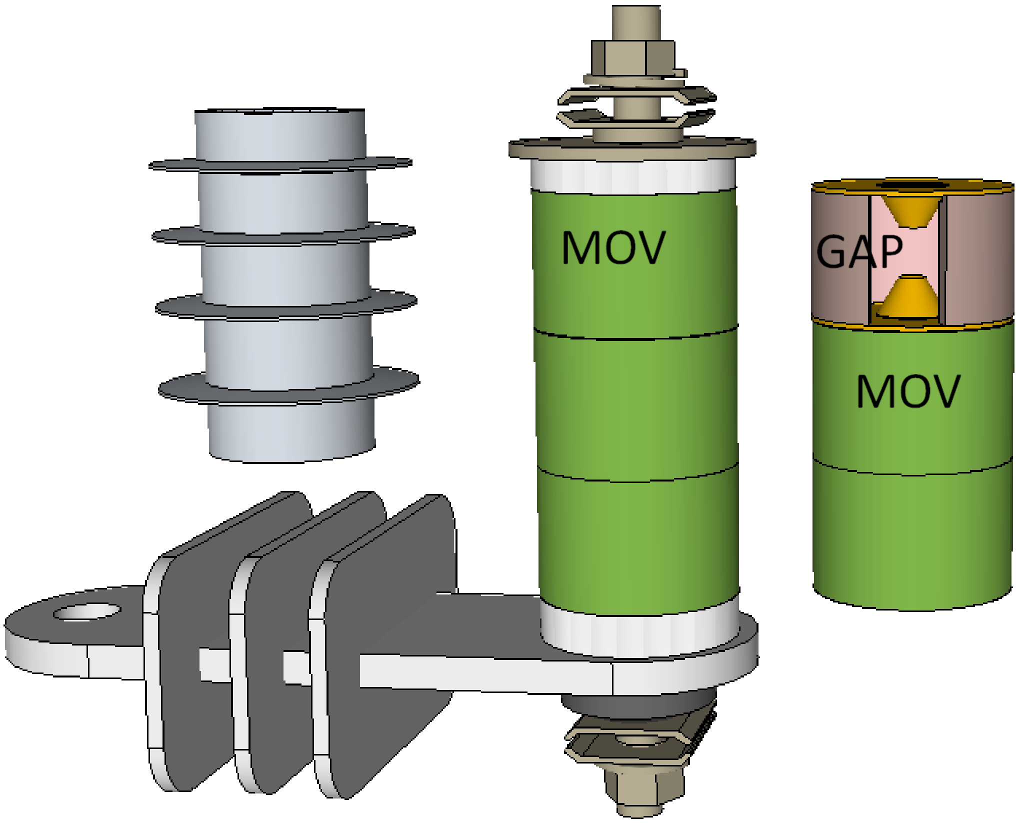
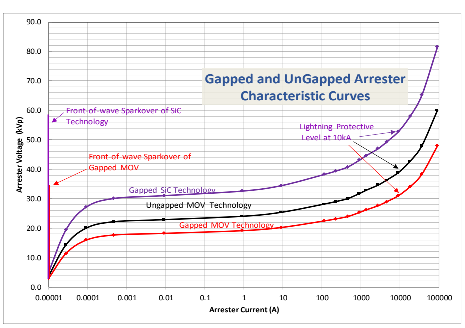
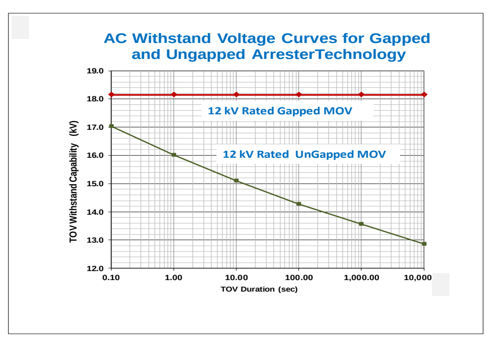
ArresterWorks

Understanding Gapped MOV Arrester Technology







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ArresterFacts 044

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The gapped arrester has been in existence for more than 100 years. During this time, it has been improved many times. In 1926 a silicon carbide block (SiC) was put in series with a simple air gap to eliminate a full ground fault when the arrester operated. By 1957 the current limiting gap had been introduced that vastly reduced the size of the arrester gap. The first Gapped MOV Arrester Technology was introduced in 1989 and is still being manufactured and installed by the tens of thousands annually in the US. The Technology behind the Gapped MOV Arrester is well understood today and offers two very high performance improvements to the standard Ungapped MOV Technology.

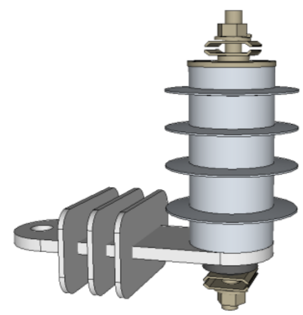


Figure 1 Gapped and Ungapped MOV Technology External Configuration

The purpose of this document is to clarify how the Gapped MOV technology is different from earlier gapped technologies and what performance enhancers are available in today's industry.

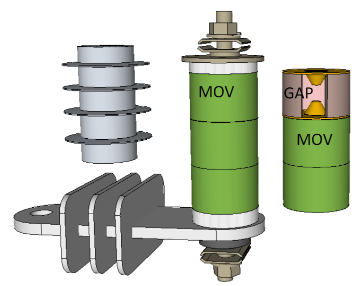


Figure 2 Gapped and Ungapped MOV Technology Internal Configuration

Gapped MOV Structure

Externally, a Gapped MOV arrester is identical to a non-gapped MOV arrester. It is in the internal components that we find the difference. In a gapped MOV arrester about 30% of the MOV material (disks) that would be present in a non-gapped arrester is removed and replaced with a gap section(s). For example, in the 12kV rated arrester, one disk is replaced with one gapped section.

The gapped section is a very simple structure consisting of two gap plates and one insulating spacer holding the gap plates apart, thus forming the actual gap. Typically, there is one gap section for every 10-12kV of rating.

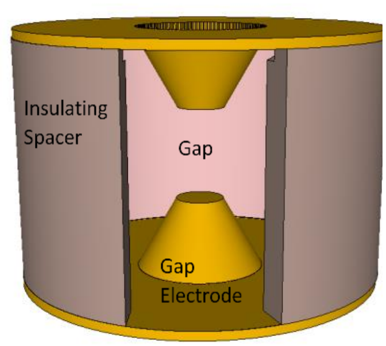
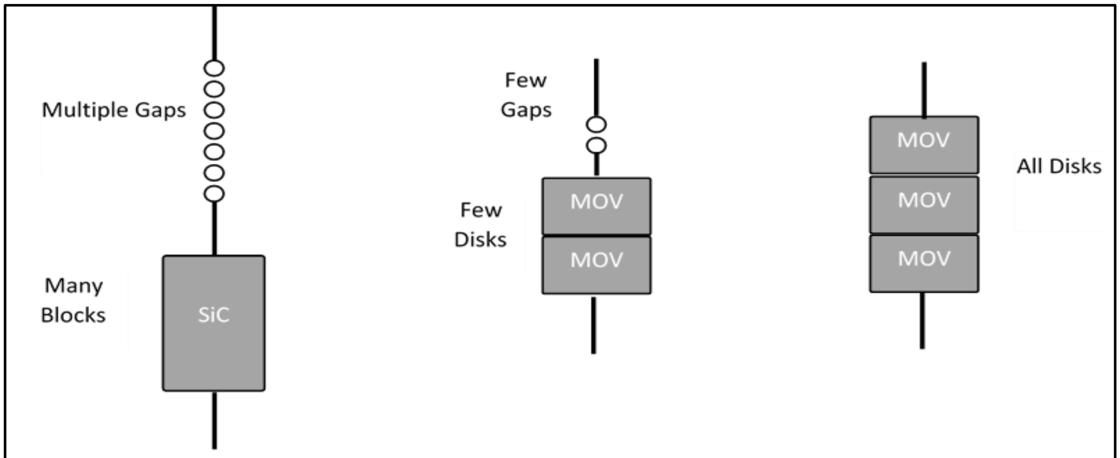


Figure 3 Gap Section Details

How it Works

With gapped MOV technology, the gap and MOV disk work in conjunction to provide better clamping voltage and higher system withstand voltage.

Whereas in an ungapped MOV arrester, the disks are the only active component and they withstand the voltage at all times. When subjected to a surge, the MOV material changes its resistance to allow the impulse current to flow. Once the surge has been passed to ground, the MOV disks terminates the event. By placing a gap in series with the MOV, the gap becomes the voltage withstand component, and the disk becomes the current limiting component that terminates current flow immediately following an impulse. The two components work in harmony and each assists the other to provide the improved protection.



Gapped SiC Technology	Gapped MOV Technology	Ungapped MOV Technology
Gaps start current flow in micro seconds and stops current flow in 8-16 milli-seconds with assist from Blocks	Gaps start current flow in nano-Seconds and Disks Stop Current Flow in Micro Seconds	Disks Start and Stop Current Flow in Micro Seconds

Figure 4 Component Configuration of 12kV Rated Arrester Technology

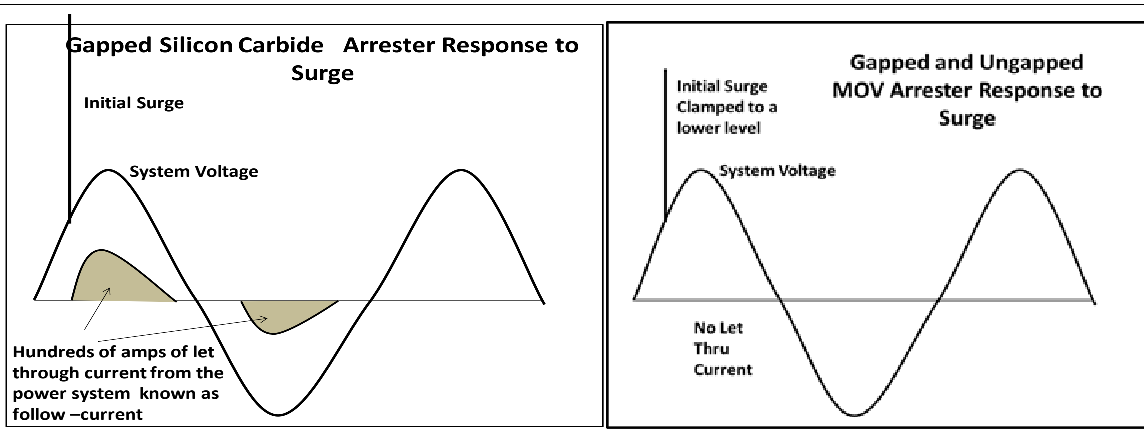


Figure 5 Surge Response of Gapped and Ungapped Technology. Note for Gapped MOV there is no follow current

With the ungapped MOV arrester, as the voltage increases the arrester begins to conduct current relative to its nonlinear resistance curve (Also known as the VI Characteristic Curve). This variable resistance allows the arrester to act like an insulator at normal operating voltages and like a conductor at high voltages. The higher the voltage rises, the lower the resistance goes, allowing the surge to pass to ground. Essentially, the solid state material acts as the on-off switch for the arrester.

With Gapped MOV Technology, the gap controls the turn-on function of the arrester and the semiconductor material of the MOV disk controls the turn-off function of the arrester. This separation of functions allows the Gapped MOV Technology to adjust the two functions separately from each other and improves on both functions. The Gap allows for higher turn-on levels based on the gap spacing. The MOV disks in series with the gap then takes over and turns off the event as the voltage drops to normal levels. Because the gap controls the turn-on function, less MOV material can be used to turn off the event which results in lower (preferred) lightning protective levels.

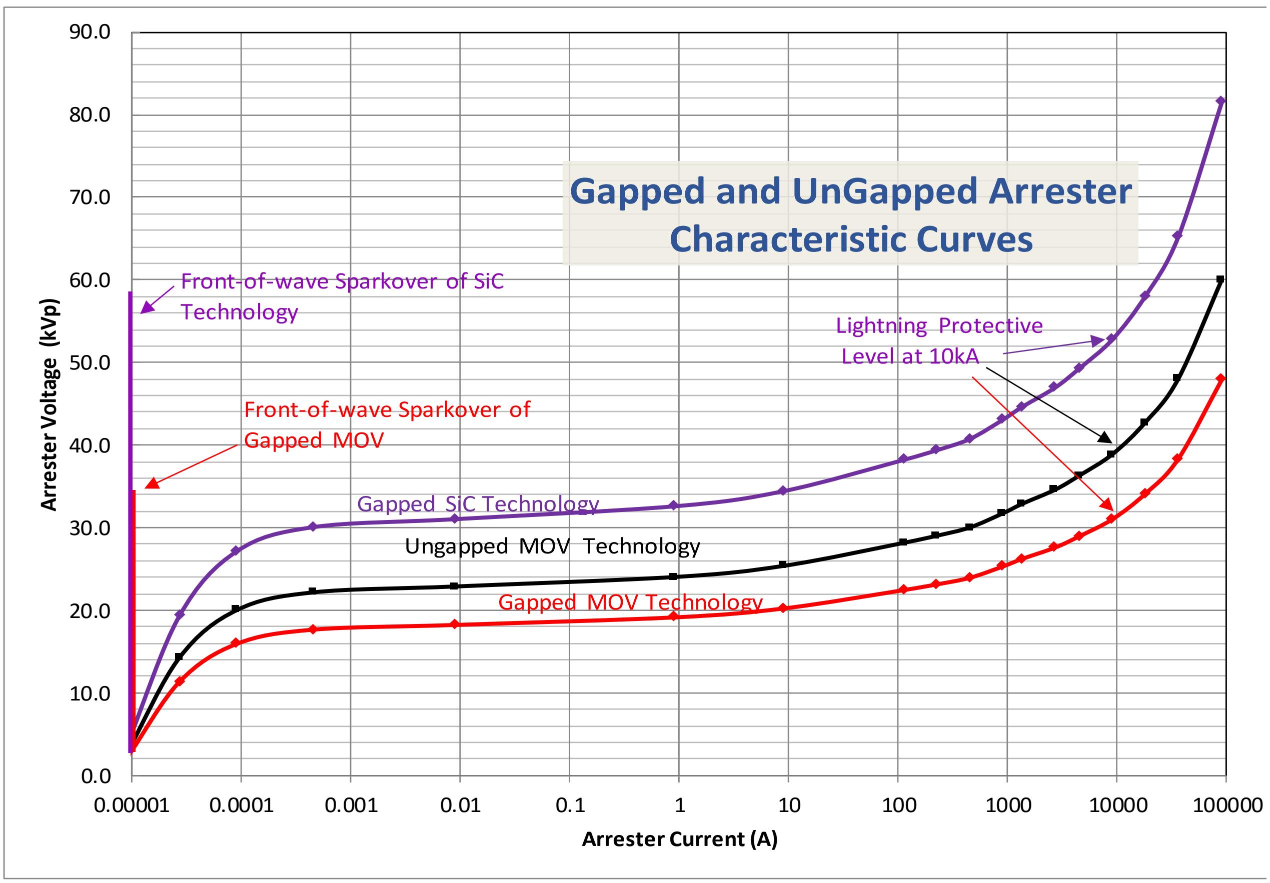


Figure 6 Gapped and Ungapped Arrester Characteristics for a 12kV rated Arrester

Better Lightning Protection: Arrester characteristic curves as shown in Figure 6 provide much information to the arrester designer and user. If we look at the Gapped SiC Technology, we see two undesirable performance characteristics that were the main factor that lead to the development of the MOV Technology. First the Front-of-wave (FOW) impulse characteristic was significantly higher than the 10kA lightning protective level (residual voltage at 10kA). This puts undo stress on the protected equipment. Secondly the Gapped SiC lightning protection at 10kA is higher than desired. The Ungapped MOV Technology significantly reduced the FOW characteristic and improved the lightning protective level. However, the Gapped MOV Technology goes one step farther by improving the lightning protective level with a 25% reduction over Ungapped MOV and nearly a 50% improvement over the former Gapped SiC Technology.

The fast front or FOW protective level of the Gapped and Ungapped MOV Technology is comparable, although both are better than that of the SiC arrester. Fortunately, the lightning current peak levels of fast front surges averages only 38% (IEEE 1410) of the standard lighting median current stoke levels. Arresters do their major protection work on slower front lightning currents that peak out in 6µs.

This significant improvement in lightning protection is the first of two reasons why the Gapped MOV Technology is considered a high performance arrester.

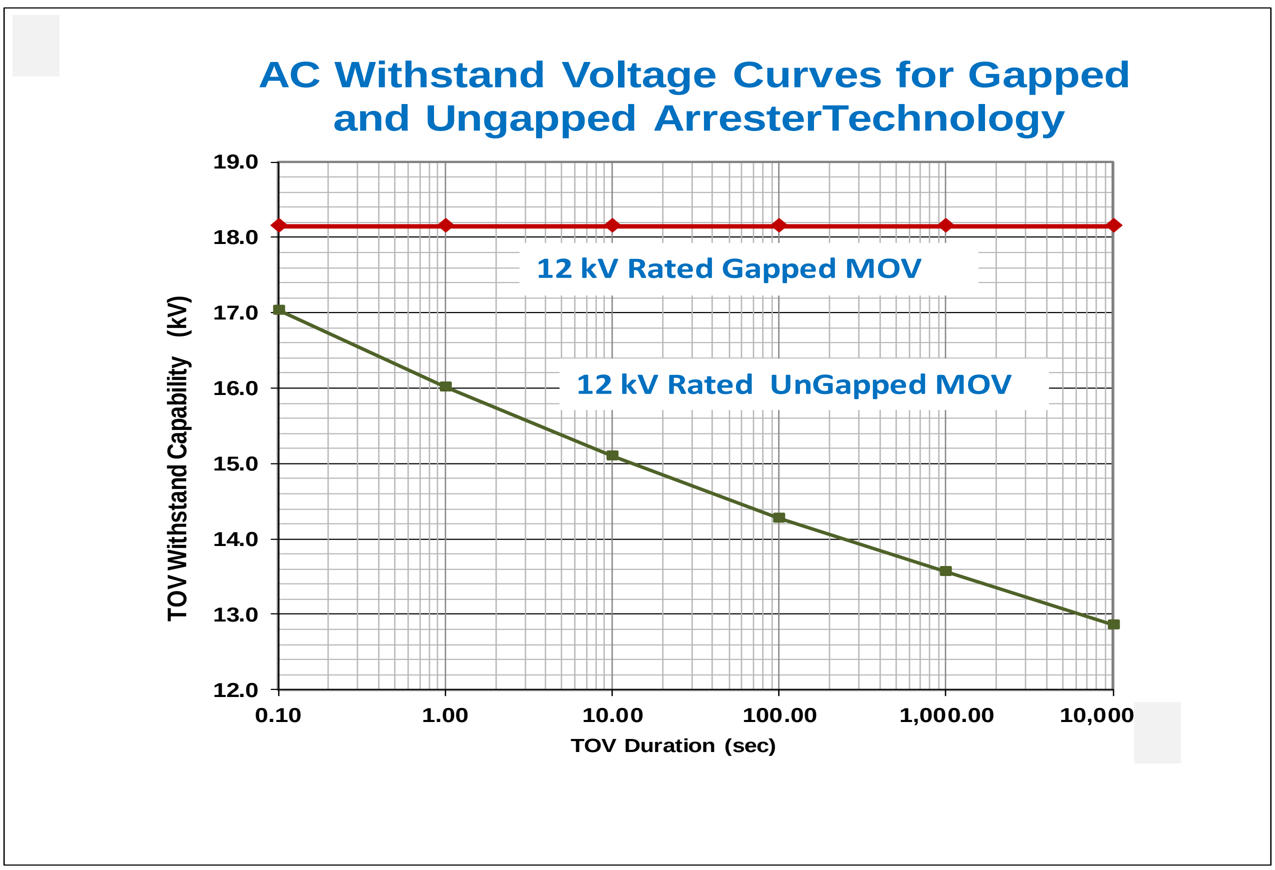


Figure 7 AC Withstand Voltages for Gapped and Ungapped MOV Technology

Arrester Rating	Arrester MCOV	.5µs 10kA Maximum IR (kV)	Ungapped MOV Technology Maximum Discharge Voltage (kV Crest)						Switching Surge Maximum IR	
(kV rms)	(kV rms)	(kV Crest)	1.5 kA	3 kA	5 kA	10 kA	20 kA	40 kA	125 A	250 A
9	7.65	33	24.6	26.1	27.3	29.8	33	37.1	17.6	18.1
10	8.4	35.0	26.0	27.2	29.0	31.6	34.9	39.4	18.1	19.8
12	10.2	43.9	32.7	34.8	36.4	39.7	43.9	49.5	28.3	30.5
18	15.3	66.0	49.1	52.3	54.7	59.6	65.9	74.2	35.3	36.1
27	22	94	70	74.6	77.9	84.9	93.9	106	50.7	52
36	29	123.0	91.5	97.3	102.0	111.0	123.0	138.0	66.8	68.5
Arrester Rating	Arrester MCOV	.5µs 10kA Maximum IR (kV)	Gapped MOV Technology Maximum Discharge Voltage (kV Crest)						Switching Surge Maximum IR	
9	7.65	31.4	18.9	20.1	21.0	22.9	25.4	28.6	13.6	13.9
10	8.4	33.3	20.0	20.9	22.3	24.3	26.9	30.3	13.9	15.2
12	10.2	41.7	25.2	26.8	28.0	30.6	33.8	38.1	21.8	23.5
18	15.3	62.7	37.8	40.3	42.1	45.9	50.7	57.1	27.2	27.8
27	22	89.3	53.9	57.4	60.0	65.4	72.3	81.6	39.0	40.0
36	29	116.9	70.5	74.9	78.5	85.5	94.7	106.3	51.4	52.7

Figure 8 Comparing Protective Characteristics of Gapped and Ungapped MOV Technologies

High TOV: Another reason why Gapped MOV Technology produces a high performance arrester is the ability of the Gap to withstand higher AC voltages than the Ungapped Technology with no compromise of protection level. As can be seen in Figure 8

Zero Watts Loss: With the Gapped MOV technology, the normal leakage current through the MOV disk is blocked by the gap resulting in zero watts loss. This characteristic makes the Gapped MOV arrester a greener loss free product.

Better Impulse Recovery: A subtler but real difference in the technologies is that the Gapped MOV Technology recovers faster from a high current impulse. Once the disk stops the current flow after a surge, the gap takes back over and keeps the leakage current at zero. This current blocking effect allows the MOV disks to cool down quicker than Ungapped Technology which continues to conduct small amount of current once the surge has passed.

All other arrester characteristics are the same between the Gapped MOV Technology and Ungapped MOV Technology.

Application Considerations

One Arrester for All Applications: Because Gapped MOV technology offers a low discharge voltage, this arrester is often used at riser poles for protection of underground circuits. Many utilities have chosen to use this arrester for all applications and reducing their arrester stock items by 50%.

Standards: IEEE standard C62.11-2012 covers all the tests necessary to certify Gapped MOV Technology, as well as IEC 60099-6-2002. IEC 60099-6 is specifically for Gapped MOV Technology for Distribution Arresters up to 52kV.

Impedance Grounded or Three Wire Uni-grounded systems.

This common system configuration can lead to long term and high temporary overvoltages that often cause arrester overloads. The gapped MOV Technology has high Temporary Overvoltage withstand capabilities making it an excellent candidate for the protection for this circuit type.

Wind and Solar Farm Circuits

Many of wind and solar farm circuits are built with the possibility of islanding when the system is suddenly taken off line. The results of rapid load loss can lead to overvoltage scenarios that cannot be handled with ungapped MOV technology, but are perfectly suited for the gapped MOV technology.

Mixing Gapped and Ungapped Technology

It is inevitable that a gapped MOV arrester and Ungapped MOV arrester will be applied on the same line perhaps a few feet apart or a span or two apart. Because the clamping level of the Gapped MOV Technology is lower than that of the Ungapped for similar ratings, you may think that the Gapped MOV arrester would take all the lightning and lead to a higher failure rate. Both simulations and real world experience indicates this is not the case. Indeed, if the two arresters are mounted within inches of each other, the Gapped MOV model will conduct the major share of the surge current, however, if they are a span apart on the same phase, the sharing will be a function of the pole ground resistance, not the arrester clamping capability.

History has told us that is very common for Gapped MOV Technology and Ungapped MOV Technology to be mixed in a system and there is no indication of increased failure rate of either model in this case.

Comparing Gapped SiC Technology and Gapped MOV Technology

Gapped Sic Technology had several technical issues that needed to be resolved when electronics equipment came into being in the 1960's both in low voltage and in high voltage systems. It was a well-known fact at the time that gaps in SiC high voltage arresters changed their turn-on characteristics over time. This was due to the fact that every time they operated the hundreds of amps of follow current that flowed puddled the metallic parts, actually changing the gap distances. This is not the case in Gapped MOV Technology because there is no power follow current after the impulse. The MOV disk turns off the event terminating any follow current. Therefor the gaps can last forever without changing characteristics in the newer technology.

Figure 9 Degraded Gaps of a Station Class Arrester

Secondly, SiC Technology gaps were notoriously known for sporadic turn-on during wet weather on the longer station class arresters. This was due to the fact that there were so many gaps in series that stray capacitance and moving ground planes during wet weather could cause premature flashover. Gapped MOV Technology only uses a fraction of the number of gaps as the SiC technology did so this sensitivity to wet weather is not an issue.

Because of these two major issues with Gapped SiC Technology, there were many utility users unwilling to try the Gapped MOV Technology even though these issues were solved by the new turn-off capability of the MOV disk in place of the SiC block.

The Future

To date, the use of Gapped MOV Technology has remained in the Distribution Class Arresters. Technically there is no reason why this technology could not be used on station class arresters up to 1000 or 1200kV. The simplified gaps and partnership of the gaps and disks make this type of arrester much more capable of protecting circuits that need lower switching surge protective levels as they do on the 1000kV systems.

ArresterFacts are a compilation of facts about arresters to assist all stakeholders in the application and understanding of arresters. All ArresterFacts assume a base knowledge of surge protection of power systems; however, we always welcome the opportunity to assist a student in obtaining their goal, so please call if you have any questions. Visit our library of ArresterFacts for more reading on topics of interest to those involved in the protection of power system at:

ArresterWorks Library of ArresterFacts

Comments on this ArresterFacts are welcome. Feedback will always be answered

About the author:

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ArresterWorks'
Principal Engineer

Jonathan started his career in 1973 after receiving his Bachelor's degree in Electronic Engineering from The Ohio Institute of Technology. His first job after graduation was at the Fermi National Accelerator Laboratory in Batavia, IL. As an Engineering Physicist at Fermi Lab, he was an integral member of the high energy particle physics team in search of the elusive quark. Wishing to return to his home state, he joined the design engineering team at McGraw Edison (later Cooper Power Systems) in Olean, New York.in 1979 During his tenure at Cooper, he was involved in the design, development, and manufacturing of arresters. He served as Engineering Manager as well as Arrester Marketing Manager during that time. Jonathan has been active for the last 30 years in the IEEE and IEC standard associations. Jonathan is inventor/co-inventor on five US patents. Jonathan received his MBA from St. Bonaventure University in 1995. In 2007 along with his life partner Deborah Limburg, they co-founded ArresterWorks an international consulting firm on surge protection of power systems.

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