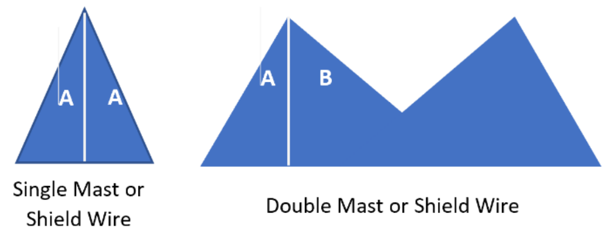
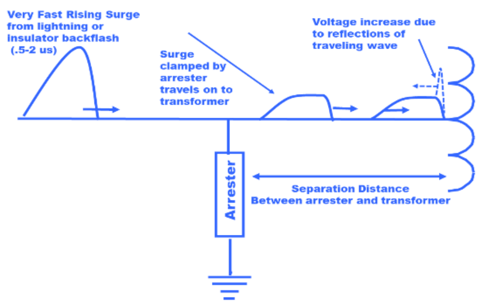
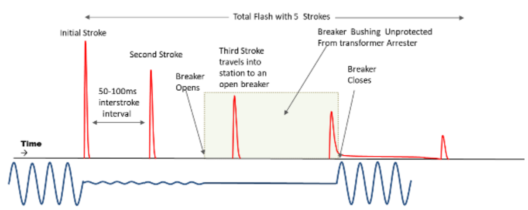
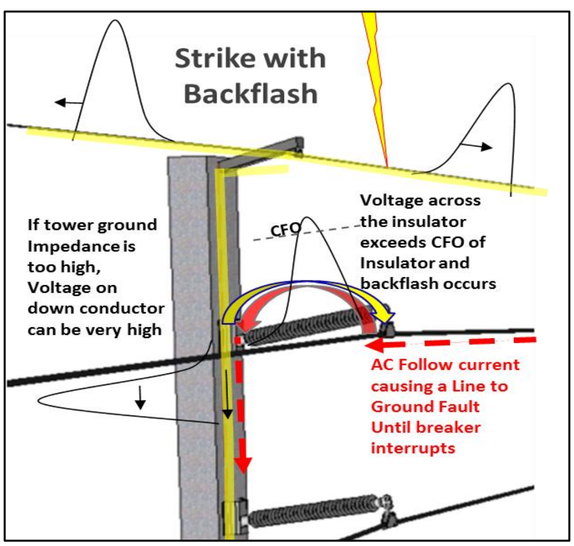
ArresterWorks

10 Practical Ways to Improve Transmission and Generation Surge Withstand Capability









ArresterFacts 053

10 Practical Ways to Improve Transmission and Generation Surge Withstand Capability

The application of arresters is one of the most effective means of improving a system's surge protection. However, for the arrester to be effective it is important that the proper arrester is applied correctly to maximum its protection value. Likewise, there are other method of protection that can be used to compliment the use of arresters. This article is a check list of items you should consider if improved system surge reliability is the goal.

1. **Check Arrester Protection Levels**
   The very first check for surge robustness is to check that the proper arrester rating is being used. The proper rating will withstand all potential system AC overvoltages, while at the same time clamp all surges that occur on the system at that location to a level that does not harm the equipment being protected. The margin of protection formulae can be found in both IEEE and IEC application guides, C62.22 and 60099-5 respectively.

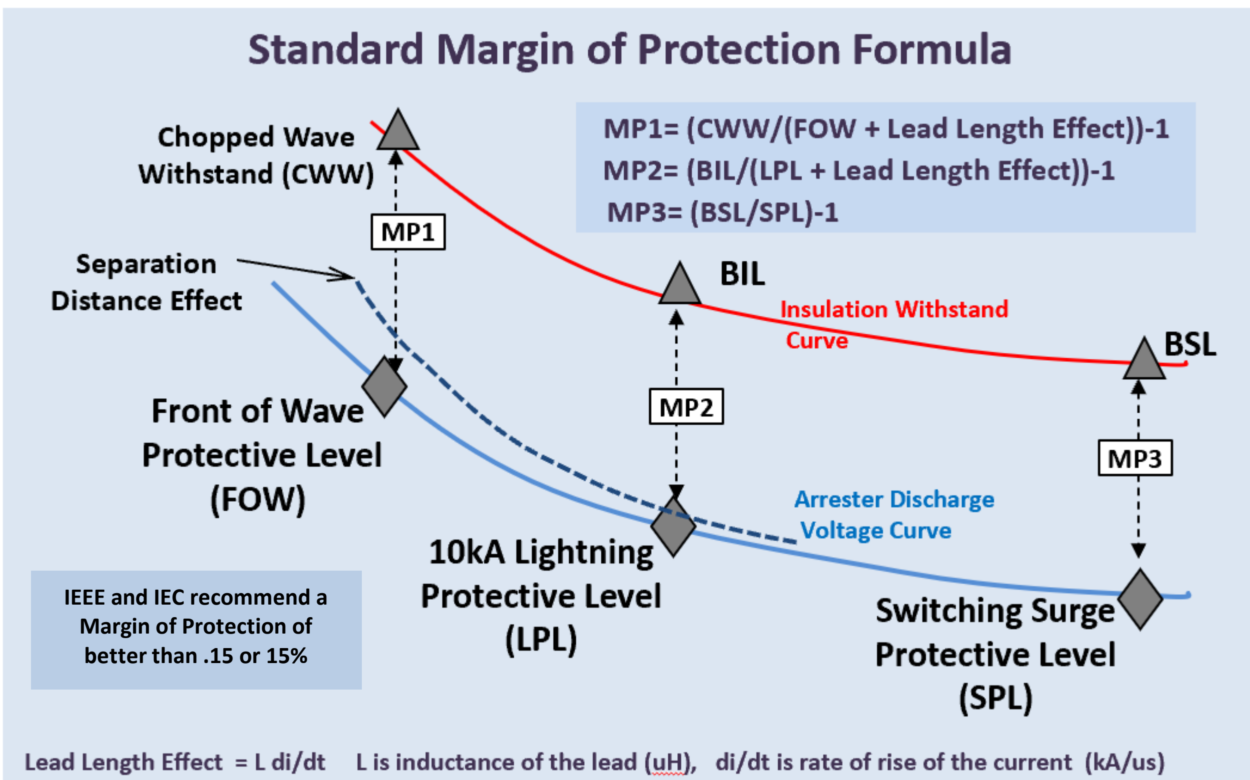


Figure 1 Margin of Protection Graphic and Recommendations

2. **Check Arrester Location**

For lightning protection, the closer the arrester is to the protected equipment, the better the protection. In a substation, the separation distance as shown in Fig 2 is largely influenced by the fast front withstand voltage of the transformer, and the fast front discharge voltage of the arrester. Traveling wave phenomena is at work in this situation, and when the distance between the arrester and transformer is long, a reflection of the surge can cause a significant increase in the voltage at the transformer. The equations to calculate the maximum separation distance can be found in both IEC and IEEE arrester application guides. Figure 3 is an example of acceptable separation distances based on IEEE C62.22 formulae

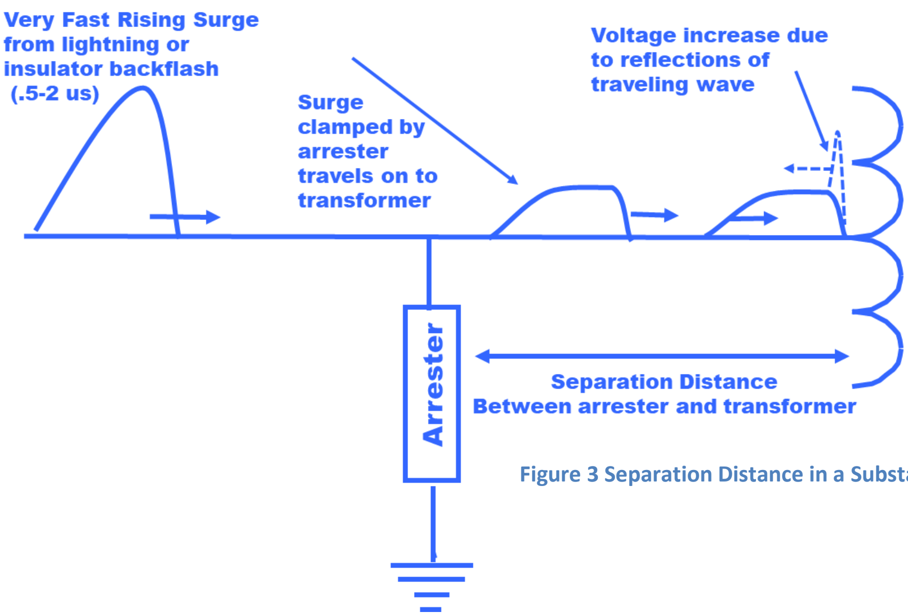


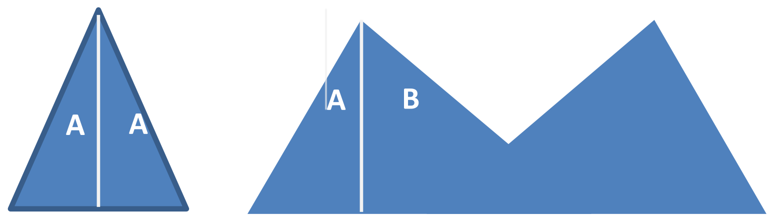
Figure 3 Separation Distance in a Substation

Maximum Separation Distance Low BIL /High BIL (m)						
Typical System Voltage (kV rms)	BIL Ratings (kV peak)	Uc or MCOV Ratings (kV)				
		42	70	140	209	318
69	250-350	15-55				
115	350-550		3-44			
230	650-900			4-20		
345	900-1175				3-14	
500	1300-1800					2-22

Figure 4 Typical separation distance maximums

3. **Check Substation Shielding Effectiveness**

Typically, substations are well shielded, but if you question whether the design is adequate, you can do an eyeball check using a 30-degree angle guide. When a straight line is drawn to the ground from the shield wire at a 30-degree angle, everything in the substation should falls under that line. The same method can be used with a mast, draw a straight line from the top of the rod in all directions to the ground at a 30-degree angle, if all parts of the station fall under the line, all is well. IEEE Std. 998 is an excellent source for learning more about this issue



Single Mast or Shield Wire

Double Mast or Shield Wire

Angle	Range(Deg)	Recommended(Deg)
A	20-60	30
B	40-60	45

Figure 4 Straight Line Method of Shield Assessment

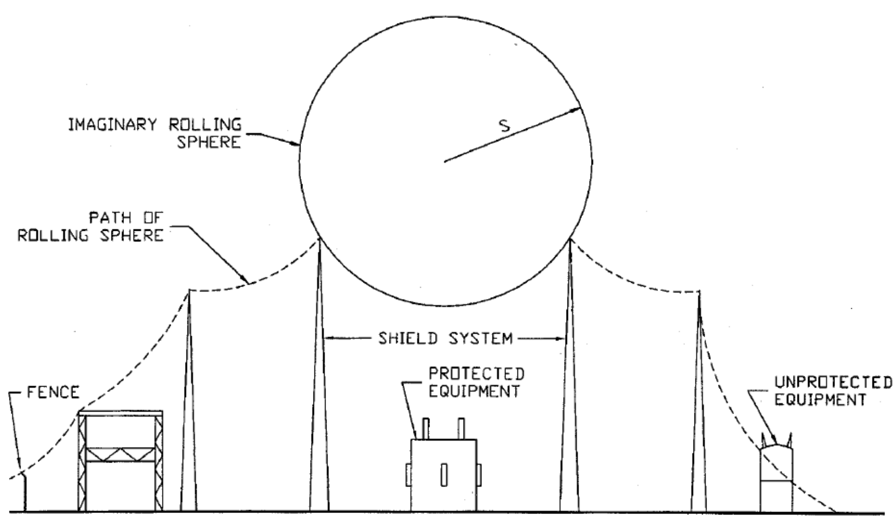


Figure 5 Rolling sphere method

Another more accurate method is known as the rolling sphere method. In this case an arc is used in place of the straight line. The radius of the arc is a section of a circle with a radius that is determined by the amplitude of the current stroke. The formulae for the radius are also found in IEEE Std. 998

4. Check Arrester Ur or MCOV Ratings

The AC ratings of arresters are important because the arrester is energized for its entire life. If there is a short-term AC overvoltage on the system due to a system transient, the arrester can be overstressed and fail. The minimum AC rating should be used so that the maximum margin of protection is achieved, but if the neutral of the system is not solidly earthed, then higher AC ratings may be needed. The following two tables can assist in selecting the arrester AC ratings

System line-to-line voltages (kV rms)		Recommended Arrester MCOV Ratings kV rms		
Nominal	Assumed Maximum	Four-wire wye Multi-grounded Neutral	Three-wire or Four-wire Wye Solidly Grounded@ Source	Delta and Ungrounded Wye
12.47	13.1	7.65	7.65 or 8.40	12.7 or 15.3
13.2	13.9	8.4	8.40 or 10.2	12.7
13.8	14.5	8.4	8.40 or 10.2	12.7 or 15.3
22.86	24	15.3	15.3 or 17.0	19.5 or 22.0
24.9	26.2	15.3	15.3 or 17.0	19.5 or 22.0
34.5	36.2	22	22.0 or 24.4	29.0 or 31.5
46	48.3	N/A	29.0 or 31.5	39.0
69	72.5	N/A	42.0 or 48.0	57.0
115	121	N/A	70.0 or 76.0	84.00
138	145	N/A	84.0 or 98.0	106 or 115
161	169	N/A	98.0 or 115	115 or 131
230	242	N/A	140 or 152	180 or 190
345	362	N/A	209	220
500	550	N/A	336	353

Figure 6 Arrester MCOV Recommendations for IEEE systems

Highest System Voltage Us (kV)	Minimum Arrester Rated Voltage (Ur)				
	Solidly Earthed Neutral at Source Transformer (kV)	Isolated Neutral at Source Transformer (kV)	Impedance Earthed Neutral at Source Transformer (kV)	Resonant Earthed Neutral at source Transformer (kV)	Neutral Protection of Transformers (kV)
3.6	3	6	3	6	3
7.2	6	9	9	9	3
12	9	15	12	15	6
17.5	15	24	15	24	9
24	18	30	21	30	12
36	27	45	33	45	15
52	39	66	45	66	21
72.5	54	96	66	96	30
123	90	154	108	154	51
145	108	183	126	183	60
170	123	216	147	216	69
245	180				102
300	222				120
362	261				147
420	336				168
550	396				222
800	580				321

Figure 7 Arrester UR Recommendations for IEC Systems

5. Check Arrester Age and Type

MOV type arresters have been available world-wide since the early 1980s. They offer improved protective levels and the more reliable operation than their predecessors. If the system reliability is in question, the replacement of all Silicon Carbide Gapped (Fig 8) arresters with MOV type arresters should be seriously considered. Not only will better protection be achieved but will also reduce the risk of arrester failure due to moisture ingress resulting from aging seals. A second factor to consider with the old silicon carbide arresters is failure mode and fault current rating. Older arresters tend to have a lower fault current rating, and if the arrester does fail, there is a higher risk of collateral damage due to exploding porcelain in the station.

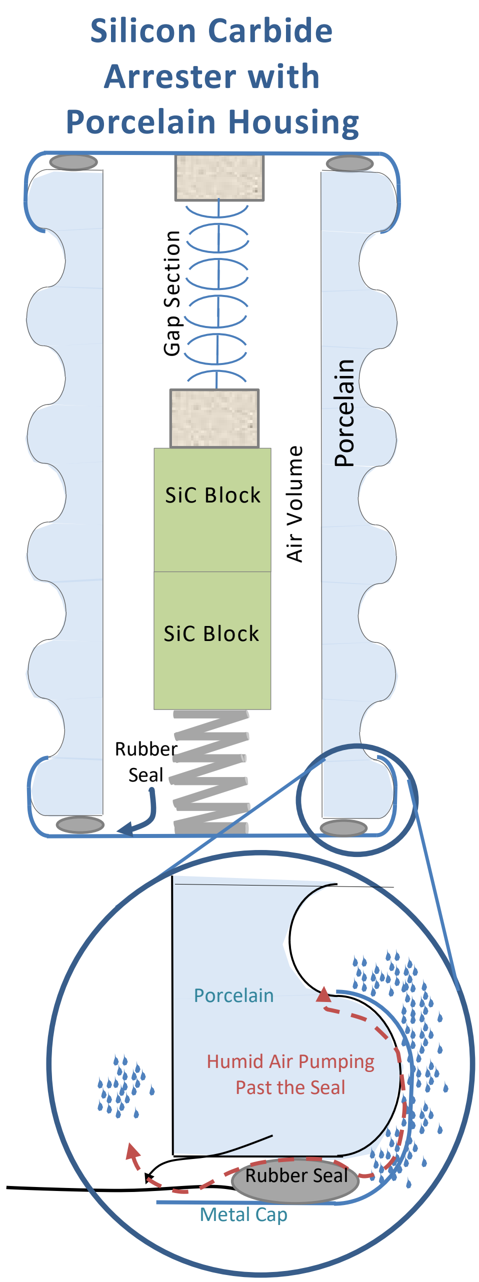


Figure 8 Silicon Carbide Arrester Seal Pumping Overview

6. Check Backflash Rate of Transmission Lines

When lightning strikes an overhead ground wire, a voltage appears along the tower caused by the tower ground resistance and the tower impedance. If the voltage at the base of the insulator is too high, it can backflash to the phase conductor (fig 9). This outage rate can be improved with arresters (fig 10). The backflash rate can be determined by checking the lightning induced outage rate of a line. If the outage rate of a specific line is higher than others, and it appears to correlate with lightning storms, then mitigation of the outage should be considered. If the outages are occurring in a specific area of the line, then the application of arresters in that area can improve the situation. If the outages are all along the line, then arresters mounted all along the line may be necessary. Another means of reducing backflash outages is to improve the tower or pole ground resistance. If this is possible to do and is cost effective, then it should be the first line of improvement. Improving grounds however can be very difficult and sometimes impossible to do.

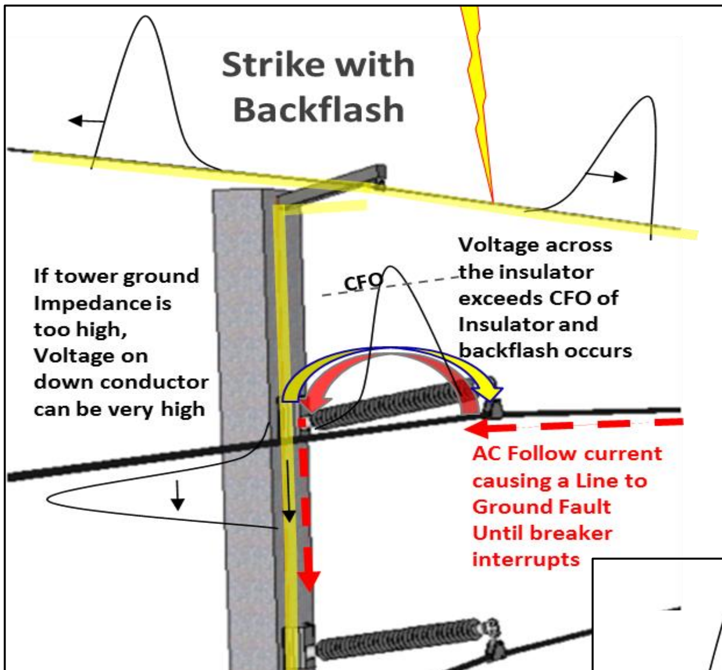


Figure 9 Backflash due to high tower ground resistance

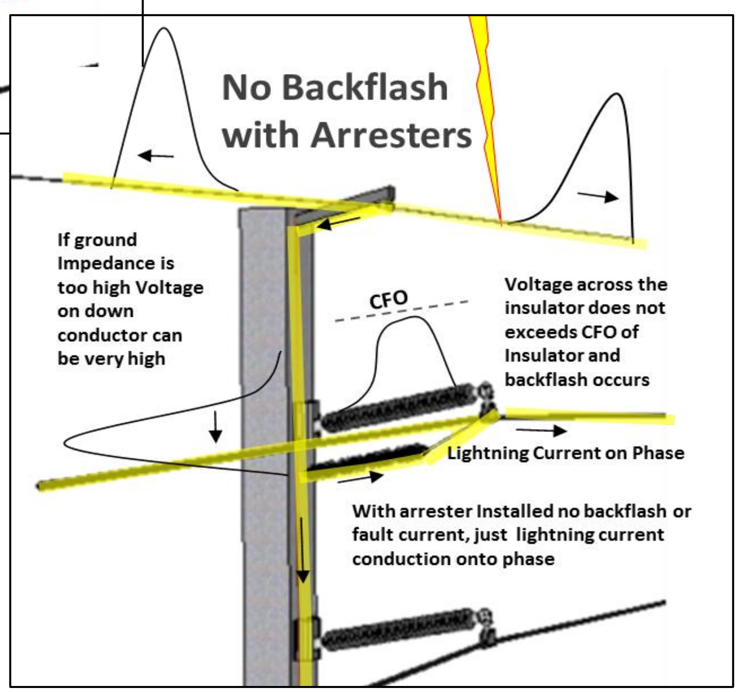


Figure 5 Backflash Mitigation with Arresters

7. Check Generator protection of windings

Generators are some of the highest value assets in power systems and at the same time they are often the most volatile insulation. If not properly protected with arresters and capacitors, they are at higher risk of failure. Specifically, the stator winding with its dry type insulation is the most vulnerable of all. Since it is difficult to see the arresters in these systems, check the one-line-drawings for the presence of a surge arrester and surge capacitor near the terminals of the generator. If either one is missing, there are very few surge improvement activities that can generate a better return on investment. Just consider the value of the generator as compared to a surge pack including an arrester and capacitor.

Figure 6 Failed Generator Stator

8. Check Open Breaker Protection

Breakers that go unprotected in substations can result in costly losses compared to the cost of protection. The scenario that results in an unprotected breaker does not have a high probability, but it does occur, and it can result in a failed breaker bushing. When a fault occurs on the line due to lightning, a breaker somewhere in the source path is called to operate and terminate the current flow. This is a good and common occurrence. However, occasionally while the breaker is in the open position (5-30 cycles), a second stroke can travel down the original lightning flash and put a second or third surge on the same system. If this surge reaches the open breaker in the open position, the surge will double in amplitude due to traveling wave phenomena. With the breaker open, the arrester on the transformer is not able to protect both bushings, only the bushing on the transformer side. The voltage doubling across the source side bushing can result in an external flashover. Since bushings are self-recovering insulators, it can result in little to no damage, but it can also result in damage that leaves the breaker unusable. This lack of protection is mitigated by the installation of arresters on the station entrance.

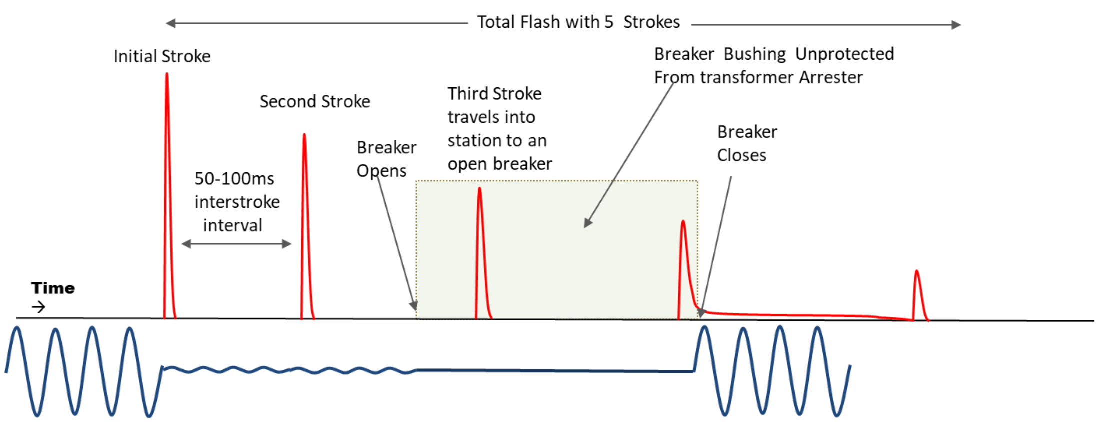


Figure 7 Open Beaker Scenario that leads to Bushing Flashover

9. Check for Missing Open Point Protection on Transmission Lines

On transmission lines, there are times where a switch is used to isolate sections of the line for one reason or another. If a switch is in the open state similar to that in the open breaker scenario, a surge can travel down the line and upon finding an end point, it will double in amplitude. The doubling can often lead to a flashover and ensuing fault if the line is energized. To mitigate this potential transient outage, arresters should be installed on each side of the switch.

10. **Check for adequate wildlife protection**
    In the zones where transmission and distribution systems meet, often times lower voltage station equipment is required. When the operating voltage is 25kV or less, the insulators, bushings, and arresters become very short and at risk from animal interaction. In these areas, it can be very beneficial to mitigate these interactions with the use of wildlife protectors. There are numerous styles and sizes of wildlife protectors to choose from, and the cost of an outage far outweighs the cost of plastic protectors. Wildlife protection should be high on the list of possible improvements if animals are a problem in your system.

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:

About the author:

Jonathan started his career after receiving his bachelor's degree in Electronic Engineering from The Ohio Institute of Technology, at 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. 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.

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