ArresterFacts 011

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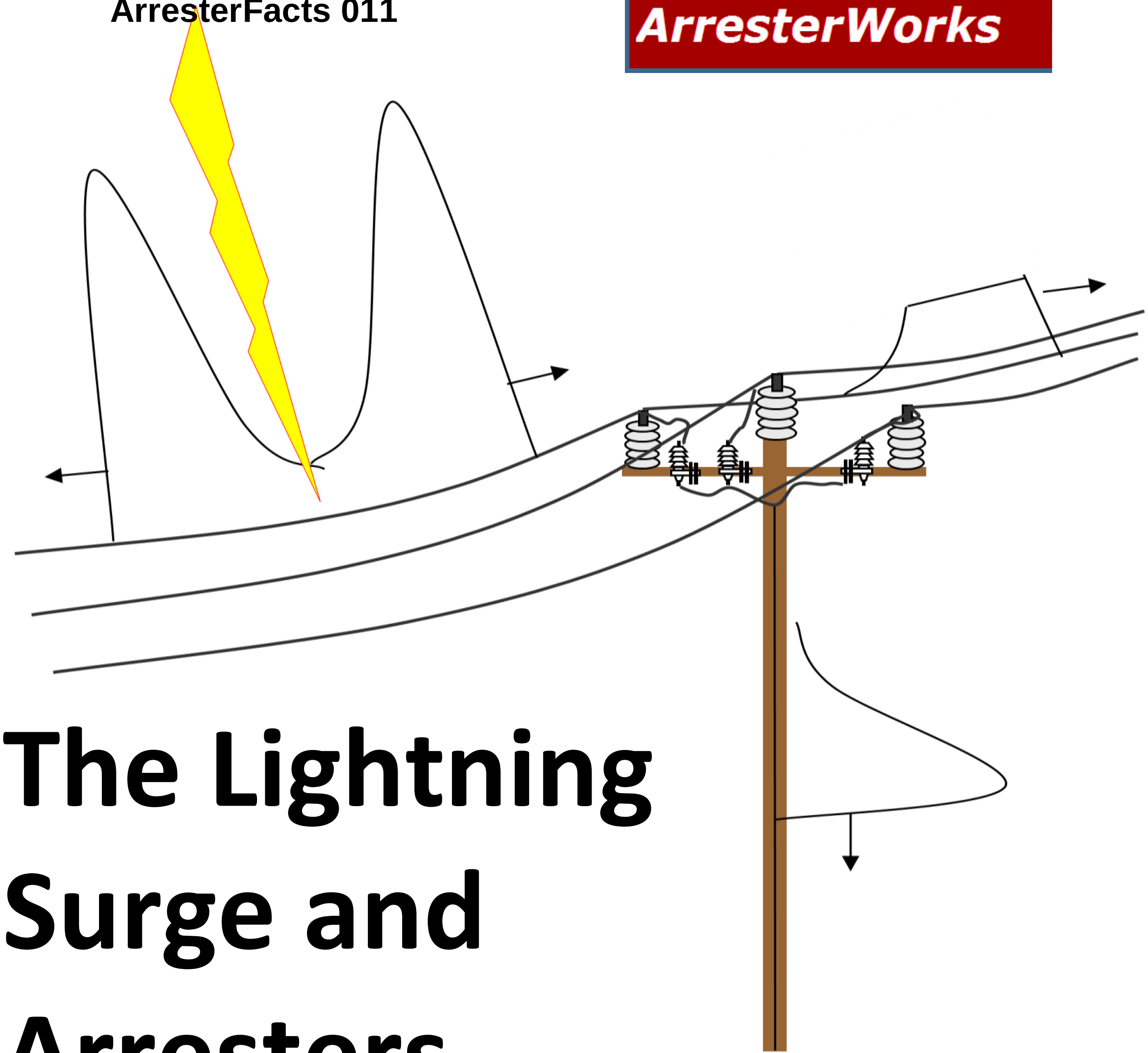

The Lightning Surge and Arresters

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Introduction

This ArresterFacts is about the lightning surge from an arrester perspective. This text does not try to add any knowledge to the vast knowledge base on lightning, but is a look at the effect lightning has on the power system and how arresters mitigate that affect.

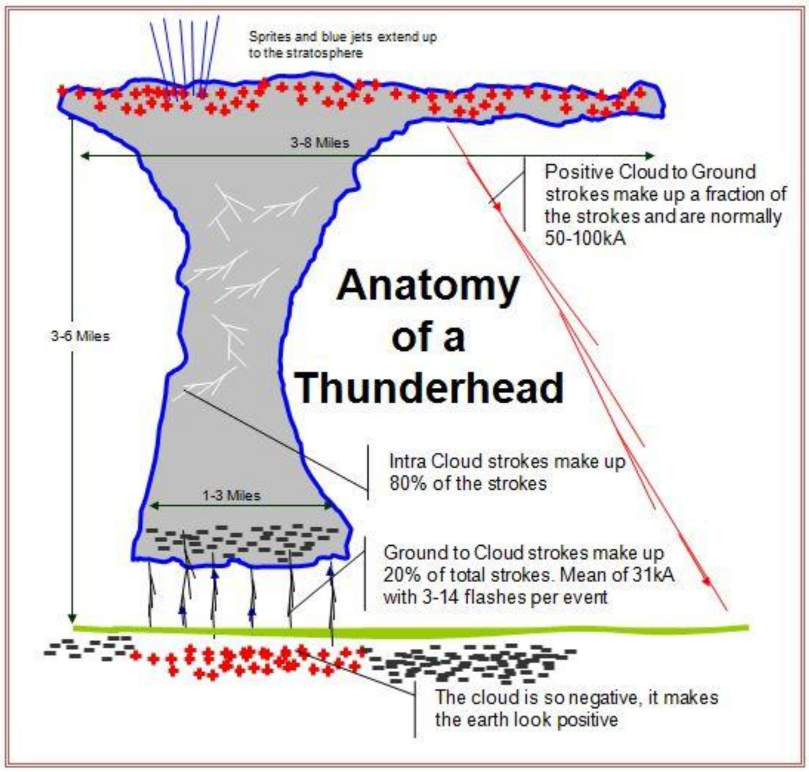
Dr. Uman and Dr. Rakov both part of the Lightning Research Laboratory at the University of Florida have published a behemoth text titled "Lightning – Physics and Effects" of which I have referenced extensively. I recommend it for any engineering library when lightning research is desired.

There are only a few things one needs to know about the lightning surge from an arrester perspective so that is the focus of this document.

The Thunder Head

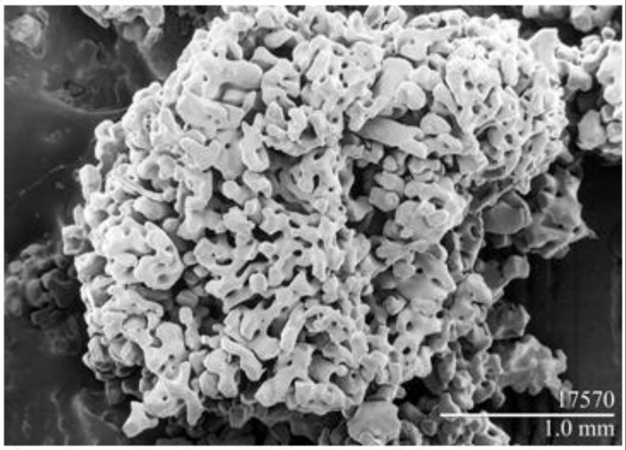
Lightning comes from several different sources, but the most common is from clouds associated storm systems. The most notable cloud that produces lightning is the cumulonimbus or thundercloud, or Thunderhead. Often times it takes the form of an anvil with its top up against the stratosphere as much as 12km above the earth.

The electrification mechanism of a thunder head is not fully agreed upon by experts. There is an old school of thought that posits that the cloud is just a conduit from the



upper atmosphere and that lightning is a result of external influences on the cloud.

A more popular school of thought on the electrification mechanism posits that the charge build up in the cloud is a result of collisions between graupels and ice crystals in the presence of water within the cloud. A graupel is a small particle made up primarily of frozen water in the form of rime that encases an ice crystal. This particle is not generally found on the ground and is contained in the cloud. A SEM micrograph of a graupel shows its features.



Graupel - a precipitation particle found in clouds that play a major role in the electrification mechanism

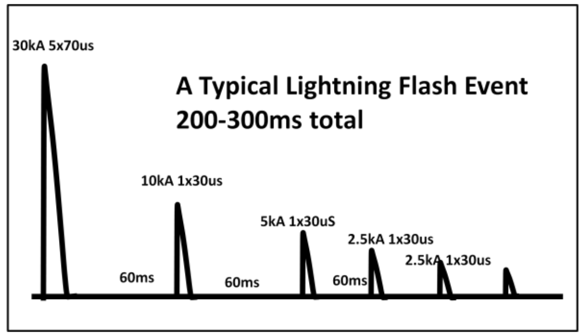
There are basically two types of lightning discharges. Intra-cloud and extra-cloud. The intra-cloud lightning accounts for 80-90% of all lightning and thunder. This lightning is the discharge of sections of the cloud and the strokes do not reach the ground. They stay within the cloud or from cloud to cloud.
The remaining 20% of strokes are between the cloud and ground. This is the lightning of importance to power systems. Of the cloud to ground strokes, 90% of these are called downward negative lightning flashes. The remaining 10% are downward positive lightning flashes.

In all cases, the lightning discharge is transferring a charge from one point to another. This charge transfer is often measured in coulombs. A typical charge transfer will contain approximately 1-5 coulombs.

From an arrester perspective it does not matter from which direction the stroke comes, nor does it matter if it is a positive or negative stroke. Arresters are bi-directional and react the same to all types of strokes.

The Flash and Stroke

The term flash is used to refer to a complete lightning event. The term stroke is used to refer to one discharge. In a typical lightning flash, 1-15 strokes are very common. A complete flash can take as much as a 1/3 of a second. If you have ever noticed a flicker during a lightning discharge, it is not just your eyes, but in fact a multi stroke event. Our eyes cannot respond fast enough to discern the strokes, but we can generally perceive the flicker.

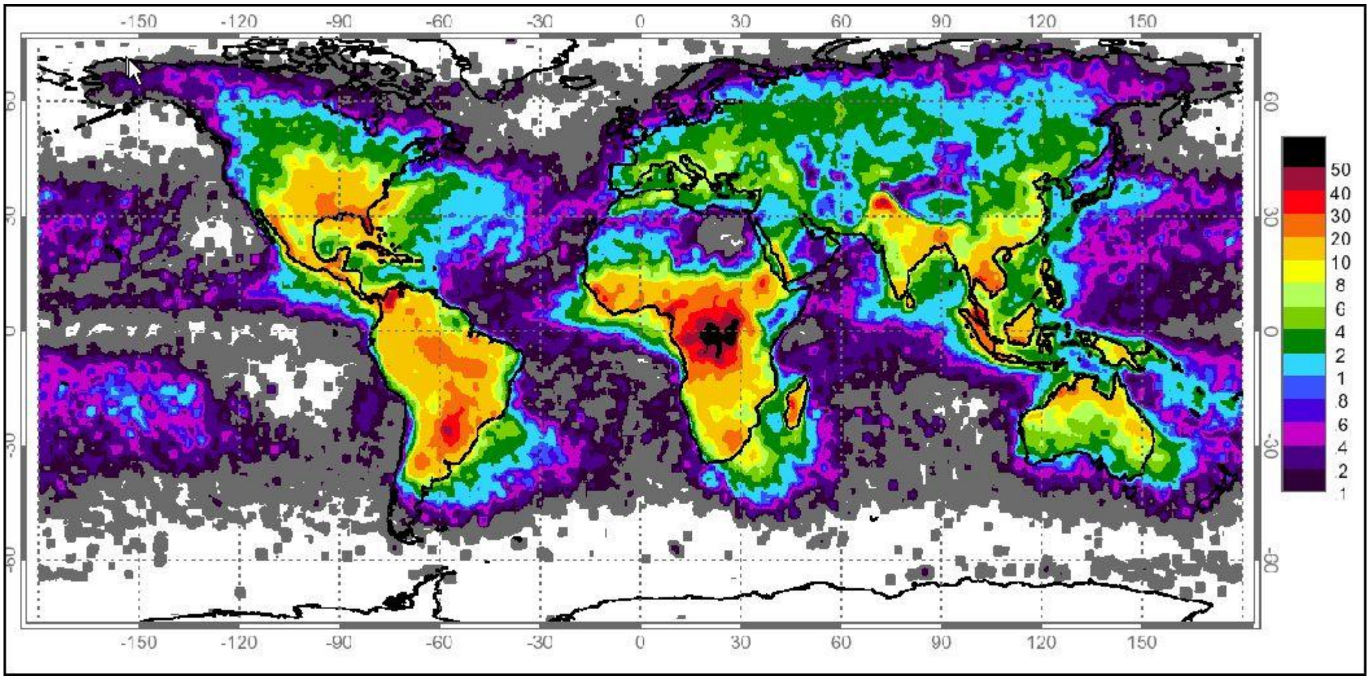


Stroke Characteristics		
Characteristic	First Stroke	Subsequent Strokes
Peak Current	30kA	1-15 kA
Time to Peak	5us	.3-.6 us
Time to Half Crest	70-80us	30-40us
Charge Transfer	5C	1C

Overall Flash Characteristic	
Duration	200-300 ms
Time to Peak	5us
Interstroke Interval	60ms
Strokes /flash	3-5
Charge Transfer	20C
Energy	10^{10}J

Incidence of Lightning

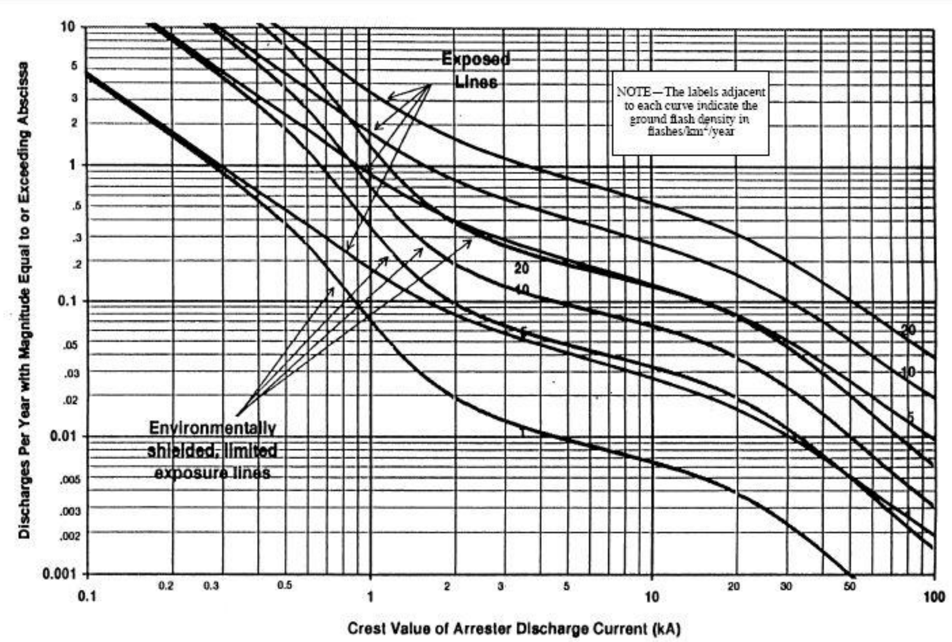
Ground Flash Density in flashes/km2/year



Another important characteristic of lightning to be cognizant of with respect to arresters, is the frequency of lightning in an area. It is appropriate to assume that the higher the lightning rates for an area, the higher the mitigation efforts. Over the last 20 years, the ground flash density has become the preferred unit of measurement for this characteristic. This value has been accurately derived for all parts of the world thanks to NASA efforts. An analysis of the above map shows that central Africa has the highest rate of lightning per km^2 per year than any other location on earth. South America, North America, Southern Asia, and Pacific Islands between Asia and Australia are the other areas where lightning is significant.

Magnitude of Arrester Currents

Once the lightning flash density is known for a given area, then the incidence as a function of amplitude can also be predicted using well accepted curves published in IEEE C62.22. For example, if you wish to



NOTE—Environmentally shielded areas are equal to situations with average to high levels of environmental shielding (nearby trees and buildings)—suburban lines usually fit this definition. Exposed lines are equal to exposed situations (few nearby trees and buildings or located along elevated ridges, etc.)—rural lines often fit this definition. (These curves are intended for arresters on lines without overhead ground wires, static wires, or shield wires.)

Figure 10—Distribution arrester discharge currents

know the number of discharges per year of 30kA for a given location the, curves predict that for an area that has a ground flash density of 20 the number is .2 per year or one every 5 years. For another example, how often an arrester does connected to an exposed line experience a surge current of 100kA if in an area with a ground flash density of 10? The prediction from the IEEE curve is .02 per year or once every 50 years.

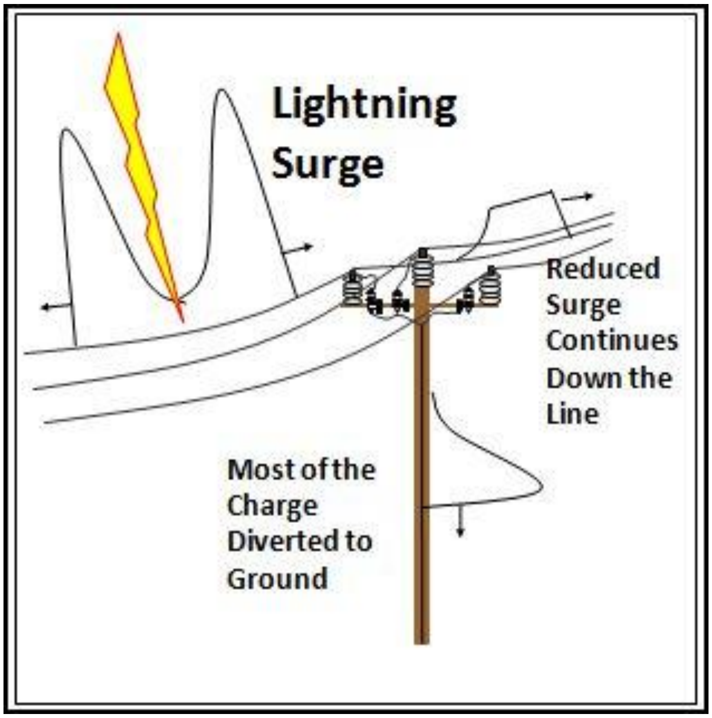
The Lightning Surge

A lightning flash or stroke only becomes a surge when its charge is transferred onto a power system. At that point it takes a wave shape partly dependent on the stroke characteristic and partly due to the system impedance.

The lightning surge represents the highest surge risk to insulation on power systems. Even low stroke currents can generate a 1000kV surge on the power system which is more than enough to flash over most insulators or puncture most equipment insulation. The lightning stroke can cause a lightning surge in two ways on a power system. The first is by a direct strike to the phase, and the second by a nearby strike to earth that results in an induced surge on the system. In the second case, the lightning surge is much lower in amplitude.

The surge arrester protects the power systems from both the direct and indirect lightning surge by diverting the charge and energy to ground. In the process of diverting, it clamps the surge on the system from the arrester onward. Since the surge arrester has resistance even in its conductive state it does not reduce the lightning surge to zero. Instead it reduces it to a level that will generally not damage equipment. In some cases, the lightning surge traveling down the system after it is clamped can still do damage to the system. This is especially true in the case where the surge comes to an open circuit and is doubled due to reflections.

If the ground resistance is too high, the surge can break down the insulation between phases and cause a phase to phase fault. It is a continuous effort of the utility to keep the ground resistance as low as possible to affect the best lightning surge protection.



In most cases, the lightning surge is reduced to safe levels for insulation and the arrester is ready for the next one.

However a lightning surge can damage the arrester in two ways (although a rare case with modern MOV type arresters). First the current from the lightning surge can stress the conducting limit of the varistor junctions that are part of the fundamental conduction mechanism. Secondly the charge transfer can results in heating of the varistor material beyond its capacity.

Lightning Surges and Traveling Waves

All surges on power systems do not only affect the system at the point of entry, but they move around the system at nearly the speed of light. In the case of the lightning surge, the resulting voltage on the system from the surge is so high, that it generally flashes over the first insulator it travels to. For this reason lighting surges do not travel nearly as far as lower voltage surges.

The Switching Surge

This will be subject of a soon to be published ArresterFacts. It is also an significant surge in the life of an arrester.

Other ArresterFacts Available

Thank you for using www.ArresterWorks.com as your source of information on high voltage surge arresters.

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