Arrester 2050

JONATHAN WOODWORTH

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Jonathan Woodworth - Arresterworks

Introduction

This paper is about the future of surge protection and what the arresters of 2050 may be like. In order to understand where we are going, I would like to take us back through a short history. Once we understand how surge protection has evolved over the years, perhaps we can better navigate the path to Arrester 2050.

Looking Back

1907 Electrolytic Arrester

In 1907 GE applied for the first Electrolytic Arrester patent. Design engineer Elmer Creighton presented a paper at the AIEE Winter Power meeting in NY, NY titled "New Principles in the Design of Lightning Arresters" Prior to this the only method available for protecting high voltage systems (25-35kV) was gaps with resistors in series.

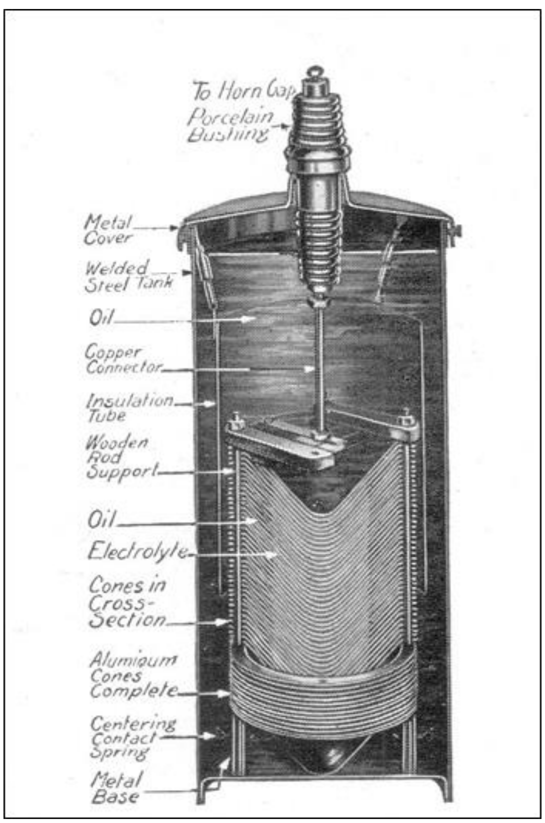

Figure 2: 1907 Electrolytic Arrester

Although the electrolytic arrester was revolutionary for its time, it came with a number of drawbacks. For starters the arrester was very large, standing over 6 feet tall. Additionally it required daily maintenance, and the losses were 5 amps at steady state. Another issue was the fact that it was filled with oil and dielectric acid.

1915 Pellet Oxide Arrester

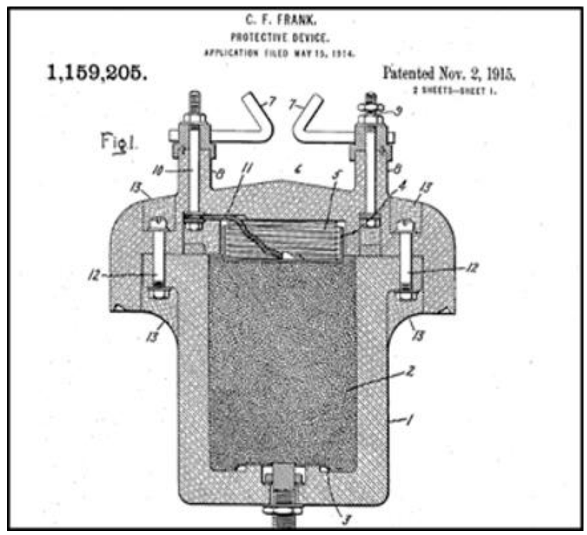

Figure 1: 1915 Pellet Oxide Type Arrester

By 1915 GE had another type of arrester ready to go. This arrester was targeted toward lower voltages. The pellet oxide arrester with a porcelain housing. This arrester required no daily maintenance and had no liquid inside.

1918 Oxide Film Arrester

The oxide film arrester evolved from both of the electrolytic arrester and the pellet oxide arrester. It had no internal liquid, the nonlinear series resistance was achieved by aluminum oxide film which was on a plate similar to that found in the Electrolytic Arrester. Note how sharp the VI curve was for this arrester. The literature also indicated that the leakage current was in the range of .25 to .5 amps. Figure 3 is a photo of a metal film arrester that was retired from service1969 with as much as 40 years of protecting insulation.

Figure 3 Oxide Film Arrester

Figure 4: Oxide Film Arrester in Service in 1969

1926 Crystal Valve

In 1926 John Robert McFarlin, who was still working for ESSCO, filed for a patent using a new material that he referred to as: "infusible refractory materials of limited conductivity and comparatively low specific resistance in the silicon carbide family." He goes on to state that "these properties greatly enhance the effectiveness, durability, stability and simplicity of surge arresters." Thus began the long history of the Silicon Carbide (SiC) family of arresters. This type of arrester remained in production into the 1990's in the US and is still in production in other parts of the world.

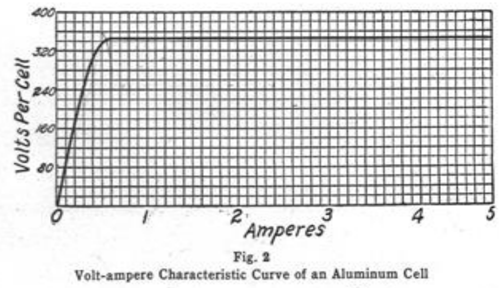

Figure 5: VI Characteristic Curve for Oxide Film Arrester

As compared to the past the benefit of the silicon carbide arrester was that it was simple with no maintenance and internal gaps. GE and Westinghouse soon followed suite and introduced similar arresters using their proprietary material based on Silicon Carbide. Over the 60 year life of this technology there were several improvements such as graded gaps to increase stability. In 1957 Jack Kalb of Hubbell patented the first Current Limiting Gap. Many of these units are still in service today.

Figure 6: 1950ish Silicon Carbide Arrester in Service in 2015

1967-77 MOV Arrester

Probably the most significant improvement in surge protection technology happened in 1967. Physicists under the leadership of Machio Matsuoka discovered bulk ZnO material properties and patented it for Matsushita Electric Co. This technology was used

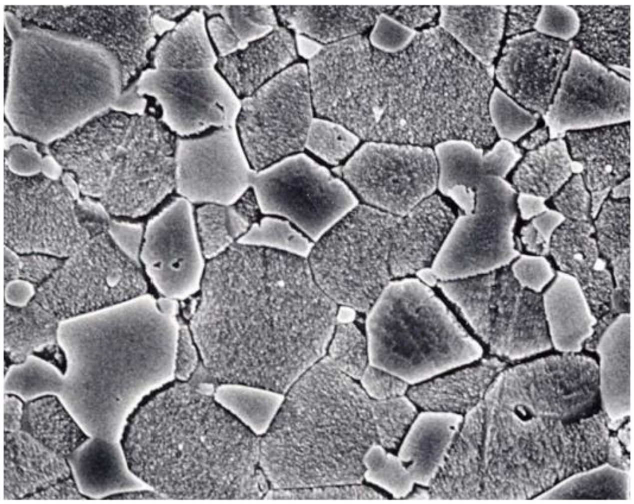

Figure 7: Zinc Oxide Varistor Microstructure and Bulk Characteristics offered no Gap Technology

mainly for low voltage arresters for the first ten years. In 1976 – 1977 it expanded into high voltage with Japan and US both having station class arresters in substations.

The major benefit of this technology was the removal of a gap that had aging issues and high front of wave transients during turn on. Another significant benefit of the ZnO technology was the turn off capabilities which eliminated the issues surrounding follow current in the SiC technology. A third and very important benefit was the size of the arrester. Figure 8 shows how much smaller an MOV type 60kV station class arrester was compared to a similar rated gapped SiC arrester with current limiting gaps. Clearly this new surge protection technology was a game changer. Several supplier of surge arresters just did not make it through this shift and others prospered.

1987 Polymer Housed MOV Arrester

The MOV Technology had expanded into porcelain housed distribution arrester by 1987 when Donald E Raudabaugh at Hubbell patented the first polymer housed overhead arrester taking advantage of the Gapless MOV technology once again. This started the

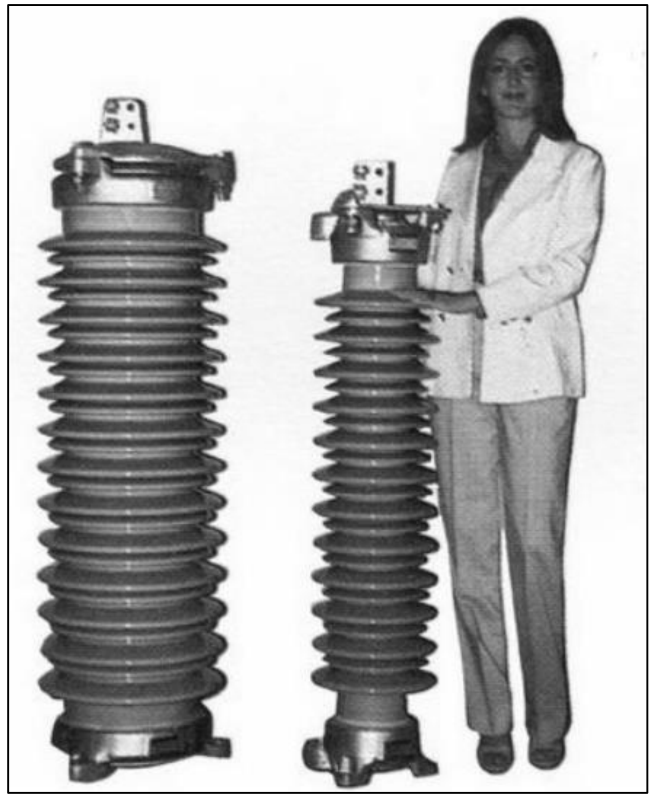

Figure 8: Comparison of ZnO and SiC Technology. Same Arrester Ratings

present era in surge arrester technology. The benefits of this combination of MOV and Polymer technologies are safety and weight. Both are significant. In the distribution class arrester, the transition to polymer housings from porcelain housings was very quick as

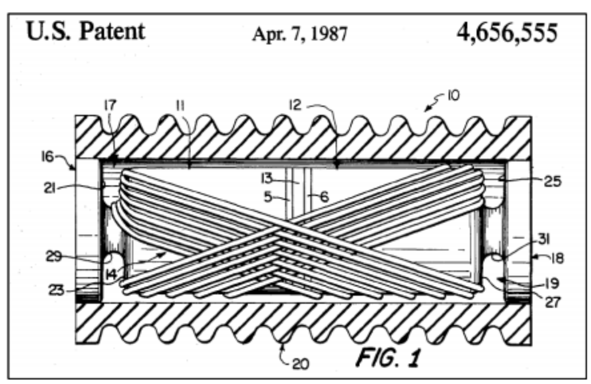

Figure 9: The concept that made the polymer housed arrester feasible.

compared to other technology changes. This speed was safety driven for the most part. In the station class world, where explosion proof arresters were possible the change did not move as quickly. There was also one negative aspect to the polymer housed MOV type arrester that slowed its conversion in the station class ratings. Strength of units above 230kV was not strong enough so a hollow core design was introduced in the late 1990s. The polymer housed arrester technology also lead to a more wide spread application of arresters on transmission lines

There you have it, a quick tour of the past to help us understand the path of the future. If you combine the history of arresters with the needs of the future, we can better describe Arrester 2050.

The Future
Certainly I do not have a clear vision of what the 2050 arrester will actually be. However I do have a number of ideas on what Arrester 2050 should do for us. If we combine our wish list of functions with a basic understanding of technology, we should be able to navigate to the future.

For sure, a paradigm shift will be needed. We have had a couple in our lifetimes, the first was in 1967 when Dr. Matsuoka made his now famous discovery of the very material we use almost exclusively. In their case they knew what they were looking for, a more effective means to protect the electronics that were so swiftly being developed. They were methodically searching for a better protection scheme and when they had selected materials for a junction based varistor, they accidently found a better way using diffusion of dopants into the bulk of ZnO. Who could have predicted such a discovery, I think nobody.

The 1987 introduction of the polymer housed arrester was similar to the hose in that the polymer housing provided the environmental seal and the fiberglass wrap provided the strength. I believe we need a new perspective to take us to the next generation surge arrester and protection.

This has been the case in most of the former game changers in our industry.

1. 1907 Electrolytic Arrester – nonlinear series resistance
2. 1926 Crystal Valve Arrester – no liquid and common material for nonlinear resistance.
3. 1967-77 MOV Arrester – semiconductor to replace gaps
4. 1987 Polymer Housed Arrester – Porcelain replaced by rubber and fiberglass
5. 20??- ????? Arrester – ZnO material as it is processed today replaced by ?????

Where do we go from Here?
"Necessity is the Mother of Invention", is a phrase I live by. When something is really needed someone will figure out how to do it. I believe the next generation of surge protection will not likely provide better protection, but will make the arrester better in other ways such as:

1. Easier to install
2. Lighter in weight
3. Fail proof
4. Easier on the Environment
5. One size fits all
6. Invisible
7. Easier and less energy intensive to manufacture
8. Has a larger protection zone
9. Easier to test and verify its capability
10. Provides better margins of protection 500-1000kV

Opportunities for Improvement in the Future

Improved VI Characteristic For example, if we had a VI curve that looked like Figure 10, we would resolve numerous needs. Imagine what the arrester would look like in this case. First the arrester would not heat up as much during a high current surge because it dissipated less energy. Thus we could reduce diameter. Also reducing diameter would not affect the residual voltage level. Station arresters would become

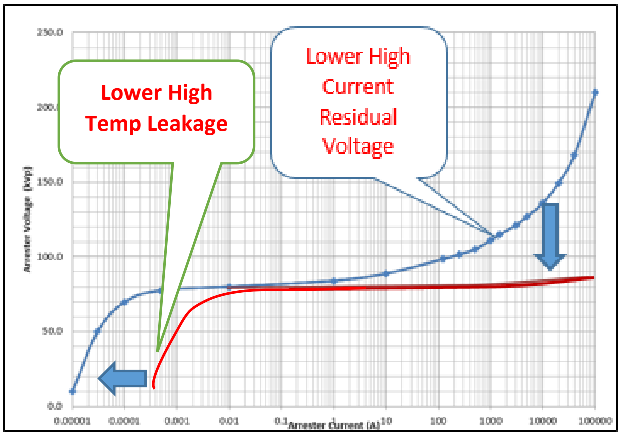

Figure 10 Improved VI Curve

the diameter of distribution arresters. Also the disks could be manufactured with higher steady state voltage stress meaning smaller grain size microstructure could be used and perhaps new lower cost processes would become possible. The technology for this does not exist at the moment, but imagine if it did.

Improved Thermal Characteristics

At the present time, the diameter of ZnO based varistors is limited by their leakage current increase due to temperature rise from either switching surges or lightning surges. We cannot change the laws of physics that govern temperature rise of a disk due to energy injection, however we can perhaps find an additive that reduces the response of the disk to this temperature rise. What if the new material was less temperature sensitive in the leakage current range than the present ZnO material? Imagine how small and environmentally friendly this surge arrester might be. This is another stretch of the imaginations, but if this technology did exist, it would be a game changer for the inventor or first user.

Fault Free Failures

Arresters are often overloaded for one reason or another. If we had an arrester that failed without a fault, it would be much easier on the entire system. Not only would the end customer not experience a blink, but the over current device would not operate and shorten its life. This should apply to both station class arresters and to distribution arresters. The technology for this already exists so the probability of this happening is high.

The Smart Arrester

I can confidently predict that in the very near future, we will see much smarter arresters at very little added

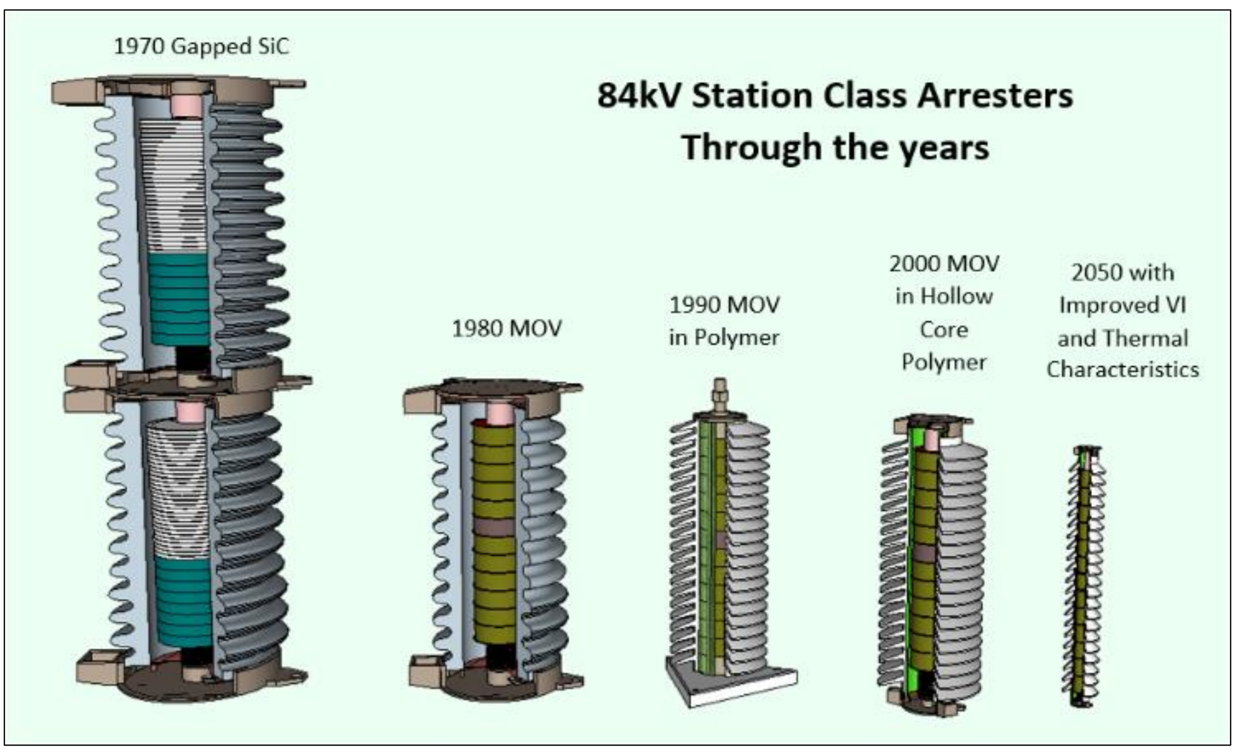

Figure 11: Arrester comparison Yesterday to Tomorrow

cost. Arresters will come from the factory with internal brains that will perform many useful tasks not even considered today. These smart arresters will not only watch over its own health, and the health of the system, it will transmit this data to those that need it the most. Here is a partial list of what a smart arrester could do for us.

1. Voltage sensor
2. PD in arrester
3. Moisture sensor in arrester
4. Impulse history
5. Temperature history
6. Aging history
7. Thermal response to TOV sensor
8. An arrester that learns normal operating temps and currents, and should it change, warn the user.

Self-healing Arrester

Air insulators are self-healing. If they flashover they re-seal. Why can't arresters perform similarly? Perhaps a spare redundant arrester of very low energy rating installed in parallel with the main arrester. If the main arrester fails, the spare could take over for a while not leaving the equipment unprotected.

Conductor Arresters

If the diameter of the protective device could be very small, then a flexible conductor size protection device would become feasible.

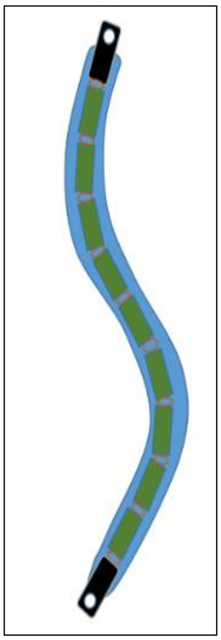

Figure 12: Flexible conductor

Because of its length it may not even need sheds. However if sheds are needed that is easy enough to add.

Water Proof Arrester

Moisture ingress is still the number one cause of arrester failures. Polymer housed designs have improved this situation, but it is still with us. We need an arrester that will never fail due to moisture. Where there's a will there's a way as we often hear.

Lightning Proof Lines

We have essentially had lightning proof power transformers for many years. With arrester mounted on both the primary and secondary, it is a very rare case when a power transformer fails from a surge. We need to have the same thing on our lines if we want to achieve the level of reliability that the customers deserve. In this case the transmission line arrester technology, whether it is NGLA or EGLA, already exists. The missing link in the expansion of this application is a good business case. Many utilities are not interested in improving lines because they do not feel the pain of line outages. However big industrial consumers of electricity can be significantly affected by line outages. We need to build a good business case with these customers as the major benefactor. With a good business case lines will soon be better protected and system reliability will be where it should be for them.

Conclusions

History tells us that generally a need for improvement has lead the evolution of surge protection. History has also shown us that a shift in perspective can also make a big difference. What has been shown in this paper is where we have come from, and some possibilities as to where we might go if we take a different perspective or just step back and rethink what we need to do. Once we realize what is feasible and the benefits of change, the next generation of surge protection will surface.

It is very likely it will happen long before 2050 and may even happen before 2020.

However for it to happen, we need to step back and look at what we can change and expect that we can change everything. It doesn't happen by accident very often, someone must be looking for a change. I anxiously await the coming event.