Lightning Striking on Surge Protector and Checking its Reflection

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ABSTRACT

Lightning and switching fluctuations are the main causes of voltage increase in the power system. If any high voltage transmission tower is struck by lightning, line insulation and equipment connected to the power system may be damaged. Surge arresters of many types may be used to protect transmission line insulators and electrical system equipment connected to the transmission tower. In this article, we will first explain the necessary and necessary points, and then we will do the simulation and express the results.

Keywords: Lightning, Surge Protector, transmission tower, surge arrester.

1-Introduction

Lightning is the phenomenon of electrical discharge between charged cloud to ground, between clouds or between the different charge centers of the same cloud. lightning is the most common and frequent cause of over voltage and insulation failure in power system. lightning and switching surge are the main reasons for outage in power transmission and distribution system [1].

Characteristics of lightning over voltage is important to be studied to design protection scheme for the power system. it is well known that the probability of a structure being strike by lightning will increase with the increasing of its height. The height of high voltage transmission tower is another major issue for which lightning got enough short distance for direct strike on tower top [2].

2- SURGE PROTECTION CIRCUIT PRINCIPLE and DESIGN

Surge protection circuit is the one referred by many as protector for voltage spikes in AC grid lines; however, it is not limited particularly in AC grid lines. Surge protector or surge protection device is a device that will provide surge suppression or voltage spike suppression so that sensitive devices will not get damage.

Surge protector can handle voltage spikes as high as some kilovolt range (depending on the type of surge protection device). There are also surge suppressors that are intended only to handle few hundred volts, and so on. Although surge protector is design to withstand to high voltage spikes in a short period of time, it is not rated to handle high voltages in longer duration.
Surge in general is a sudden increase in level or magnitude from a normal or standard value. In electricity, surge is often used to describe voltage transient, voltage surge or voltage spikes. Voltage surge or spike or transient is not a permanent event. It is occurring only within a short period of time but more than enough to destroy devices if there is no counter measure.
Voltage surge is not only present in power lines but also in circuits with inductive property. However, the voltage surge in the power lines is the most destructive one as it can go as high as few kv range.

Below illustration shows a voltage surge on the AC power line in Figure 1 [3].
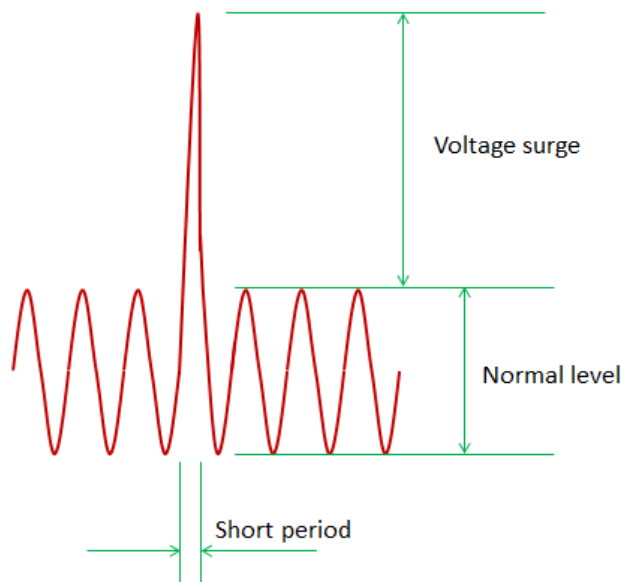

Figure 1 Single line distribution network

Surge protector for AC line transients is installed commonly in houses, offices and buildings to prevent appliances or devices from damage. It should be installed in the section where all devices or appliances get their sources. By doing so, all appliances will be protected by line surges and spikes. This approach is called universal surge protection. Universal surge protector may not be needed if all the appliances or devices have its local surge protection circuit.

3- Effects on electrical installations

Lightning damages electrical and electronic systems in particular: transformers, electricity meters and electrical appliances on both residential and industrial premises.

The cost of repairing the damage caused by lightning is very high. But it is very hard to assess the consequences of:

• disturbances caused to computers and telecommunication networks;

• faults generated in the running of programmable logic controller programs and control systems.

Moreover, the cost of operating losses may be far higher than the value of the equipment destroyed. Lightning is a high-frequency electrical phenomenon that causes overvoltage's on all conductive items, especially on electrical cabling and equipment. Lightning strikes can affect the

electrical (and/or electronic) systems of a building in two ways:

• by the direct impact of the lightning strike on the building.

• by indirect impact of the lightning strike on the building.

• A lightning stroke can fall on an overhead electric power line supplying a building. The overcurrent and overvoltage can spread several kilometers from the point of impact.

• A lightning stroke can fall near an electric power line. It is the electromagnetic radiation of the lightning current that produces a high current and an overvoltage on the electric power supply network. In the latter two cases, the hazardous currents and voltages are transmitted by the power supply network.

4- SURGE ARRESTERS MODELS FOR FAST TRANSIENTS

By creating a model to determine the behavior of a metaloxide surge arrester to lightning strikes it is important to take into account their dynamic behavior. This is represented by non-linear V -I characteristic. The waveform of the residual voltage has a strong dependence from the front time of lightning current, increases as the front time of the current is reduced and reaches the peak before the peak of lightning current .

The dynamic effect becomes significant for currents with a front time of 8f.ts or less. The group of IEEE indicates that the residual voltage is increased by 6% when the front time is reduced from 8 to 1.3 us. For front time less than 4 us, undesirable spikes are present in the waveform, which sometimes exceed the maximum value of the residual voltage of the lightning arrester. The magnitude of these peaks is affected by the parasitic inductance, which usually is usually caused by the loops generated in the measuring device .

A lot of contributions have been carried out to propose or improve models to simulate the dynamic surge arrester performance. In this We will describe some of these modelings

The main problem in modeling is determining of model parameters. When creating a circuit model for studying the behavior of lightning arresters, the reliability of the simulation is proved when the selected features take into account the front time or the frequency in order to have the expected results.

IEEE model

The circuit model of the lightning arrester proposed by the IEEE is shown below:
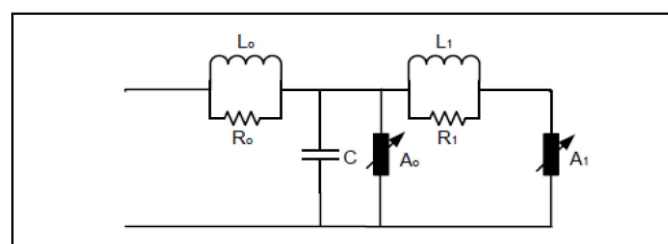

Figure 2 Circuit model of the lightning arrester by IEEE

For the model proposed by the group of IEEE, the nonlinear V -I characteristic of a lightning arrester is presented as two parts of nonlinear resistors Ao and Al (Figure 1). The two parts are separated by an R-L filter that presents small impedance for currents with

slow front times and the two nonlinear resistors are connected in parallel. For currents with fast front times the impedance is high and this results in more current to pass through the nonlinear resistor A0. Since A0 has a greater tendency for a given current than the A1, the result is that the circuit model generates higher voltage which corresponds to the dynamic behavior of the lightning arrester. are suggested fonnulas for choosing the model parameters. These formulas are based on the height of the lightning arrester and the number of parallel columns of metal disks. The inductance L1and the resistance R1 are the filter between the two non-linear resistors.

$$L1 = 15 \ d/n \ , \ uH$$

$$R1 = 65 \ d/n \ , \ \Omega$$

Where d is the estimated value of height of the lightning arrester in meters and n is the number of parallel columns of metal oxide of the lightning arrester.

The induction Lo represents the inductance associated with the magnetic fields in the vicinity of the lightning arrester. The resistance Ro is used to stabilize the mathematical processing when the model is analyzed on the computer. The capacitance C represents the capacity between the two edges of the lightning arrester.

$$L0 = 0.2d/n \ , \ uH$$

$$R0 = 100d/n \ , \Omega$$

$$C == 100n/d \ , \ pF$$

Pinceti-Giannettoni model

The Pinceti-Giannettoni circuit model (Figure 3) is a simplified IEEE model. The calculation of the V-I characteristic is the same as that of the IEEE model. But the determination of the parameters is based on the electrical characteristics of the lightning arrester.
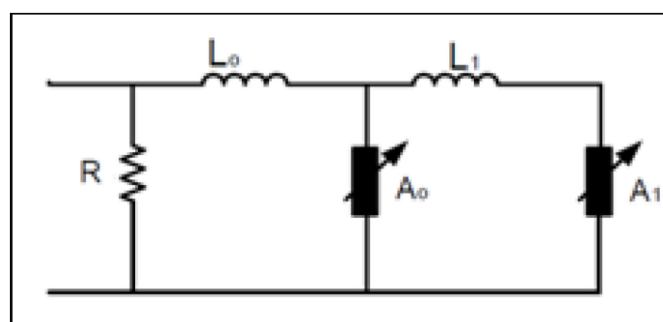

Figure 3 Circuit model of Pinceti-Giannettoni

Comparing the two models, in Pinceti-Giannettoni's model the capacity has been eliminated because its influence is negligible for the model's behavior and the two resistors that are parallel with the inductances have been replaced by a resistor R (about IM!1) between the edges of the input in order to avoid problems in numerical simulation. The

operating principles of the model are more or less similar to the model of the IEEE and based in two rules:

• The identification of nonlinear resistors Ao and Al is via the current-voltage characteristic presented above in the model of the IEEE and refers to the maximum

residual voltage measured during a test with impuls current 10kA.

• The determination of the inductances can be done by

using the following equations:

$$L_0 = \frac{1}{12} \frac{V_{r1/T_2} - V_{r8/20}}{V_{r8/20}} V_n$$

$$L_1 = \frac{1}{4} \frac{V_{r1/T_2} - V_{r8/20}}{V_{r8/20}} V_n$$

Vn   the rated voltage of the lightning arrester

Vr,1/t2 residual voltage for lightning current of 1/T2 uS, 10kA

Vr,8/20 residual voltage for lightning current of 8/20 us, 10kA

This process does not take into account the physical characteristics of the lightning arrester, but only the electrical data given by the manufacturer. The proposed criteria for the parameter's selection are based only on the electrical characteristics of the samples and this is the difference among other models that have been proposed. The equations are based on the fact that the values of parameters Lo and LI are associated with the role that these elements have in the model. In other words, since the inductor identifies the dynamic behavior of the lightning arrester during lightning currents with fast rise time, it is reasonable to define the values of these parameters to manufacturer's data related to lightning arrester's behavior during a potential lightning strike. Errors between measured and calculated by this model residual voltage are low for lightning currents with front time from 1 to 30 uS. The error decreases when the rise time is up to 8 us.

Fernandez Model

Figure 4 shows Fernandez arrester model. This model is based on IEEE arrester model too. However, the inductance value in the inlet can be neglected and resistance is set as 1MΩ.
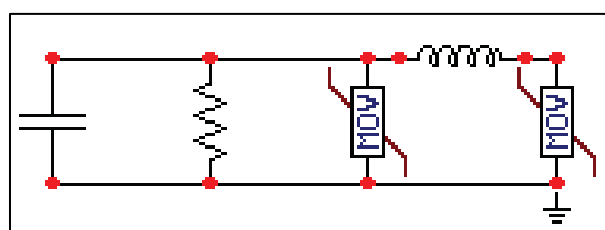

Figure 4 Model of Arrester Fernandez

The Fernandez arrester parameter could be calculated by:

$$C = \frac{1}{55} \cdot \prod \frac{\frac{V_{r8} - V_{ss}}{20}}{\frac{V_{r8}}{20}} \cdot V_n$$

$$L_1 = \frac{2}{5} \cdot \frac{\frac{V_{r8} - V_{ss}}{20}}{\frac{V_{r8}}{20}} \cdot V_n$$

Vn = Voltage ratings of arrester, kV

VSS = Residual voltage for circuit surge current 500 A

Vr8/20 = Residual voltage for surge current 10 kA (8/20 μs)

5- MODELING AND SIMULATION

In this model, there are two non-linear resistors with two inductions with L0=7.52E-3 and L1=22.58 (H) and large parallel impedance with R=1MOHMS. The source voltage is 240 V with a frequency of 50 Hz.

The transformer steps up the voltage to 400K volts for better simulation calculations. The current of two non-linear resistors is measured and shown in the range and has a final voltage.
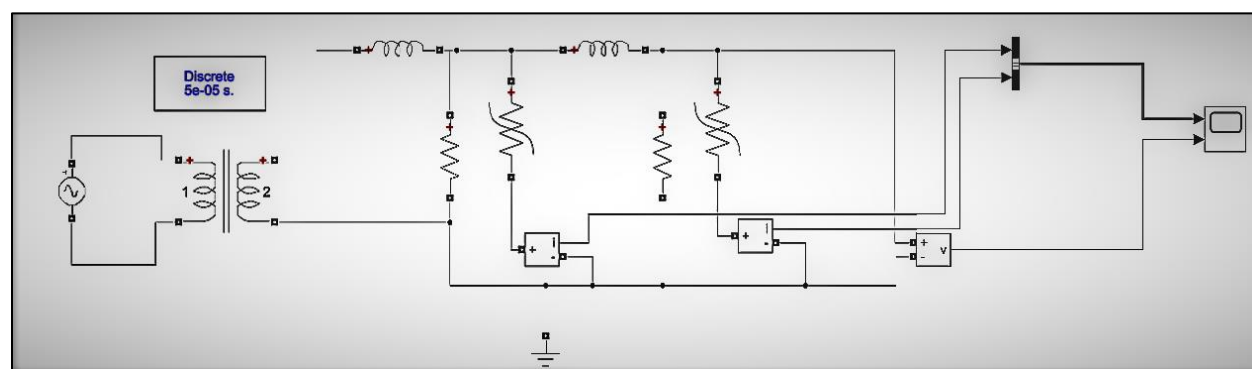
Figure 5 single phase lightning arrester model

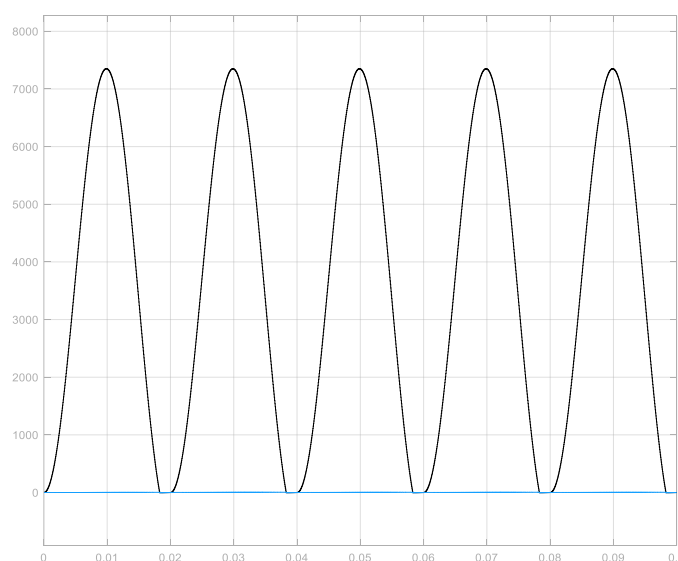In the following, figures 6 and 7 respectively represent the current waveform in full and in detail.
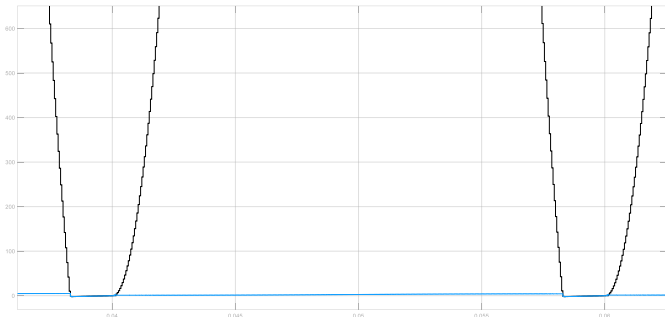
Figure 6 current waves

Figure 7 closer view of current waves.

In the following, figures 8 and 9 respectively represent the voltage waveform in full and in detail.
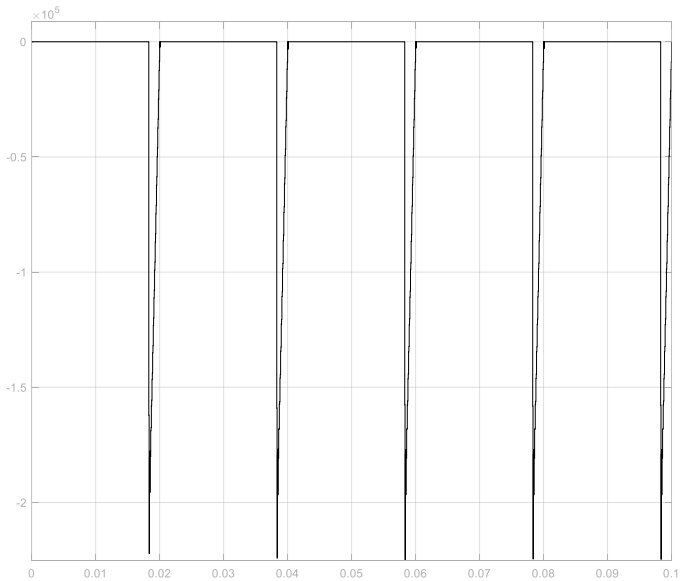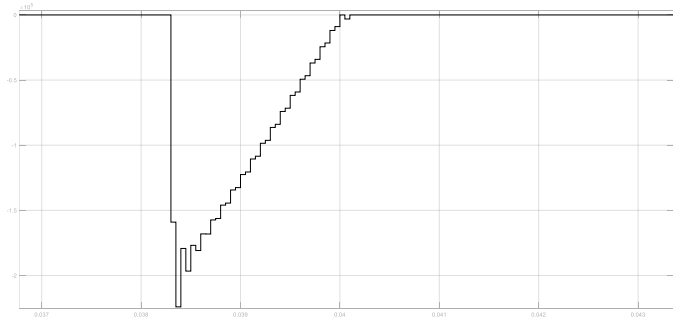

Figure 8 voltage wave

Figure 9 closer view of voltage wave

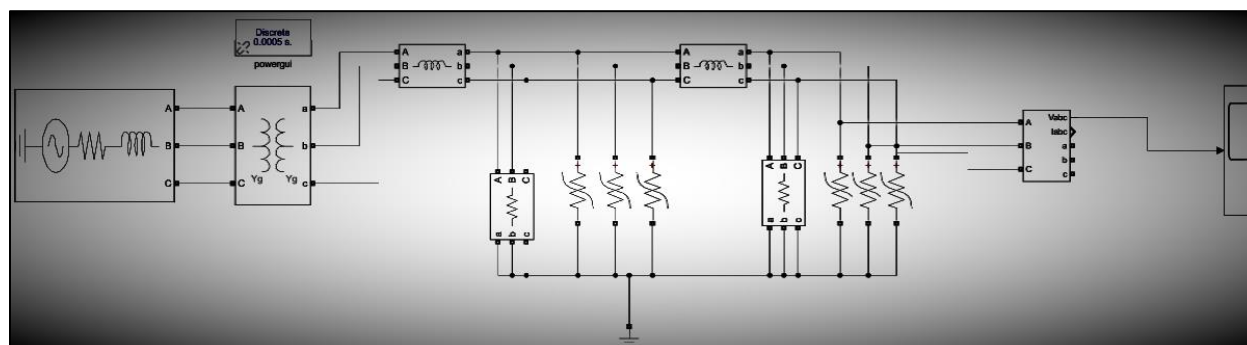Finally, in the next part, the 3-phase circuit is analyzed as show as in Figure 10.

Figure 10 3phase lightning arrester model

The transformer is 250kva with 25kv/400kv and 50 hz frequency. the resistance and the inductor value are as the same above circuit. the main source is 25 kv.
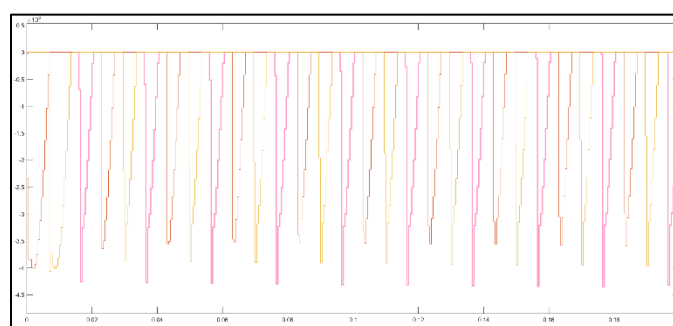

Figure 11 voltage wave diagram of circuit

As can be seen in this image and the images above, the wave has some disturbances and uncertainties that cause the lightning wave. Finally, the wave can converge to the nominal voltage and current.

6-Conclusion

In in this article has talk about kind of the lightning arresters and how it works with two MATLAB simulation (single phase and 3 phase).when the lightning could hit the phase wire, it may have transient conditions and have the asymmetrically in voltage under the e-3 second .and after exit the lightning the line would work normally without any disturbance .but when it hit and connect to the surge arrester or lightning arrester it has the ground impedance and going to ground that over current . if in the before situation, the lightning would longer or harder, the relays have to open the line braker.

7-Reference

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[3] IEEE Std C62.22a (2013). IEEE Guide for the Application of Metal- Oxide Surge Arresters for Alternating-Current Systems.