Performance of Protection Devices Against Transient Overvoltage Due to Lightning

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Abstract— **Nowadays, many devices have been developed to overcome transient overvoltage due to lightning strike. This paper presents the performance of protection devices against transient over voltages due to lightning strike in a 33/11kV distribution system at UiTM Shah Alam. The objective of the project simulation is to compare and analyze the performance of metal oxide varistor (MOV) and transient suppression voltage (TVSS) against indirect lightning effect. The effectiveness of the protection system was tested and compared that implemented in (PSCAD/EMTDC) software. The PSCAD software is a power system simulation that enable problem regarding on the power system be solved. It was found that metal oxide varistor proposed by IEEE model can reduce the surge voltage to the minimum clamp voltage.**

Keywords: 33/11 kV UiTM Shah Alam, lightning strike, transient over voltages, metal oxide varistor (MOV), transient suppression voltage (TVSS).

I. INTRODUCTION

In most tropical countries, lightning activity is high especially in Malaysia compared to other countries. According to the meteorological department [1], almost 80% of lightning discharges current to the ground in Malaysia exceed 20kA with potentials approaching 50-100MV and 50% of strokes in Kuala Lumpur exceed 36kA. Lightning occur when the ambient temperature is high and the air is humid. The strong electric field initiates discharges inside the cloud, and a negative stream of electrons emerges as a dim spark called a stepped leader or dart leader. The stepped leader reaches close to the earth's surface, reaching an upward positive leader, and forms the main channel. The main channel carries initially a discharge current of a few hundred amperes up to 100 000A [2]. It can hit substations, electrical cable, and line tower and may be due to indirect strokes or direct strokes. In the indirect stroke, induced charges can take place in the line as a result of close by lightning strokes to ground. In any case, the voltage induced on the line propagates along the line as a travelling wave until it is dissipated by attenuation or arrester operation. This results in transient current or over voltages.

Transient over voltage is a sudden increase amplitude from normal operating level within microsecond activities and can reach several thousands of volts. There are two different types of transient over voltages: low frequency transient caused by capacitor switching, and high frequency transient are often called 'surges' caused by lightning. Typical rise times are on the order of a microsecond; typical decay times are on the order of a ten to hundreds of microseconds. Often, the decay will be an exponential damped ringing waveform, which corresponds to the frequency of an equivalent system [3]. This phenomenon always occurs in the power grid system.

Power generation, transmission line, distribution line, and finally to the consumer (conversion load) are interconnected by electrical wire. When lightning strikes directly or indirect on a phase conductor or line phase, it can be regarded as a current injection. Lightning currents are different in amplitude and shape. The majority of the lightning strokes vary from kA to several tenths of kA. To facilitate testing in the laboratory and computations either by hand or by computer, the shape of the current wave of the lightning stroke is standardized. The Malaysian standard of general principles of protection system against lightning strike [4] has standardized the so called 8/20μs waveform as shown in Figure 1. The cable in power supply become the main way where lightning enters and get through the equipment and possibly damage it. As the current attempts to flow, devastating transient over voltages can be seen across the equipment caused damage [5].

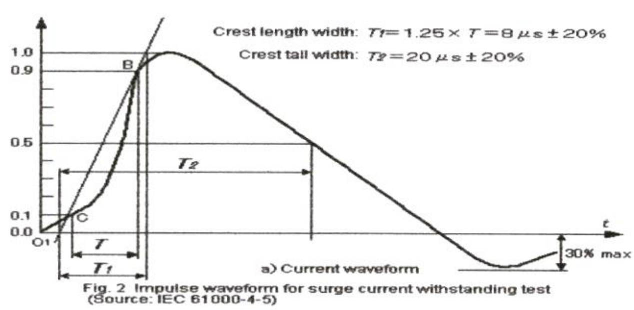

Figure 1: Waveform of 8/20μs current surge into a short circuit

Momentary outages are a main concern for some utilities trying to improve their power distribution. One consequence of a lightning strike to a power system is a disturbance in the power supply voltage. It can result in extensive damage to equipment. A prolonged main over voltages can cause damage to equipment and to protection devices which, without proper selection, cannot cope with excessive voltage. In recent times, lightning protection in distribution power system become the main concern. Improving protection device system in the distribution power from lightning in which some way can reduce the number of momentary outages. Metal oxide varistor (MOV) and transient suppression voltage (TVSS) are two method used to protect lines. With clamping method, lightning surge can be clamped according to protection level desired.

For the purposes of the study, this project inject lightning current waveform stroke at 33/11kV distribution system at UITM Shah Alam [6]. The impulse current test wave of typical value of 8/20μs is used for laboratory testing [7]. The selection of protection system categories is in categories C [8], which cover external services, overhead/underground lines to detached building. The distribution system has been redraw and analyzed based on the single line diagram schematic. In order to implement this model into PSCAD software, the following procedure has been realized:

1. Distribution system of UITM Shah Alam is re simulated and lightning current injected into the phase cable system.
2. Then, the set of parameter is varies and according to the values of the system (e.g the voltage, kVA rating..)
3. Modeling of protection devices is re constructed and to be tested one by one.
4. Finally, once all the parameter is known, the simulation is run and its pattern recorded to be evaluating soon. Its waveform pattern is compared with others to identify their performance for best protection.

II. METHODOLOGY

The flow chart during the course of this project is shown in Figure 2. The line cable is connected between generation and load. As the focused of the project is at the line cable, all the assumption are made enable a completely analytical solution. The goal of this study is, thus the analysis to show how the results of a simulation changes when a model or parameter of protection devices changed. Simulation is done by injected a set of lightning surge current at phase line cable. Voltage waveform is then recorded for each before and after lightning surge injected. The MOV and TVSS were located at the same point that needs to be protected.

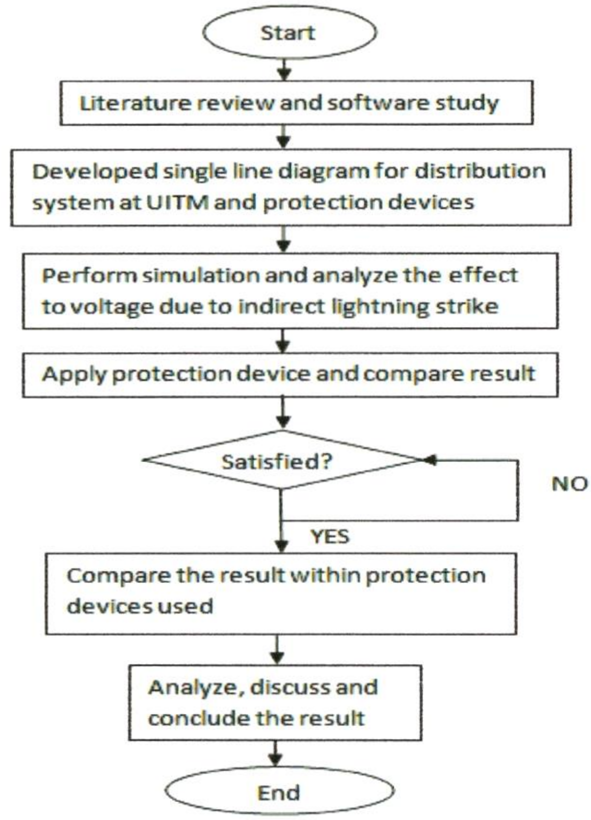

Figure 2: Flow chart of project

III. PSCAD MODELLING OF DISTRIBUTION SYSTEM

PSCAD software is used to simulate the lightning performance of 33/11kV distribution system at UiTM Shah Alam in the paper. PSCAD program is known as a knowledge-protected user-drawing program perfectly interfaced with EMTDC, and has made users easily conduct power system simulations. Modem computed simulations including PSCAD have been developed with the progress of various models of components.

A. LIGHTNING CURRENT AND COMPONENT NETWORK

A lightning stroke to the cable will create induced current [9]. The typical values of this paper selected to be ±8/20μs. The wave shape is according to IEEE standards [4]. These wave shape are describes as “combination wave” because these can be delivered by a generator on short circuit. These can be readily generated in many simulations and are commonly used for the study of lightning strike. The lightning current shape is taken into account by an appropriate formula [10]. The lightning surge current can further be modeled electrically as shown in Figure 3.

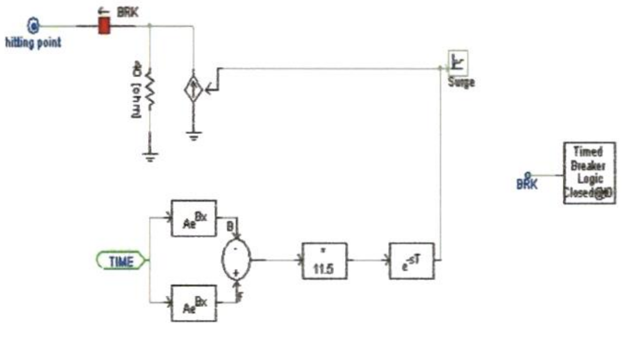

Figure 3: Lightning model

B. MOV USING IEEE PROPOSED MODEL

The most frequently used surge model is that proposed by the IEEE working group 3.4.11 [11] as shown in Figure 4. Although the IEEE model provided an accurate estimation of the value and their behavior, this is important to determine the accuracy degree of the protection system. Element used in this model were inductance and resistor as a parameter to determine all the possibilities of the value for protection.

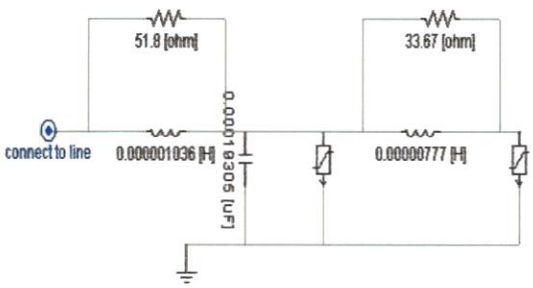

Figure 4: Single line diagram of IEEE proposed model

C. TRANSIENT SUPPRESSION VOLTAGE MODEL

TVSS are designed to suppress transients regardless of their origin. They form a low impedance path which bypasses the transient away from the protected equipment. An important rating of TVSS devices is clamping level [12]. Figure 5 shows the example of TVSS devices that will be used in this project simulation. There are many devices capable of surviving the long wave transient overvoltage. The longer duration of this surge has a high energy level associated with it.

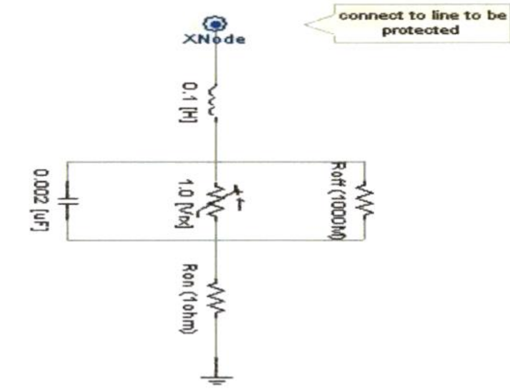

Figure 5: Single line diagram of TVSS model

Figure 6 shows the configuration of the distribution network at UiTM Shah Alam used as an example in this paper. The network consists of three phase voltage source together with inductive element on it, three phases wire cable which is divided to three (single phase each), line impedance and load. The same voltage is assumed to be induced in one of the phase conductor with characteristic impedance of 1.0 ohm. Loads are attached at the end of the point.

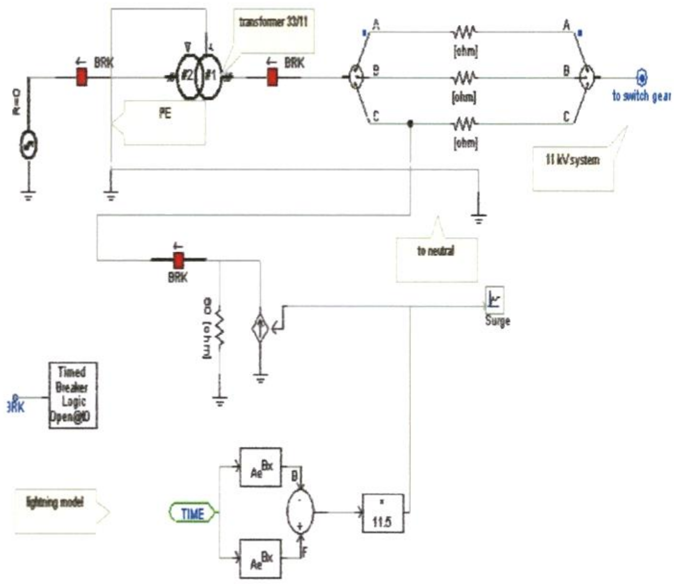

Figure 6: Single line diagram of distribution system at UITM Shah Alam

Measurements on distribution network system and developed models are in the frequency of 50Hz. The configuration investigated in this paper is a simplification with the purpose to illustrate the protection device system in waveform, and how the lightning and loads or voltage influence it.

IV. RESULT AND DISCUSSION

With the purpose of comparing the protection devices, several simulations have been made. Figure 7 shows the effect of lightning strike to the cable. Impulsive transient occur, where it can be seen there is voltage surge. The transient propagate along the cable (induced) making disturbance to the voltage system. The graph shows that surge voltage rise up to 74.240kV compared to the nominal voltage of 20.968 kV.

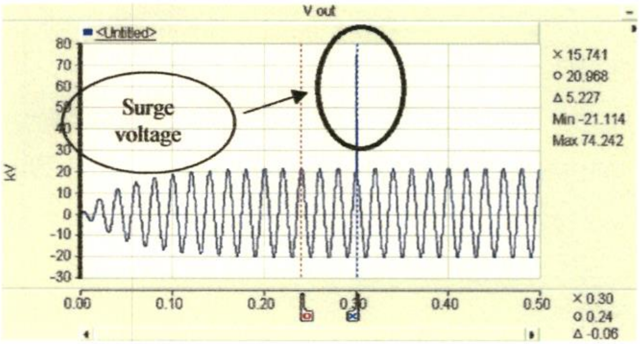

Figure 7: Graph of surge voltage when lightning surge current is injected

Figure 8, shows the effect of installing MOV using IEEE proposed model, as can be seen the voltage clamped as shows in the graph to the value of 27.896kV which is improved previously.

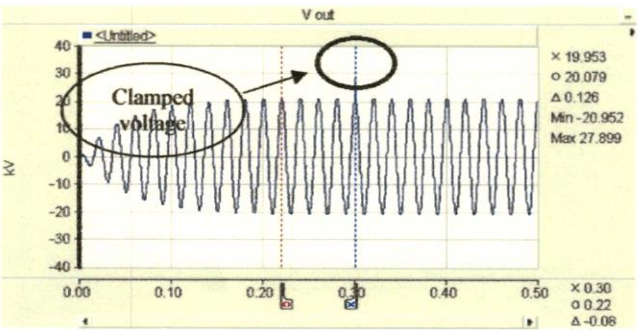

Figure 8: Graph of clamped voltage after installed MOV using IEEE proposed model

Figure 9, shows the protection devices of TVSS model was applied, as can be seen the voltage clamped to the certain value of 61.656kV at the mark signed which is better than previous one. During the simulation for this type of protection, it can be seen, there are voltage sag occurs in the waveform after the placement of device, this is because of the inductive element itself.

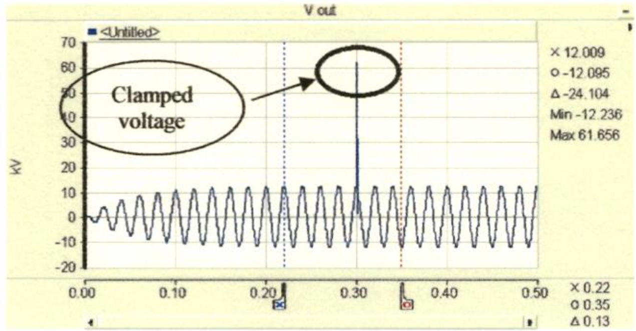

Figure 9: Graph of clamped voltage after installed TVSS

It can be seen that there is voltage sag occur when TVSS installed in the network distribution system as shown in Figure 10. This is happen because of its inductive element. Inductors oppose changes in current through them, by dropping a voltage directly proportional to the rate of change of current. According to Lenz's law, the voltage dropped across an inductor is a reaction against the change in current through it. The suggestion is to put either RL/RF filter in series with the model to get rid of the ripple.

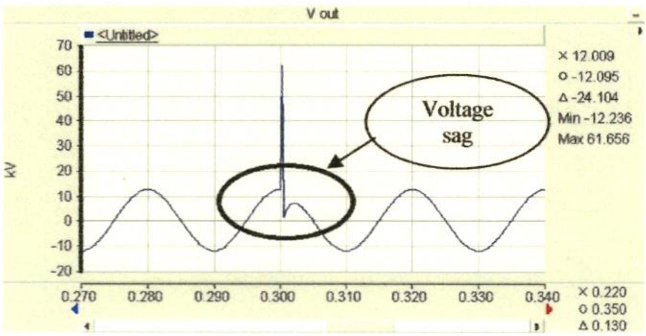

Figure 10: Graph of voltage showing voltage sag after installed TVSS

V CONCLUSION AND RECOMMENDATION

The effect of lightning on the distribution lines is important in power system engineering. It gives rise to a number of related phenomena such surge protection, insulation coordination and safety of equipment and personnel, and concerns about continuity of power supply. It was shown that the protection performance can be improved by applying MOV. In summary, the metal oxide varistor (MOV) allows identifying its parameter based on the Malaysian standard. If a transient occurs, current flow across the impedance and the varistor that, because V = Z * I, causes a proportional voltage drop across the voltage independent impedance.

The accuracy of the simulation can be improved when the protection devices characteristic is chosen correctly. A quality transient voltage suppressor limits the amplitude of transient overvoltage at all times. There are, however, been instances where both protection devices have been improved for transient overvoltage reduction.

As for the recommendation, a certain degree of "overdesign" must be considered because in most cases, the waveform, amplitude and frequency of occurrence of these transients are not known and the scale of local differences makes such an approach subject to uncertainty.

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