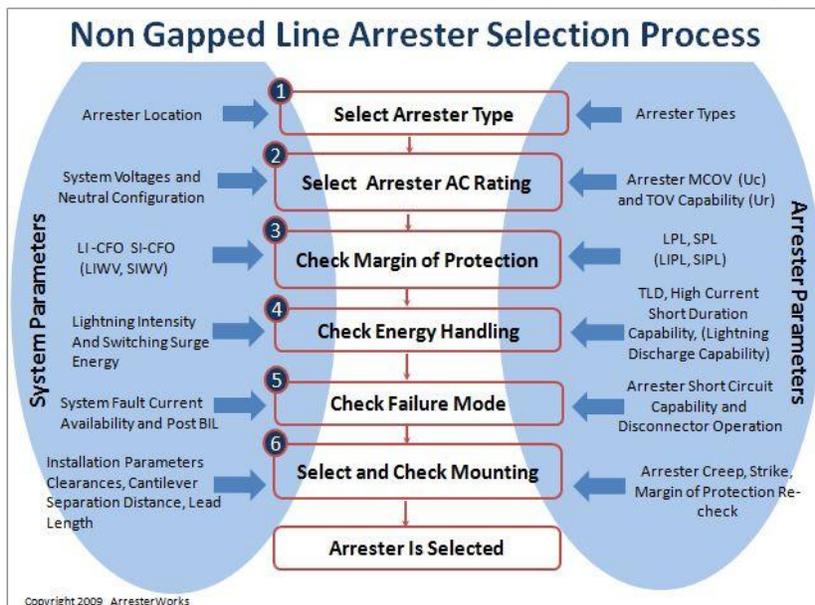
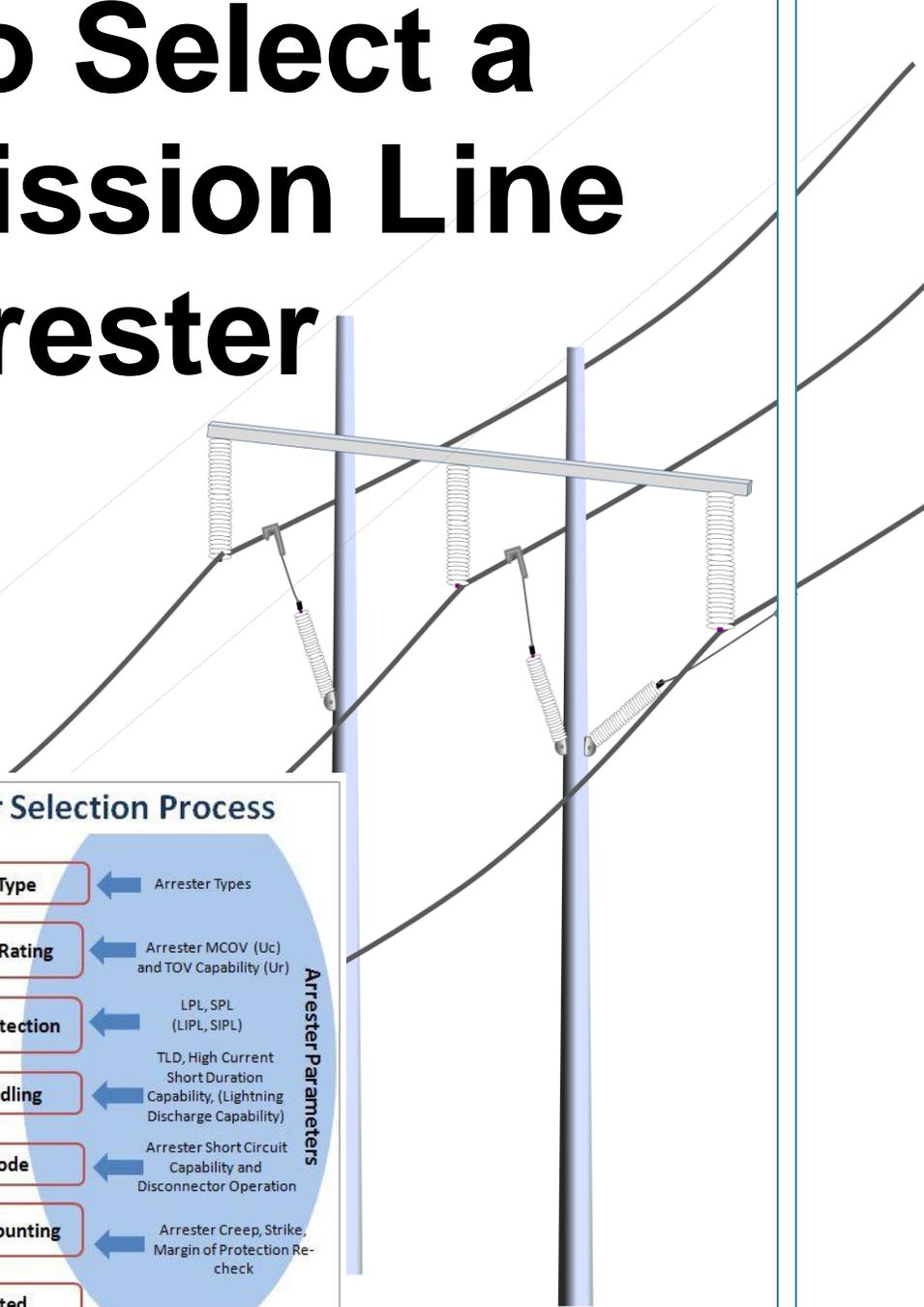


ArresterFacts 017a

How to Select a Transmission Line Arrester



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Introduction

Selecting any arrester for an application can be as easy as copying the catalog number from the last inquiry your company submitted or as difficult as running a full blown system lightning/switching surge study. The objective of this ArresterFacts is to help the novice as well as the experienced specifier of transmission line arresters (TLA) by taking you through the necessary steps in TLA selection. Along with outlining the selection steps, it offers rationale and guidance in each step. This is the second ArresterFacts in a series on transmission line arresters. The first in the series is titled "[What is a Transmission Line Arrester](#)" and can be found in my [ArresterFacts Library](#) on

[ArresterWorks.com](#). The third in the series will focus on how to determine where to install transmission line arresters.

What is a Line Arrester

Before we can define a line arrester, allow me to clarify the name. This power system component has been given several names over the years. Recently in the IEC community the term has been divided into two more distinct terms, NGLA (non-gapped line arrester) and EGLA (externally gapped line arrester). In Cigre and other circles, it is referred to as an LSA (line surge arrester). In the IEEE regions, it is often called a TLA (transmission line arrester) and LA (line arrester or lightning arrester). This process will focus on the NGLA and I will refer to this

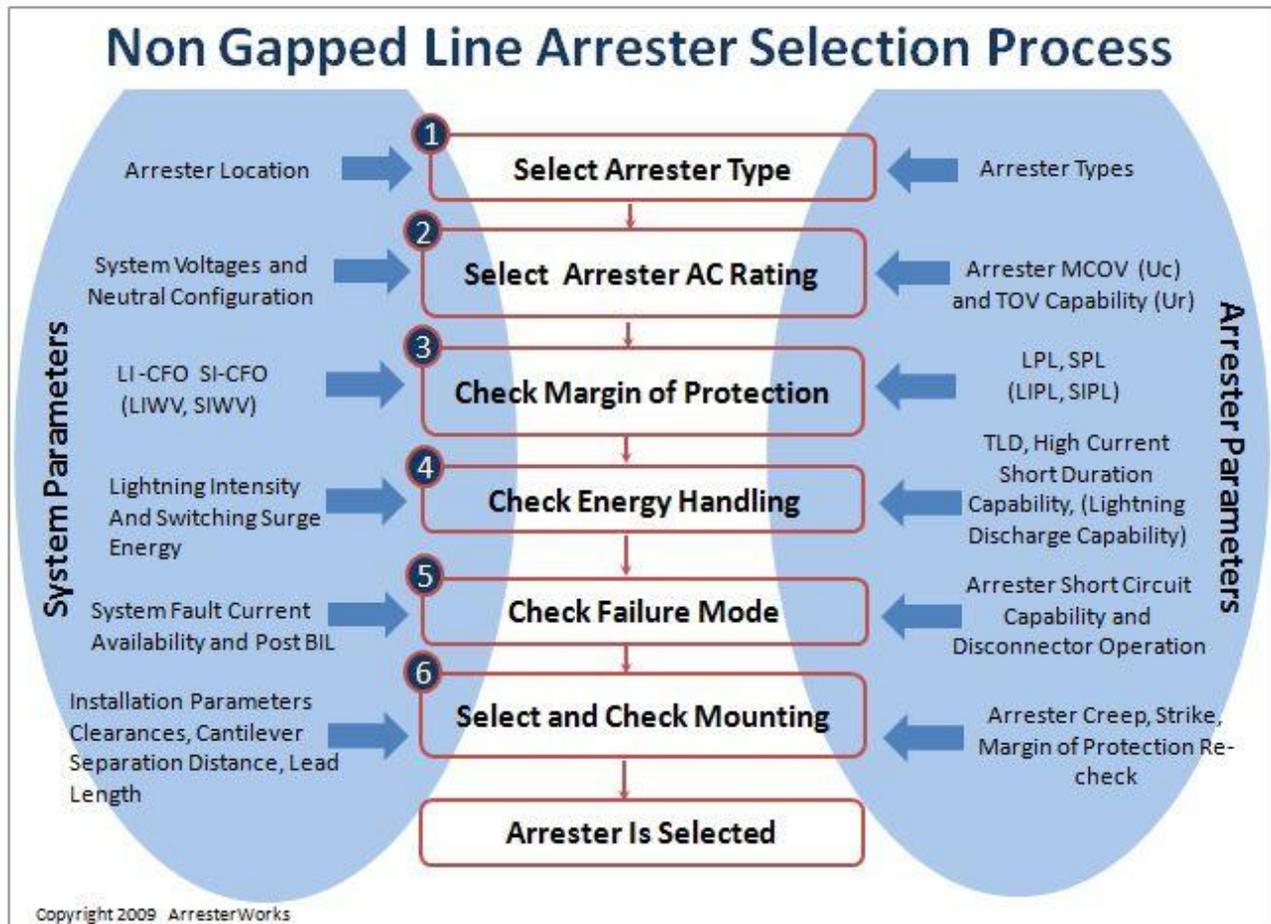


Figure 1 Transmission Line Arrester Selection Process

arrester using this acronym. A future ArresterFacts covering the EGLA selection will be published later this year.

Even though the NGLA has been in existence for many years, it is still a product that is difficult to obtain information on. If you check the IEC standards you will not find any definition or reference to a NGLA or transmission line arrester. In the IEEE standards the term line arrester is defined as follows: "A line arrester is a type of arrester that is commonly applied to power systems to reduce the risk of insulator flashover during a lightning transient." I would like to add it may or may not be used to protect the insulator from other types of transients such as switching surges. A line arrester is not generally used to protect any equipment other than line insulators.

The NGLA Selection Process

The process of selecting an NGLA can be very daunting for the novice and even for the expert in power systems since it is done so seldom. Both IEEE and IEC application guides give versions of how to select a standard arrester however neither one covers the selection of a NGLA arrester.

The fundamental process of selecting an arrester for a particular application is to determine the characteristics of the system and location where the arrester will be installed, and then select the arrester characteristics that will meet the requirements of the application. To facilitate the selection of an NGLA, I have configured a clear straightforward 6-step process that considers all issues. Using the process as shown in Figure 1 you can see that for each step in the selection process, the system parameters are determined first and then the corresponding arrester parameters are selected.

Step 1 Selecting the Arrester Type

The selection process begins with choosing the arrester type that appears to best meet the needs of the application. Even though this is fundamentally one of the most important steps it is routinely left out of procedures in the standards. For example when the objective is to select an arrester for a 33kV sub-transmission line, there is no need to think about Class 5 arresters that would ordinarily be installed on a 400-800kV lines. This initial choice can easily be modified if an issue arises in upcoming steps.

The important actions of this step are:

1. Identify the approximate location of the arrester in the system.
2. Review available arresters and their characteristics data.
3. Make the Initial Selection of the Target Arrester Family

Another important consideration when selecting an arrester to be installed on a transmission line or sub-transmission line is to consider the housing type. Whenever possible, first priority should be given to the polymer housed type arresters as shown in Figure 7, since they often are lighter and more easily mounted on a transmission line than porcelain housed arresters.

Step 2 Selecting the AC Rating

Since most arresters are energized with an AC voltage throughout their life, this step is critical and cannot be skipped. An incorrect AC rating could result in premature arrester failure and a system outage. The MCOV or U_c of a TLA is the AC rating of concern. This is the maximum AC voltage that can be applied continuously across the terminals of the arrester. For NGLAs this AC rating must be checked for temporary overvoltage (TOV) withstand capability and may be adjusted higher to meet the TOV requirements. The initially selected AC rating of an NGLA is generally a minimum

value and in subsequent steps, it may be increased to meet other constraints. Significant considerations in this step are:

2.1 Determine maximum steady state system line-ground voltage.

This is defined as the nominal phase to phase voltage divided by 1.73 times the regulation error. For example, on a 760kV transmission system, the nominal system phase to phase voltage is 760kV therefore the line to earth voltage would be 440kV. Since all systems have some regulation error, this too must be taken into consideration. If the regulation error is 10%, then for example, on the above system, the line to ground voltage could be $440 \times 1.10 = 485\text{kV}$. The MCOV/ U_c of an arrester for this system, at a minimum, should be 485kV before TOV is taken into account.

2.2 Select an arrester MCOV/ U_c that is equal or greater than the voltage determined in 2.1:

A general IEC practice is to select a U_c that is 1.05 times the highest continuous line to earth voltage. The IEEE practice is that MCOV should be \geq than the level in step 2.1. Since this arrester is only eliminating insulator flashover, another 10% can be added to this level to reduce the energy the arrester adsorbs during a switching surge if desired.

2.3 Determine the maximum amplitude and duration of potential overvoltages on the system:

This is one of the most difficult steps in selecting any arrester. The difficulty arises from the fact that determining the amplitude and duration of temporary overvoltage events is not an easy task. For arrester selection, the overvoltages of interest are ones that occur during an earth fault on the system. During an earth fault on a 3 phase power system, the voltage on the unfaulted phase will rise to levels that can easily damage an arrester if not promptly removed by a breaker operation. The neutral earthing configuration is the determining factor in calculating the amplitude of the overvoltage during this type of fault on the system.

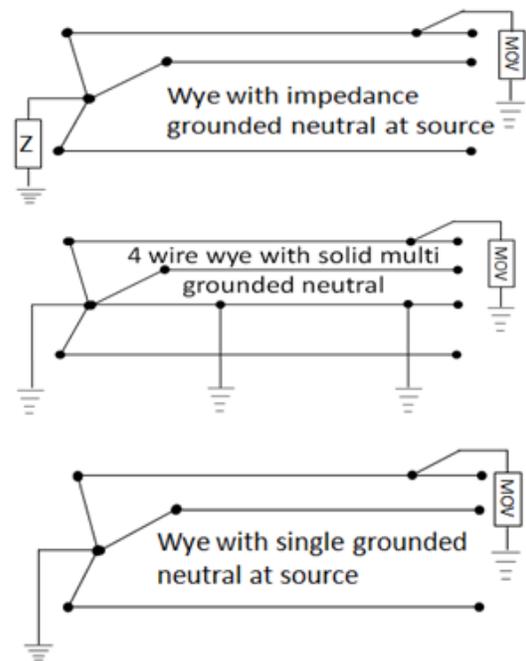


Figure 2 Neutral configurations of Importance

Figure 2 shows examples of system configurations of importance. For distribution systems, the worst case amplitude can be determined by the earthing configuration but seldom is the duration clearly understood. Due to the lack of data for these applications, the durations are estimated based on the system type. Figure 3 gives an overview of the typical worst case scenarios.

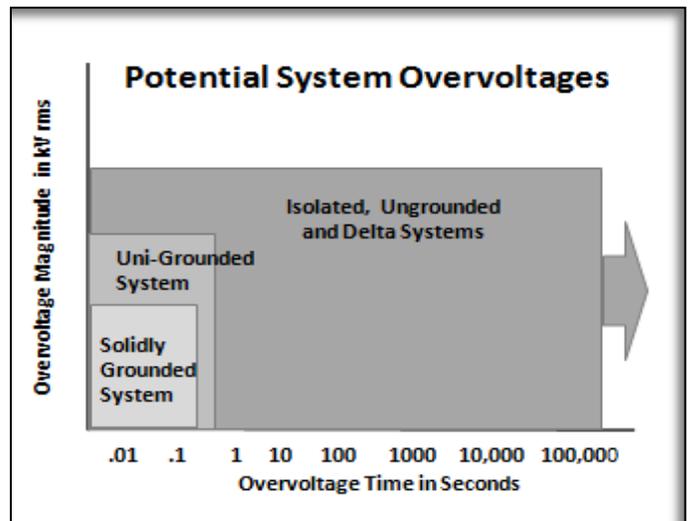


Figure 3 Typical TOV Amplitudes and Duration

For transmission lines and substations, the amplitude and duration are much better

understood and the worst case scenario is seldom used. The systems are most often modeled and the potential TOV levels and durations are available from these fault current studies. Use these amplitudes and durations to compare to the arrester TOV withstand curves in the next step as shown in Figure 4.

2.4 Check that the arrester selected in 2.2 can withstand the overvoltages determined in 2.3 using the arrester TOV curve.

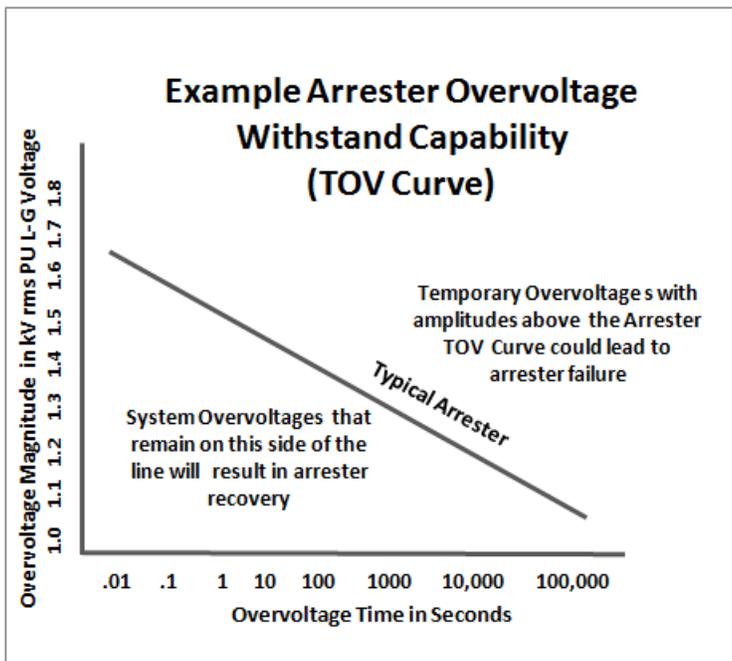
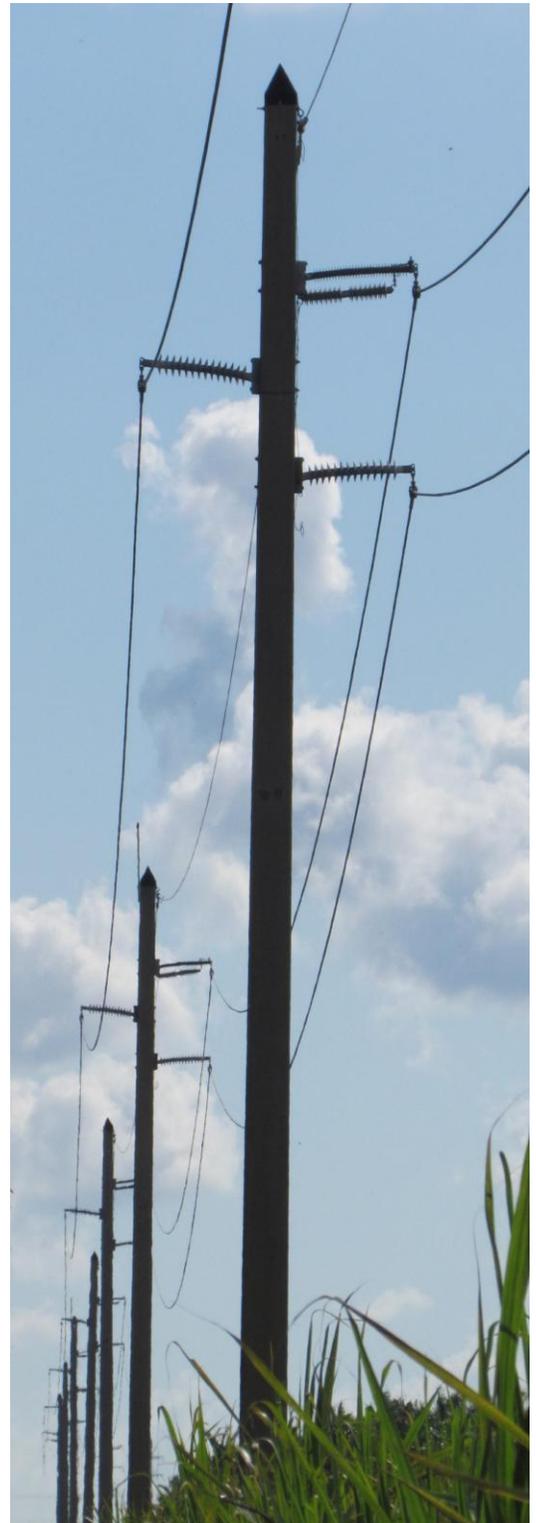


Figure 4 Arrester TOV Curve

Once the arrester MCOV/Uc rating is selected, the characteristics of that arrester will then be tested against other constraints in the selection process. If the other constraints require an increase in the Uc or Ur to meet their requirements, then the AC rating in this step will be overridden.



Step 3

Check the Margin of Protection

The fundamental purpose of a transmission line arrester is to reduce the risk of insulator flashover due to either switching surges and/or lightning surges. The margin of protection is a standard means of evaluating the level of risk of this flashover. If the arrester clamps the voltage at a fraction of the Critical Flashover Voltage (CFO) of an insulator, then the risk of insulator flashover is quite low. Neither the IEC or IEEE standards make a recommendation as to what is adequate margin of protection for line insulators. They do recommend that the arrester residual voltage not be more than 80-85% of insulator BIL in stations. A graphic representation of margin of protection calculations is shown in Figure 5.

The fundamental parts to the step in the Margin of Protection selection process are:

- 3.1 Determine the Insulation Withstand Characteristics
 - 3.1.1 LI CFO (LIWV)
 - 3.1.2 SI CFO (SIWV)
- 3.2 Determine Arrester Protective Characteristics
 - 3.2.1 Lightning Protective Level (LIPL)
 - 3.2.2 Switching Protective Level (SIPL)
- 3.3 Determine if there is any Lead Length Effect
- 3.4 Calculate Margin of Protection
 - 3.4.1 Lightning Protection Margin
 - 3.4.2 Switching Protective Margin

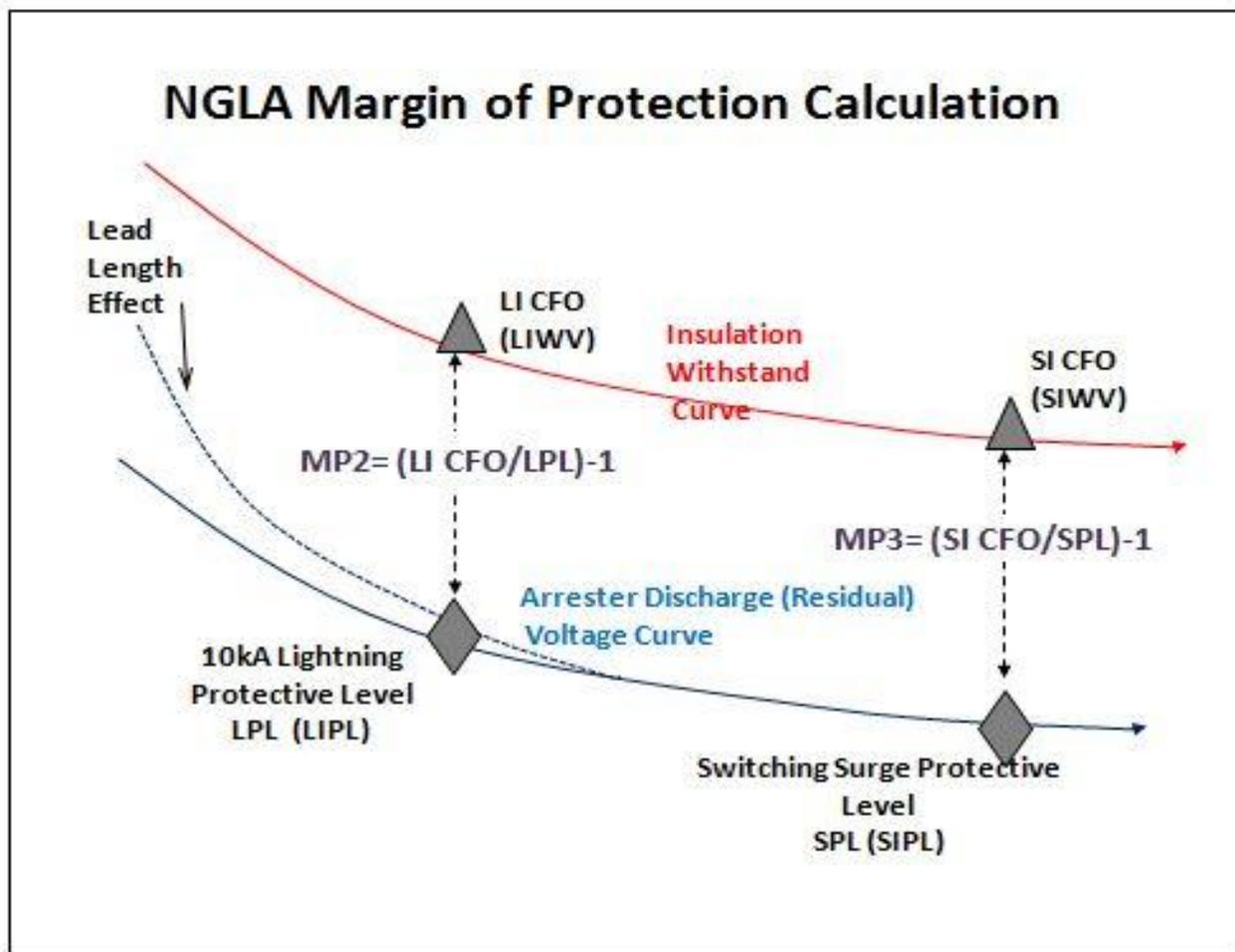


Figure 5 Arrester Insulation Coordination Formula

Step 4 Check Energy Handling Capabilities

This is another very important part of the selection procedure of an NGLA. During this consideration, the purpose of the arrester installation must be well understood.

Considerations that need to be taken into account in this part of the selection are:

System with OHGW

If the arrester is to be used on a system that is equipped with an overhead ground wire (OHGW), the energy requirements of the arrester are much lower than if it is not equipped with the OHGW. This is due to the fact that most of the lightning current during a stroke is shunted to ground via the down conductor and only 10-20% of the lightning current flows through the arrester on to the phase. If the footing resistance of the tower is quite high, more current will be diverted through the arrester and into the phase but in the worst case, most will still flow to earth instead of on to the conductor. For configurations less than 300kV system voltage, a distribution class arrester is all that is needed for ample reliability and protection. Using a distribution class arrester for lightning protection where little switching surge energy is available is standard practice in the US and Japan. If a more conservative rating is desired for this configuration, a lower station class arrester can be used, but is not necessary. For systems above 300kV, the class of arrester will likely be higher than a distribution class arrester due to switching surge energy demands.

Systems without OHGW

If the NGLA application is on a system without an OHGW, the full lightning stroke is likely to pass through the arrester. Since a very low system outage rate is desired, then it is suggested that an Intermediate or Station Class arrester be used to protect this type of system. Distribution arresters are an option of course, but to ensure that the arrester has an extremely low risk of failure due to a high current stroke, it is

better to use an Intermediate or Station Arrester.

Switching Surge Energy Considerations

If the NGLA application is to control surges generated during switching events, the potential switching surge energy of the system needs to be calculated and compared to the energy handling capabilities of the arrester. For distribution systems and transmission systems below 230kV, the potential switching surge energy of the system does not exceed that of a Distribution class arrester. Therefore, when considering switching surge control on these systems, there is no need to consider higher energy ratings.

For systems above 230kV, a precise energy dissipation requirement can be determined using transient analysis software or an estimate can be made using simple formulas found in either IEC 60099-5 or IEEE C62.22. IEC 60071-2 offers an excellent estimation of what magnitude of switching surges to expect on power systems from normal energization operations. According to this standard, switching surges can range from 1.2pu to 3.5pu depending on the system and action during the event. This translates into energies between 4-10kJ/kV MCOV/U_c which is well within the range of most station arrester designs.

IEC Lightning Impulse Discharge Capability Test

For arresters applied to systems up to 52kV, the High Current Impulse capability is the only means of classifying the lightning impulse capability. For all distribution-10kA arresters, the designs must be capable of withstanding 100kA 2x10 μ s impulse at least 2 times. For 5kA arresters, this high current capability is reduced to 65kA.

For arresters applied to systems 52kV and above, a special test requirement and withstand capability is available to the specifier of arresters. Since 2006, all line surge arresters applied to systems above 52kV are required to be tested per the

Lightning Impulse Discharge Capability test outlined in IEC 60099-4 Annex N. This new lightning impulse capability test uniquely tests the arrester with an impulse that crests in 200uS and is sinusoidal in shape. This test is unique because the arrester does not pass or fail, they just fall into one of many available categories of withstand. A further unique feature of this test is that the arrester withstand can be measured in either energy (joules) or in Charge (A-Seconds). A Distribution type arrester can have ratings as high as .5 coulombs and a Station Class arrester approximately equal to 3.6 coulombs of charge transfer. When selecting an arrester for line protection above 52kV, this characteristic should be considered.

the arrester is overloaded, it often becomes a short circuit to the system to which it is applied. If this happens, the power system will supply all potential fault current to the circuit including the arrester. If a shorted arrester experiences more power-frequency fault current than it was designed to handle, it could eject very hot components at significant distance and velocity. A fragmenting overload is a highly undesirable event. To insure that this type of overload event does not occur, the short circuit current withstand capability of the NGLA needs to be higher than the available fault current of the system. The short circuit rating of all arresters is found on the nameplate of the arrester and in the manufacturing literature.

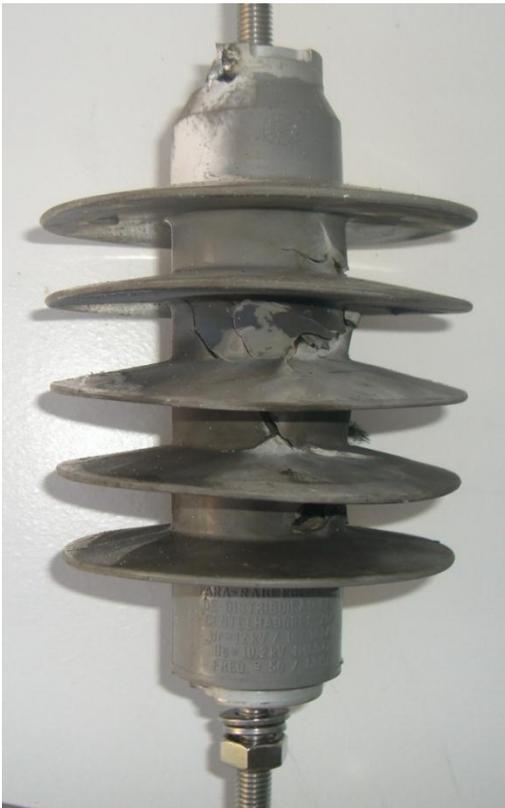


Figure 6 Acceptable Failure Mode



Figure 7 Undesirable Failure Mode

Step 5 Check Failure Modes

This is another important arrester selection steps for an NGLA if the arrester is located near highways or occupied buildings. If

Typically distribution systems can supply only 10kA fault current, occasionally higher. Therefore the NGLA for distribution systems needs to be 10-15kA maximum. For transmission lines above 50kV, the available fault current can be as high as 65kA with grounded systems, and low as a

few hundred amps for impedance grounded or floating delta systems. When an arrester has been subjected to an overload, it should look similar to Figure 6 when the event is over. However if the system ground fault current exceeds the rating of the arrester what is seen in Figure 7 may occur which is highly undesirable.

The user needs to know the available fault current on the system to which the arrester is to be mounted. This data is readily available from the relay or system analysis personnel.

Step 6 Mounting Considerations

Line surge arresters are stressed physically more than any other arrester. This is because they are mounted on or near towers that are very exposed to the elements. Vibration, wind, torque, impact stress and animal abuse are the main



Figure 7 Lead Reinforcement with a chain

reasons for the high stresses. For these afore mentioned reasons the selection of mounting components is very important and often times the most difficult part of NGLA selection. Also since there are so many tower configurations the mounting requirement for each installation is unique. The following are specific and important mounting features to consider.

Vibration: Presently there are no standard tests to determine if an NGLA can withstand vibrations found at tower tops and on conductors. It is advised that the user discuss this with suppliers.

Disconnecter Strength: If the NGLA is equipped with a disconnecter it is imperative that the mounting does not stress this component beyond its capability. If the arrester is to be mounted with the disconnecter in any way other than the weight of the ground lead, then this should be discussed with the supplier. Some disconnecters are designed for this type of stress, but not all of them.

Lead Swing: This is one of the biggest reasons for NGLA issues since a swinging lead not only can break itself, but it can also transfer the mechanical stresses to the other components. Again there is no standard for this issue so it must be discussed with the supplier. One solution that is often used is to string the lead through a chain that reduces the frequency and amplitude of the swing as well as reduces the direct strain on the lead. Figure 7 shows this arrangement.

Bird Droppings: Just like an insulator, if the NGLA is to be mounted where it is subject to bird droppings, use the same precautions you would if it was an insulator.

BIL Restoration: If the NGLA had been overloaded and failed, it should be mounted so that it will disconnect allowing full system BIL to be restored. This is accomplished by mounting the arrester so that it or its lead will swing out of the way if it becomes a short circuit.

Photo Compliments of Hubbell Power Systems

Summary

Once you have completed all 6 steps of the NGLA selection process, you will likely have the optimum arrester chosen for the application. There may be times that this process will need to be completed several times before the final arrester is chosen. When the arresters are installed, you will be

pleased with the results. NGLAs are major reliability enhancers for power systems.

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