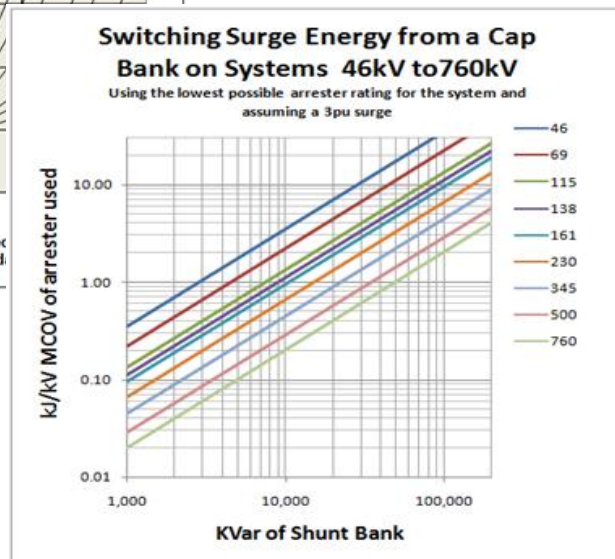
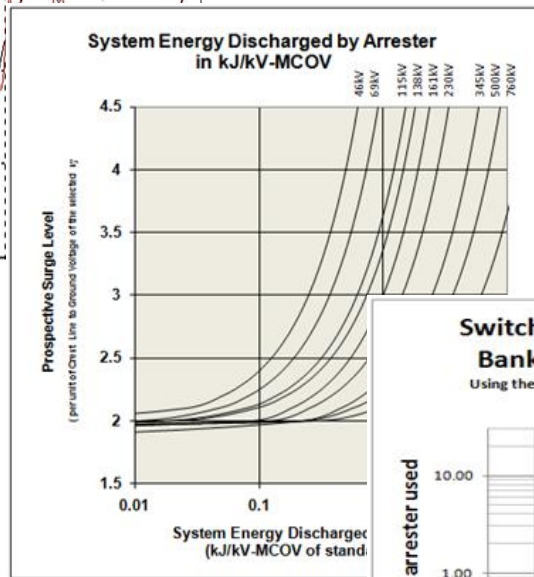
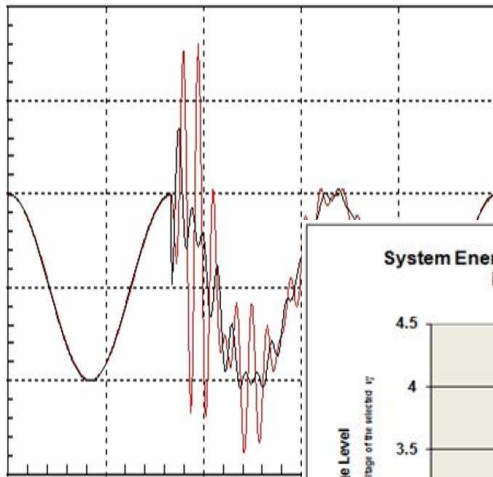


The Switching Surge and Arresters



Prepared by
Jonathan Woodworth
Consulting Engineer
ArresterWorks
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Introduction

This ArresterFacts is about the switching surge from an arrester perspective. This text does not try to add any new data to the vast knowledge database on switching, but is an overview of the effect switching surges have on the power systems and how arresters mitigate that effect.

As with lightning surges, the reason switching surges are a concern is that they can produce voltage levels that can damage insulation or cause flashover of insulation. Damage and flashovers often lead to outage minutes on a power system and this is highly undesirable in today's industry.

There are only a few things one needs to know about the switching surge to effectively mitigate them with an arrester, and that is the focus of this document.

The Switching Surge Defined

The switching surge comes in many different forms, and has many different sources. What is consistent between all switching surge events are:

- 1) They are low frequency events usually under a kilohertz and related to the fundamental power frequency.
- 2) They are always associated with a change in the operating state of the system.
- 3) They are always associated with a switching event on the power system.

- 4) They always involve trapped energy and its release.

Unlike the lightning surge, the switching surge is generally self induced by the operation of a breaker, switch or disconnect switch. However switching surges can be associated with lightning if during a lightning storm a lightning surge causes a breaker to operate and a switching surge is induced.

Figure 1 is an example of a typical switching surge. The wave shape is very complex. The amplitude of this switching surge is about 2.5pu which is a quite common amplitude for switching surges. Also note the duration of

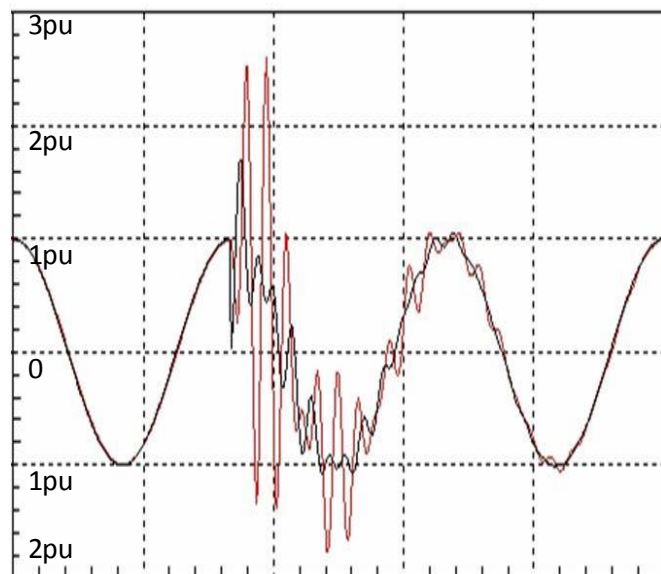


Figure 1 Typical Switching Surge Effect on a Power System

this event is not much more than one power frequency cycle which again is quite common in switching surge events.

Sources of Switching Surges

The reason switching surges exist is because of the inherent inductance and capacitance of power systems. The lines and transformers are major contributors of inductance. The lines are also very capacitive relative to earth and other phases. Cables in underground

systems offer significant capacitance to systems. Capacitor banks and reactors also add reactance to the circuits. Whenever these inductive and capacitive components are added or removed, they require the system to find a new steady state voltage level and current flow. In the process of making the transition from one system configuration to the next, voltages rise and fall rapidly seeking a new balance. The currents flow accordingly and often cause current surges simultaneously with the voltage surge.

In the circuit shown in Figure 2 several types of switching surges can be created when S1,

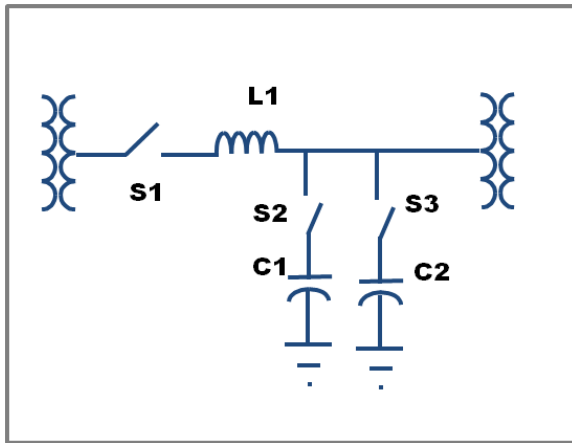


Figure 2: Typical Double Shunt Banks on a Transmission Line

S2 or S3 are operated. If S1 is closed to energize the line, a 1pu surge travels down the line toward the transformer and is reflected back toward S1. This reflection can cause a 2pu switching surge that will appear on the system and put all insulation in a higher stress situation.

Another scenario is if upon closing or opening S2 and S3 either pre-strikes or restrikes of the switch can lead to switching surges 2pu to 3pu as shown in Figure 3.



Figure 3: Typical Transient due to closing a switch to energize a line

Traveling Waves

For as long as there have been transmission lines, there has been the phenomenon of traveling waves. All transients on power systems are influenced by the fact that their effect is transferred throughout the system one meter or one unit at a time. This transfer of charge and energy is known as a traveling wave. The speed of the wave approaches the speed of light on transmission lines but due to the higher capacitance of underground cable it is only about half the speed of light. It is this traveling wave characteristic of transients that lead to reflections and refractions on the system. These reflections of the wave at points on the system where the system characteristics change are the most significant reason for transients above 1 pu.

When there is a termination of a line, the effect of traveling waves is most pronounced. In this case, the wave is fully reflected and the transient effect at the source can be a full 2pu.

Because switching surges are generally low in magnitude when compared to lightning and slow in frequency as compared to lightning, they act quite differently on the system. Due to the traveling wave phenomena, the same source of a surge can affect the system for hundreds and hundreds of miles in each direction. In the US, if a circuit breaker is

operated on a line in California, its affect can be felt in Montana 500 miles away.

Geographic Locations of the Switching Surge

Figure 4 shows where switching surges are found in the US. Wherever there is a transmission line, there is a possibility of having switching surges. Sometimes the surges are irrelevant on lower voltage lines (<230kV) but they will be there. Switching surges can occur on distribution systems where capacitance and URD cable are prominent. Overhead distribution lines are



Figure 4: Locations of Switching Surges in US
(The map is available at www.researchandmarkets.com)

too short and the impedances too low for any significant switching surge activity.

Line Energization and Arrester Energy Requirements

Since arresters are voltage limiting devices, any time a switching voltage exceeds its turn on level, the arrester will conduct and suppress the surge. Arresters are generally chosen to provide the most protection possible for equipment thus their turn on voltage is normally 1.6 to 1.9 pu of the line to ground voltage so any switching surge above

2pu will have an effect on the arrester. When the arrester is in conduction, it is dissipating energy and heating. If the switching surge is high enough in magnitude and long enough in duration, it can stress the arrester beyond its limits. Fortunately this the energy related to switching surges is easily calculated and the arresters chosen for this type of protection can be appropriately sized.

Figure 5 shows energy vs switching surge level for different system voltages using an arrester with a standard turn-on voltage. In section 5.3 of IEEE standard C62.22 and in section 3.2.3.3 of IEC standard 60099-5 the algorithms are given for calculating the energy a system would impart on an arrester in a line energization event of a switching surge of different magnitudes.

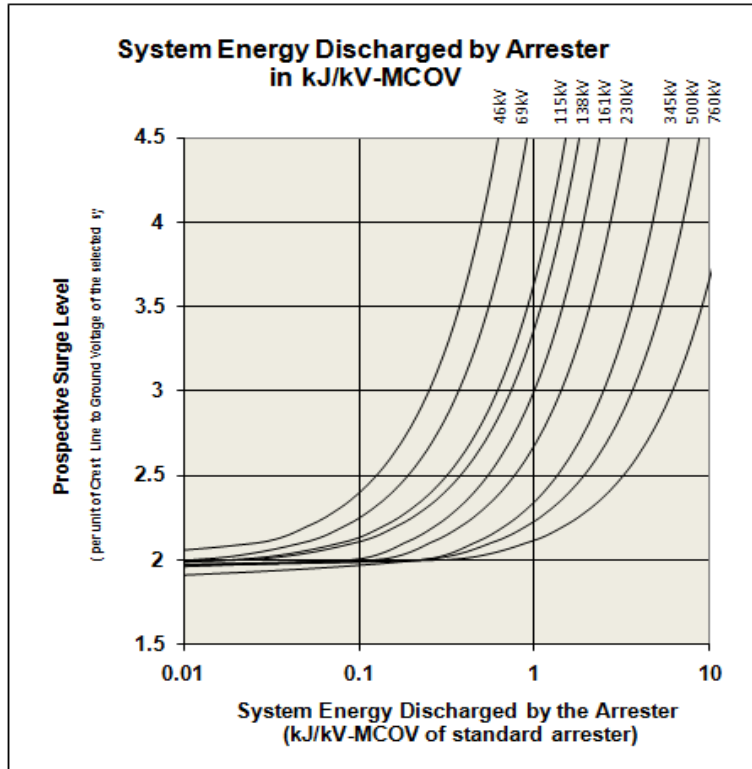


Figure 5 Energy Injected into the arrester from a switching surge (100 mile line, minimum MCOV)

Shunt Bank Re-strikes and Arrester Energy Requirements.

As stated earlier, if a cap bank experiences a prestrike or restriking, stored energy in the caps can result in a switching surge. It is estimated that from this type of switching surge, a 3pu surge is the maximum possible amplitude. Figure 6 is derived using equations given in 60099-5 section 3.2.3.3. Also for the curve derivation the minimum MCOV arrester for each system is used.

The fundamental purpose of arresters on transmission systems are to mitigate the effects of

switching surges. They will also mitigate the effects of lightning and if dimensioned properly for one, they will mitigate properly for the other.

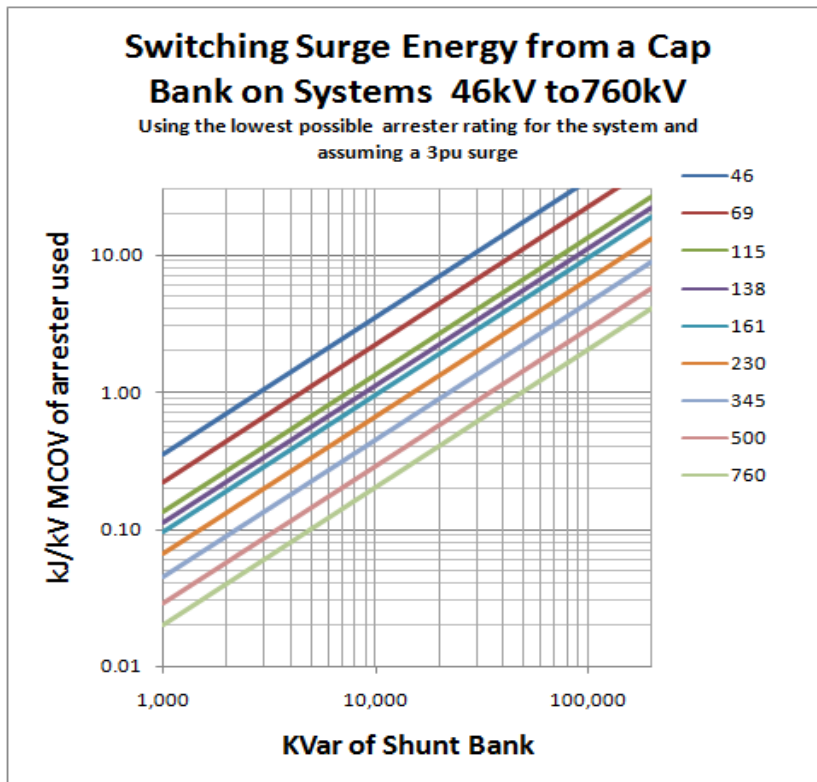


Figure 6 Shunt Bank Energy Discharge Levels

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- [Infrared Thermometer](#)
- [Guide for Selecting an Arrester Field Test Method](#)
- [VI Characteristics](#)
- [The Externally Gapped Arrester \(EGLA\)](#)
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