International Journal of Advancement in Electronics and Computer Engineering (IJAECE)
Volume 12, Issue 3, March 2023, pp.107-111, ISSN 2278 -1412

Study and Evaluation of Light Storm Over Voltages For Protection of Transmission Lines

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Abstract *– Light storm is one of the most significant sources of over voltages in overhead transmission lines. The light storm over voltages could lead to failure of the devices connected to the transmission line. A fundamental constraint on the reliability of an electrical power transmission system is the effectiveness of its protective system. The role of the protective system is to safeguard transmission system components from the effects of electrical overstress. Shield wire and light storm arresters are an important means of light storm protection in transmission and distribution systems. Therefore, it is necessary to analyze the over voltages caused due to lighting.*

Keywords: LSOV, Transmission Line, Over Voltage, Light Strom

I. INTRODUCTION

From the earliest days of the power industries, light storm faults on lines as well as equipment fault have been the major cause if interruption of service. The importance of electric power to both industrial and residential customers, attention was increasingly directed towards protective system and devices to improve service continuity. At an early stage, the source of over voltage was believed to be induction from the electric charge of the thundercloud, and this led to installation of grounded conductors usually erected above the power conductors to divert some of the induced charge from them [1].

Statement of Problem

Since transmission lines are usually shielded by one or several wires, light storm over voltages can be caused by strokes to either a shield wire or a phase conductor. The stroke to shield wire can produce a flashover if the back flash overvoltage exceeds the insulator strength. Over voltages caused by a shielding failure, that is, by a stroke to a phase conductor, are more dangerous, but their frequency is usually very low due to the shielding provided by sky wires.

Due to the random nature of light storm flashes, the analysis of the light storm performance of transmission lines must be based on a statistical approach. Based onthis, the flashover rate of a transmission line can be divided into the back flashover rate (BFOR) and the Shielding Failure Flashover Rate (SFFOR). Back flashover rate occurs when light storm strikes the tower (or the overhead ground wires), the current on the tower and ground impedances causes the rise of the tower voltage.

A small fraction of the tower and shield wires voltage is induced in the phase conductors due to the electromagnetic coupling, nevertheless the tower and shield wires voltage becomes much larger than the phase conductors voltages. Shielding Failure Flashover Rate is a stroke that terminates on a phase conductor, in spite of the presence of poorly located overhead ground wires. To obtain these two quantities, it is important to develop a model that can represent the nature of light storm strokes to shield wires, to phase conductors and those to ground wire.

II. METHODOLOGY

The methodology used to complete this research is described by figure 1

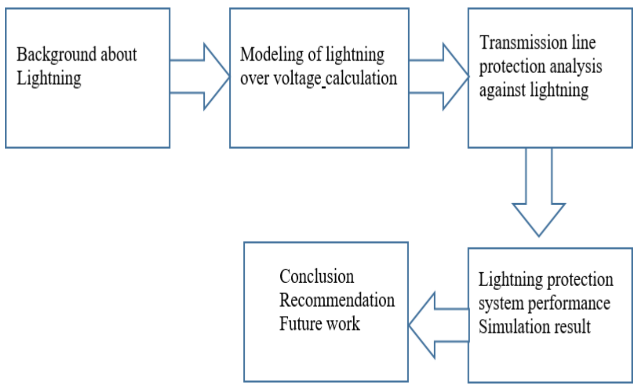

Figure 1 Methodology

Model of light storm arresters

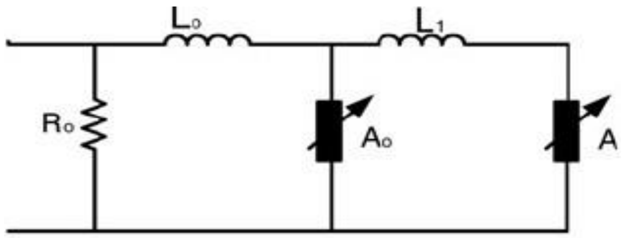

Figure 2 Model of Light Storme Arrester

Mechanism of current conductivity in metal oxide varistors

Light storme arresters contain one or more varistors with various diameters and heights. Varistors are made of ceramic of non-linear voltage-current characteristic. It is a ceramal of zinc oxide with admixtures of other metal oxides – i.e. of cobalt, manganese and aluminum. Structure of the varistors' mass is in the shape of close-packed grains. A small part of the grains constitute admixtures inside the grains while others, mainly bismuth, are accumulated in outer layers. Resistivity of the grain inside is small as op -posed to resistively of outer layers. Non-linearity of the volt -age-current characteristic results from phenomena occurring just mainly on the

boundary of the grains. Between grains appear potential barriers, which regulate intensities of cur -rents in dependence on voltage, as on the grain boundaries is considerable negative charge accumulated, being a result of existence of acceptor admixtures. With small voltage, volt -age- current characteristic remains in accordance with the Ohm's law, and depends on temperature. While increasing the voltage, energies of electrons can be high enough to pull electrons out of valence band. Electron-hole pairs of charges are created. Holes direct towards negatively chargedboundary between grains, neutralizing considerably surface charge and contributing to decrease of potential barrier. Sudden decrease of this barrier results in rapid current increase in the varistors. In this work range is the characteristic strongly non-linear. The non-linearity decreases, however, with potent light storm currents flow. With high density of currents, voltage increase is revealed, as a result of rise of voltage drop on grain-inside resistance. Character of phenomena on the grain boundary is the same as with lower current density.

Modelling Of Light storme Arrester

Metal oxide light storme arresters are fundamental elements of protecting systems of electric devices against over voltage. They contain varistors, which main constituent is zinc oxide as well as small amounts of other metal oxides. Light storme arresters are exposed to transient effect of over voltage generated as a result of light storm discharges, switching and damage states in electric power systems.

III. Result

Here the transmission lines light storm performance will be studied under different light storm stroke conditions with MATLAB Simulink software.

Direct and indirect stroke Effect

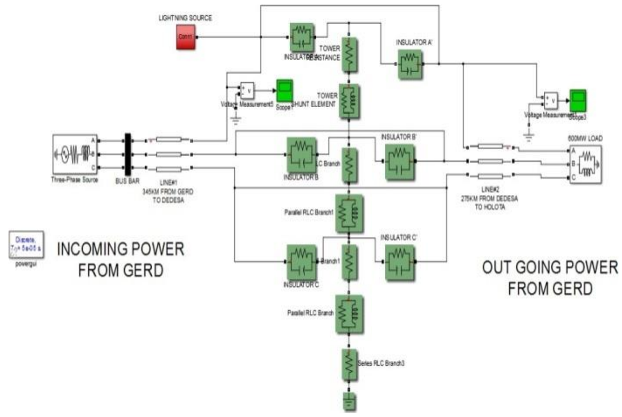

Figure 3 Direct stroke HV tower model in MATLAB

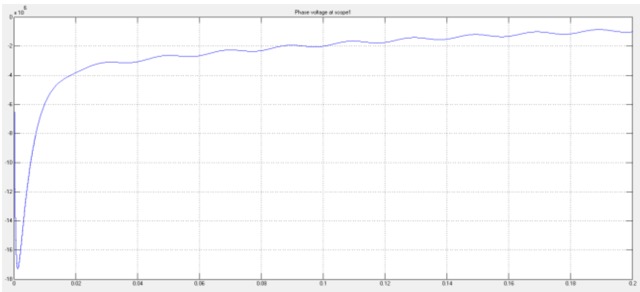

Figure 4 plot of phase voltage at scope 1 under direct stroke

From this result it is easy to see that when light storm strikes over phase conductor voltage will go high operating voltage for very short duration and then it will disappear quickly . Here light storm source is modeled by using current source of amplitude 20kA in parallel with series RLC branch of 400 ohm to present light storme impedance of the tower. When direct stroke occurs the voltage is increased to 17MV and go down to 1MV.

Indirect stroke

This will occur when the light storm strike over wire or tower structure.

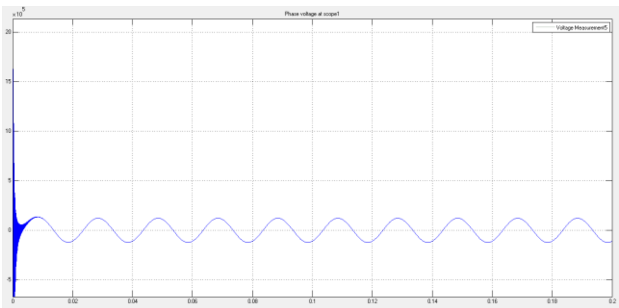

Figure 5 Phase voltage under indirect stroke

when light storm stroke occurs over wire or on tower body, operating voltage or phase voltage will be decreased as insulator voltage goes beyond operating voltage there by reducing phase voltage to very small value.

Transient Simulation

The model described in this section the protection system of series compensated transmission system that represents transmission line which is protected by METALOXIDE VARISTOR.

To increase the transmission capacity, each line is series compensated by capacitors representing 50% of the line reactance. The line is also shunt compensated by a 330 MVAr shunt reactance. Each series compensation bank is protected by metal-oxide varistors (METALOXIDE VARISTOR). The two circuit breakers of line 1 are shown as CB1 and CB2.

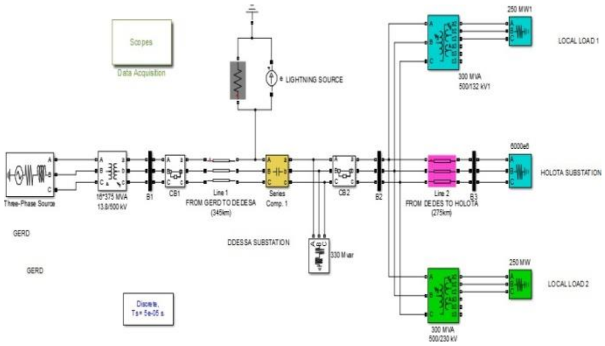

Figure 6 MATLAB model for transient analysis

Subsystem of Series Compensation

The three-phase Series Compensation module consists of three identical subsystems, one for each phase. A note indicates how the capacitance value and the METALOXIDE VARISTOR protection level are calculated. The transmission line is 50% series compensated by 83.92 µF capacitor. The capacitor is protected by the METALOXIDE VARISTOR block of 60 columns and that its protection level (specified at a reference current of 500 A/column or 30 kA total) is set at 268.35kV. This voltage 2.5 times the nominal capacitor voltage obtained at a current of 2 kA.

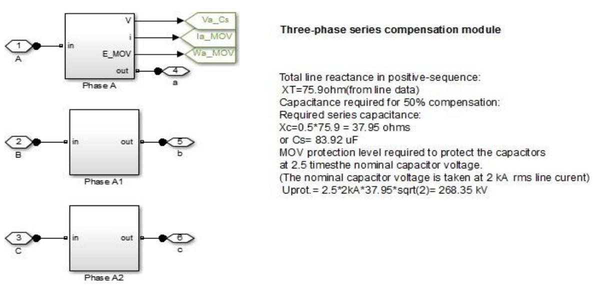

Figure 7 Three phase series compensation module

Again if we further open the modules we will see how METALOXIDE

VARISTOR is modeled

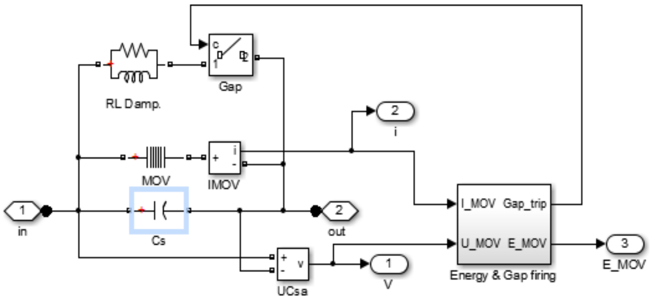

Figure 8 Module of three phase series compensation

Simulation of Light Storm Transient

METALOXIDE VARISTOR voltage, current and energy shown below.

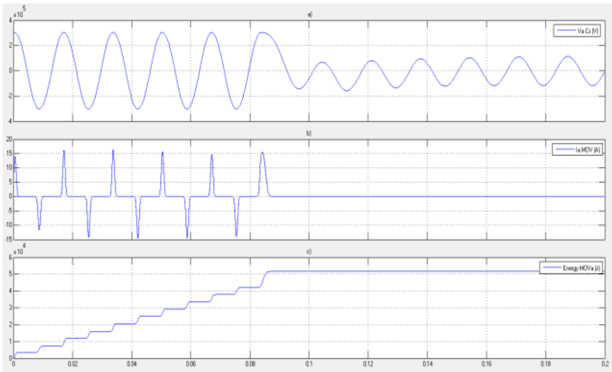

Figure 9 Result of light storm transient simulation

Simulation of Transmission line protected both end by METALOXIDE VARISTOR

Below given figure shows a 500 kV transmission line system with two transmission line arrester placed at both end of the line.

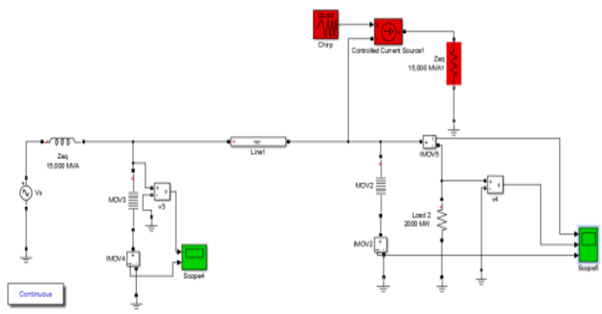

Figure 8 Model of TL simulation protected by METALOXIDE VARISTOR

The light storm light storme system of 20 kA is produced and the simulation result is shown by MATLAB software.The simulation result shows the temporary increase in current at METALOXIDE VARISTOR It is done by the light storm when 20 kA light storm current is applied. The temporary increase in voltage also shown in each arrester.

In this generation and load both are protected by METALOXIDE VARISTOR. The METALOXIDE VARISTOR protecting the components at 2.5 times its rated voltage.

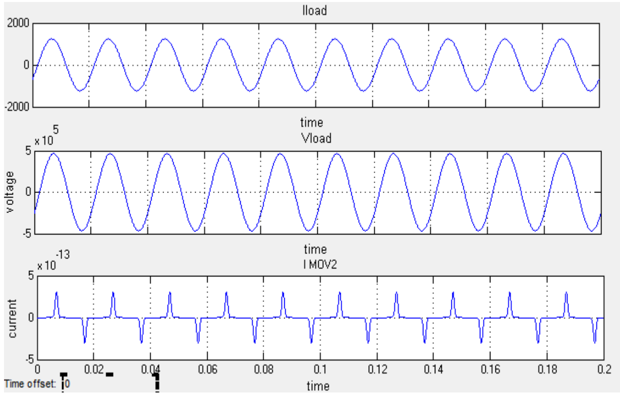

Figure 9 under normal condition Load current, load voltage, and current of METALOXIDE VARISTOR

Fig 9 shows the stroke occurs at receiving end of TL, the resulting current and voltage wave form (without employing METALOXIDE VARISTOR Light storme arrester) are represented. In starting , the current will go upto 10kA and the voltage will goup to 4MV.

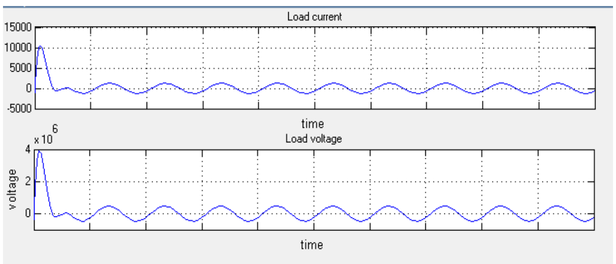

Figure 10 under light strom stike the line the line Load current, load voltage, and current of METALOXIDE VARISTOR.

IV. Conclusion

The results of analysis of protection effectiveness of overhead lines by shielding wires based on the electrometric power line model confirms, that phase conductors of overhead lines protected by shielding wires can be risked by directly light storm strokes with small currents. The analysis of light storm over voltages in overhead lines should take into account both over voltages generated during strokes to shielding wires as well as to phase conductors with maximum light storm currents which can be determined on the basis of the line construction analysis.

The results of computer simulations of light storm over voltages in overhead lines show that over voltage which create risk to the earth insulations systems of lines and transformers generated during light storm strokes to shielding wires do not exceed residual voltages of light storme arresters. In this conditions the light storme arresters work on the beginning and practically linear parts of the current-voltage characteristics and practically have no influence on over voltage courses and their maximal values. The analysis shows that over voltage generated in the phase conductors during light storm strokes to the shielding wires are limited to values which are safe for insulation systems.

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