# ANALYSIS OF TRANSIENT OVERVOLTAGE IN MEDIUM VOLTAGE DISTRIBUTION

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*Abstract* – **This paper presents the analysis of transient overvoltage in medium voltage distribution. Transient overvoltage is one of the common power quality disturbances in electrical distribution result from the unavoidable effects of lightning strikes. The objective of this paper is to analyze the performance of shield wire and surge arrester when lightning strike on phase wire and distribution substation. This analysis is performed by varying the value of lightning current stroke at medium voltage distribution. PSCAD/EMTDC software program is used to carry out the modeling and simulation works. The result of the significant role of shield wire and surge arrester in protecting overhead distribution lines is analyzed.**

*Keywords – lightning, transient, MV distribution lines*

## 1. Introduction

The lightning is a natural phenomenon generated during thunderstorm by electrostatic discharge which produced electromagnetic radiations[1]. Lightning overvoltage are one of the most frequent causes of the medium voltage distribution system outage[2]. Also a major cause of fault on typical overhead distribution lines and a powerful natural electrostatic discharge produced during a thunderstorm. Transient overvoltage causes power system faults that eventuate into supply interruptions and voltage sags throughout the distribution network [3]. There are three classification categories of lightning discharge which is intra cloud lightning, cloud to cloud lightning and cloud to ground lightning[4]. The cloud to ground discharge has been considered for overhead distribution lines design.

For lightning course, it can divided into strike either direct or indirect strike. Considering direct strike, an impulse lightning current is injected into an overhead line section which lead to cause surge voltage propagate towards the power transformers, cables and the rest of the system transformer. Besides that, lightning can induce currents and voltage on power lines without touching them known as an indirect strike[3]. The large electromagnetic fields produced by lightning discharge can couple into the power network and produce induced transient[3]. Mostly the major cause of contribution for line tripping could be flashover of insulator due to transient overvoltage in the medium voltage network by lightning. There are many types of behavioral pattern and performance of medium voltage network during transient overvoltage by depend on parameter such as line equipment, range of surge arrester and availability of shield wire also lightning flash density.

In order to improve the quality of power supply, it very important to study of transient overvoltage and mitigation measure since transient overvoltage plays a major impact to the reliability of medium voltage network.

## 2. Methodology

This project represent to analyzed cause of overvoltage in medium voltage distribution. According to the flow chart in figure 1, the step of analyzing the cause of overvoltage in a medium voltage system consider as the first step. PSCAD software is used for the analysis of behavior of transient overvoltage distribution network. The simulation was evaluated by using the different value of lightning stroke. The flow of the diagram is shown in figure 1.

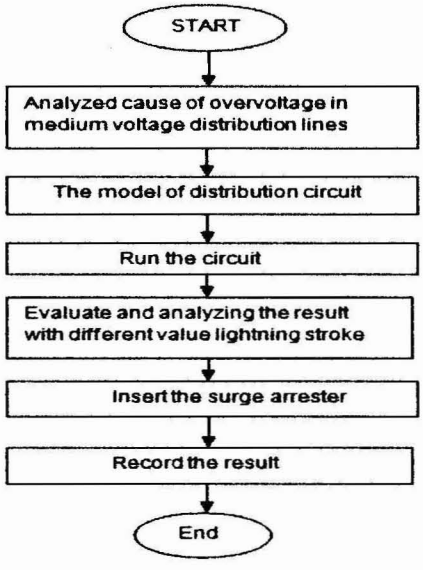


Figure 1: flow chart of the system

### *2.1 Lightning source*

The lightning stroke model with specific input applied to vary the exponential for simulation. The required test pulse can be obtained by applying two double exponential pulse voltages, through the equation:

$$F(t) = A(e^{-at} - e^{-bt}) \quad (1)$$

Where:

The crest amplitude, A=1kA
a= -13000,
b= -4. 4E6

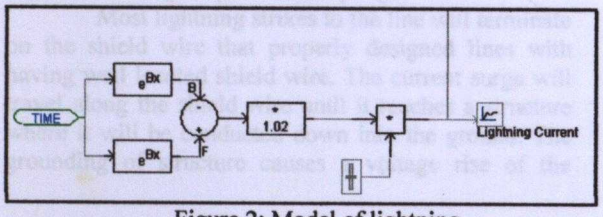


Figure 2: Model of lightning

### *2.2 Surge arrester*

Surge arresters are very common method to improve the lightning performance of overhead distribution lines[5]. Arrester must be installed in order to eliminate direct stroke flashover.

### *2.3 Shield wire*

Shield wires are grounded conductor placed above the phase conductors to intercept lightning strokes so they cannot directly strike the phase conductor[5]. Other than that, to reduce induced voltages from external electromagnetic fields and to lowering the self surge impedance of an overhead ground wire system. Shielding factor, Sf is defined as the per-unit portion of the distribution line shielded by nearby object. The number of strikes per 100km line length is[6]:

$$Ns = N(1 - Sf) \quad (2)$$

Where:

Sf = shielding factor
N = flashes/100km/year

### *2.4 Surge impedance*

Surge impedance of a line can be calculated as follows:

$$Z_0 = \sqrt{\frac{l}{c}} = \sqrt{\frac{\mu 0}{\varepsilon 0}} \left(\frac{\log e \frac{d}{r}}{2}\right)^2 \quad (3)$$

Where:

r = radius of conductor
d= conductor spacing
$\mu_0$= permeability constant
$\varepsilon_0$= electric constant

Since velocity of light is $\frac{1}{\sqrt{\mu 0\, \varepsilon 0}}$

Therefore by substitute the velocity of light as 3x $10^{\wedge 8}$ m/s, the formula can be simplified as:

$$Z_0 = 60 \log_e (d/r)\ \Omega \quad (4)$$

The radius for raccoon conductor, r=0.00606m and conductor spacing, d= 1.1m, therefore the surge impedance of distribution lines can be calculated as;

$$Z_0 = 60 \log_e \left(\frac{1.1}{0.00606}\right)$$
$$= 312\ \Omega$$

## 3. Modeling of distribution lines

### *3.1 Transient overvoltage variation*

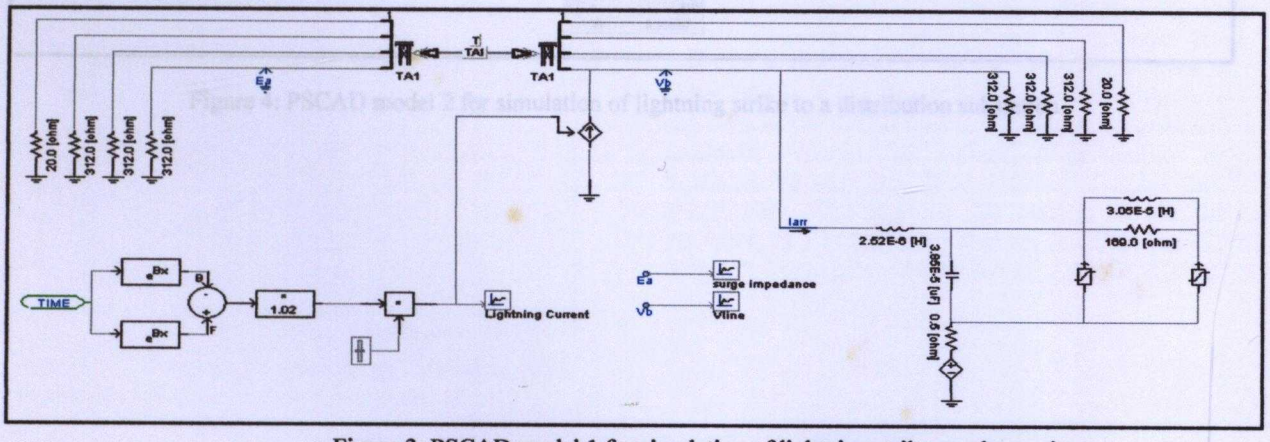


Figure 3: PSCAD model 1 for simulation of lightning strike on phase wire

Lightning stroke on phase wire are shown in the figure 3. With the different peak value of lightning current is use to measured the surge voltage of the phase wire. The result is recorded to see the performance of transient overvoltage variation with surge current when lightning strike on phase wire.

Moreover, by using the same model, simulation is done when lightning strikes on earth wire to measured the overvoltage in phase wire. This simulation is to prove the function of shield wire which can reduce the risk of flashover because the grounded conductor reduces the voltages stress across the insulation through capacitive coupling.

Most lightning strikes to the line will terminate on the shield wire that properly designed lines with having well located shield wire. The current surge will travel along the shield wire until it reaches a structure where it will be conducted down into the ground. The grounding of structure causes a voltage rise of the structure above ground voltage and voltage is induced on the phase conductors through capacitive coupling.

### *3.2 Analysis of performance of surge arrester*

Lightning arrester also known surge arrester is used on electrical power systems to protect the insulation on the system from the damaging effect of lightning. Surge arrester has a high voltage and a ground terminal.

When a lightning surge or switching surge travels down the power system to the arrester, the current from the surge is diverted around the protected insulation in most cases to earth[7]. Lightning arresters are used in 33kv to protect distribution transformers from lightning effect[3]. Parameters like arrester current, voltage and energy absorption were studied by injecting a lightning current to the distribution substation.

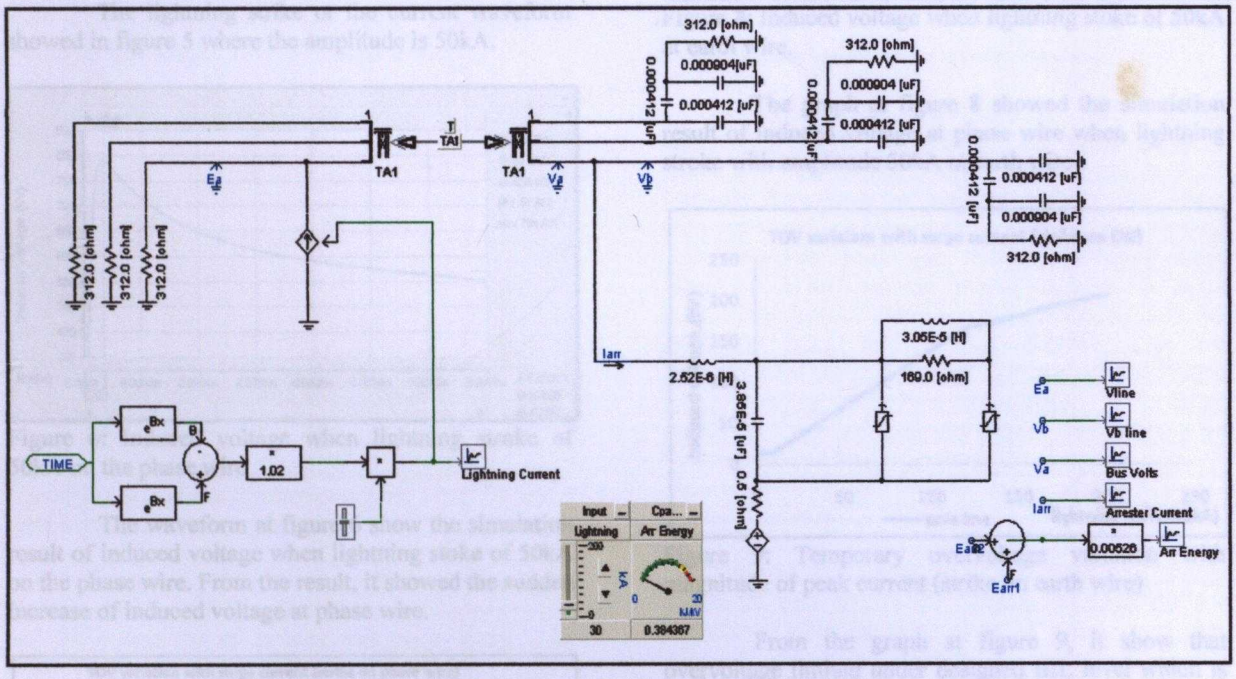


Figure 4: PSCAD model 2 for simulation of lightning strike to a distribution substation

## 4. Result and discussion

The simulation result is considered the performance of shield wire and surge arrester when lightning strike on phase wire and distribution substation.

### *4.1 Lightning strike on phase wire*

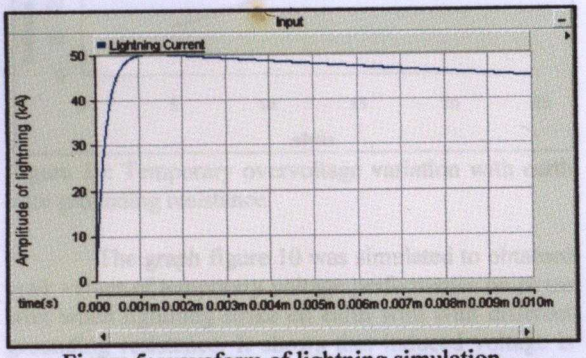


Figure 5: waveform of lightning simulation

The lightning strike or the current waveform showed in figure 5 where the amplitude is 50kA.

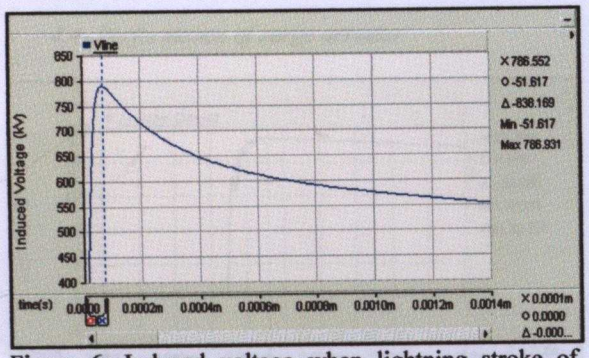


Figure 6: Induced voltage when lightning stroke of 50kA on the phase wire

The waveform at figure 6 show the simulation result of induced voltage when lightning stoke of 50kA on the phase wire. From the result, it showed the sudden increase of induced voltage at phase wire.

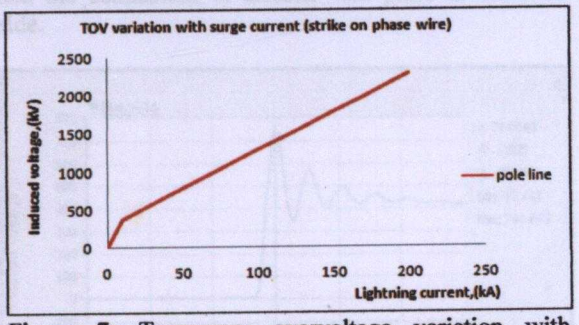


Figure 7: Temporary overvoltage variation with magnitude of peak current (strike on phase wire)

The graph at figure 7 has shown the result when lightning strike on phase wire. Surge voltage of the phase wire was measured for different value of lightning currents. From this graph, temporary overvoltage increase when lightning value currents increase where can cause insulator flashover.

### *4.2 Simulation lightning strike on earth wire*

Lightning strike on earth wire was simulated and measured the overvoltage in phase wire.

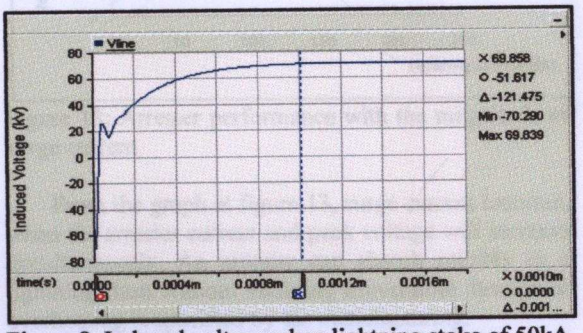


Figure 8: Induced voltage when lightning stoke of 50kA at earth wire.

The graph at figure 8 showed the simulation result of induced voltage at phase wire when lightning stroke with amplitude 50kA at earth wire.

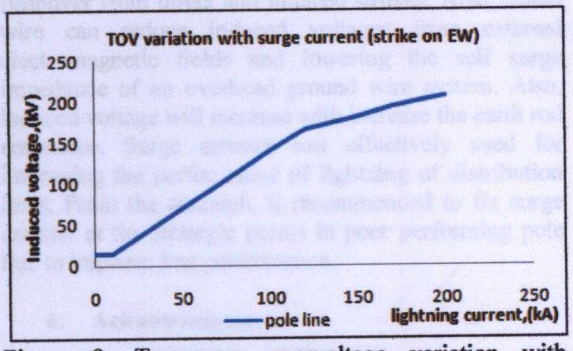


Figure 9: Temporary overvoltage variation with magnitude of peak current (strike on earth wire)

From the graph at figure 9, it show that overvoltage limited under designed BIL level which is under 200kV. From that, it can prove that shield wire can reduces the risk of flashover because the grounded conductor reduces the voltage stress across the insulation through capacitive coupling. Besides that, shield wire will decrease the voltage across the insulation by a factor which depends on grounding and proximity of the grounded conductor of the phase wire.

### *4.3 Transient overvoltage variation with Earth Rod Resistance and soil resistivity*

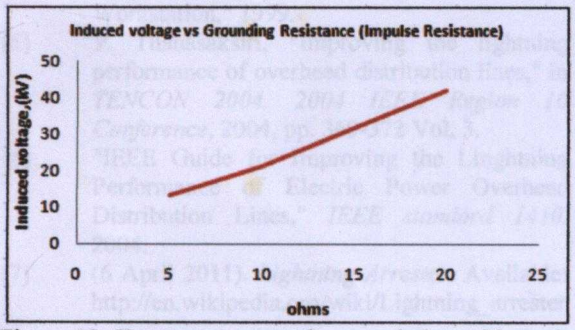


Figure 10: Temporary overvoltage variation with earth wire grounding resistance

The graph figure 10 was simulated to obtained peak values of temporary voltage performance on phase wire when lightning strike on earth wire with different grounding resistance. It shows that induced voltage is proportional with resistance value. Induced voltage will increase when resistance increase. The value of earth rod resistance and soil resistance influenced to reduction of voltage stress by grounded wire.

### *4.4 Performance of surge arrester*

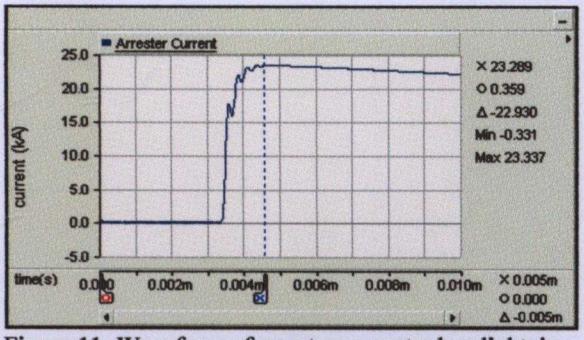


Figure 11: Waveform of arrester current when lightning stroke on distribution substation

Figure 11 showed the waveform of arrester current when lightning stroke on distribution substation and the connection of arrester was place at the load side.

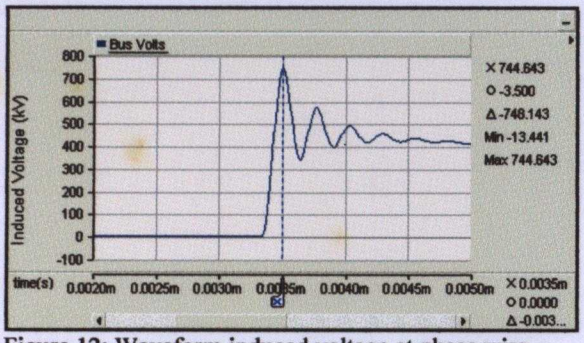


Figure 12: Waveform induced voltage at phase wire

Simulation result at figure 12 showed the waveform of induced voltage when lightning strike at distribution substation.

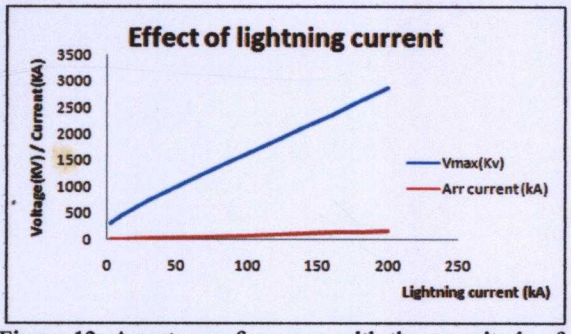


Figure 13: Arrester performance with the magnitude of surge current

From the graph at figure 13, surge current increase, when the arrester current and peak voltage will increase simultaneously. An arrester can absorb reliably in a lightning flash without suffering irreversible damage or overheating is specified by the manufacturing.

## 5. Conclusion and recommendation

As a conclusion, it reveals that when lightning strike on phase wire, transient overvoltage are very high. With the shield wire, it reduces the risk of flashover from direct and induced strokes. Also, shield wire can reduce induced voltages from external electromagnetic fields and lowering the self surge impedance of an overhead ground wire system. Also, induced voltage will increase with increase the earth rod resistance. Surge arrester can effectively used for improving the performance of lightning of distribution lines. From the research, it recommended to fix surge arrester at the strategic points in poor performing pole line to improve line performance.

## 6. Acknowledgement

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