Application of Line Surge Arresters in Power Distribution and Transmission Systems

COLLOQUIUM Cavtat 2008

Modeling of overhead transmission lines with line surge arresters for lightning overvoltages

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SUMMARY

Lightning is one of the most significant source of overvoltages in overhead transmission lines. The lightning overvoltages 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 system components from the effects of electrical overstress. Surge arresters are an important means of lightning protection in distribution systems. Therefore, it is necessary to analyze influence of such overvoltages in order to applying the line surge arrester for improving the reliability of transmission line system. The method used to analyze the increase in voltage due to lightning was done by using the ATP/EMTP software
This paper is aimed at analyzing the lightning performance improvement of a transmission line after installing line surge arresters.

KEYWORDS

overvoltage, arrester, simulation

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OVERVIEW

In spite of protection of distribution lines by shield wires, they are still exhibit to lightning caused interruptions by shielding failures and backflashes. With effective shielding, it is possible to minimize direct strokes to the phase conductors, but this does not necessarily mean that the line will have satisfactory lightning performance.

Shielding failures occur when the lightning stroke does not terminate on the tower or shield wire, but on the phase conductor instead. If the travelling wave - generated at the stricken point - is of sufficient magnitude, it will cause an insulator flashover. This flashover will result in a service interruption.

Strokes to either a shield wire (or strokes to pole) or a phase conductor. can produce a flashover if the backflash overvoltage exceeds the insulator strength. The stroke current induces voltages in the phase conductor. The voltages induced in the phase conductors is a function of time, footing resistance and structure geometry. The voltage stress on the line insulation is equal to the difference between the structure voltage at the insulator attachment point and the induced voltage in the phase conductor. If the voltage stress across the line insulation exceeds the flashover voltage of the insulator, a flashover will occur [1].

The resulting backflash has a very fast rate of rise. There is evidence that these rapidly rising waves may be responsible for substation transformer failures, even where metal-oxide arresters are used in the substation [2].

The metal-oxide surge arresters use nonlinear metal-oxide varistors having a high impedance at system voltage. When a high voltage surge (such as from lightning) is impressed on the surge arrester, the impedance of the metal-oxide varistors drops dramatically.

The metal-oxide surge arrester is connected electrically in parallel with the line insulation. The metal-oxide surge arrester limits the surge voltage across the line insulation by going into conduction at a voltage below the flashover voltage of the line insulation. After the surge arrester has successfully discharged the lightning surge, the voltage across the arrester returns to the line-to-ground value. The arrester is only in conduction for the duration of the lightning stroke. This event is of too short duration to be detected by relaying methods. Therefore, the operation of the surge arrester will not result in an interruption.

Strokes to phase conductor are limited in magnitude to the maximum shield failure current, which for the usual line is between 5 and 15 kA. These shield failure currents plus currents from subsequence strokes produce arrester energies that normally exceed the energy caused by strokes to shield wire. However, in general, the energy discharged through the arrester is within the energy capability of the arrester [3].

Lightning interruptions are becoming a major problem for electric utilities. The application of surge arresters provides better performance than overhead shield wires. The use of surge arresters gives up significant improvement in lightning performance over use of overhead shield wire alone.

In addition to improved lightning performance, the use of polymer-housed surge arresters insulators have other benefits, like [2]:

- reduced pole top weight,
- reduced line structure heights,
- reduced line losses due to elimination of shield wire,
- reduced magnetic fields due to closer phase spacing.

The use of surge arresters on existing shielded construction with higher footing resistances can reduce lightning caused interruptions. For footing resistances of 100 ohms, the addition of the surge arresters reduces the interruption rate by 34 percent over shield wire alone [2].

SIMULATION PROCESS

The most simple MOV model, presented in Figure 1, corresponds to the physics of metal-oxide disc [4].The resistance R corresponds to the nonlinear resistance of the intergranular layers, where the resistivity ρ changes in the range from 10^5 Ωm to 0.01 Ωm. The resistance R_Z is the resistance of the ZnO grains with low resistivity 0.01 Ωm. The inductance L is inductance of the MOV and is determined by the current flow path. Frequency dependence is obtained with the serial inductance L, providing that the voltage peak across the MOV occurs before the current peak. The inductance L also provides different amplitudes of the clamping voltage for different surge current amplitudes and rates of rise. The major disadvantage of this model is that model parameters must be tuned for each current waveform shape and amplitude.

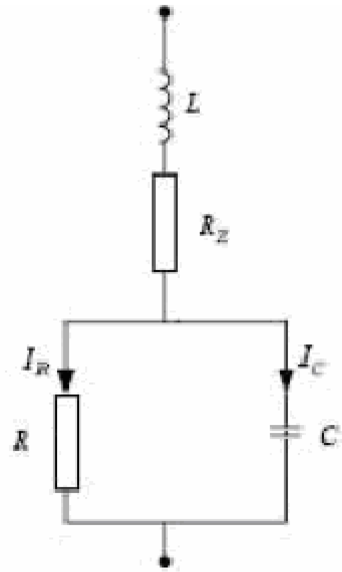


Figure 1. Physical model of ZnO varistor

The IEEE (Working Group 3.4.11) proposed the frequency-dependent model with two nonlinear resistors, presented in Figure 2. The IEEE model is the most accepted varistor model for transients and we will treat, in this paper, implementation of IEEE MOV model in ATPDraw.

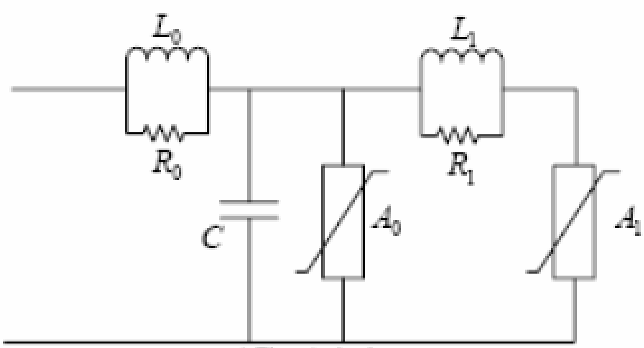


Figure 2. Model of ZnO arrester proposed by IEEE Working Group 3.4.11

This model take into account different delays in the conduction mechanism at different wavefronts of current surges with a set of nonlinear V-I curves. The nonlinear elements A_0 and A_1 are divided by the R-L filter, which ensures high impedance for the fast surges. The characteristics A_0 and A_1 (Figure 3) are defined in relative units, according to the MOV rated voltage.

For long duration surge wavefronts, filter has low impedance and elements A_0 and A_1 are in parallel. For fast surge wavefronts, element A_1 is blocked and current flows only through the element A_0. Since characteristic A_0 is higher than A_1, MOV model provides the higher voltage than for the slow surge.

The inductance L_0 represents the inductance of the current path through the arrester, also present in the physical model. The role of resistance is to provide convergence in the numerical simulations.

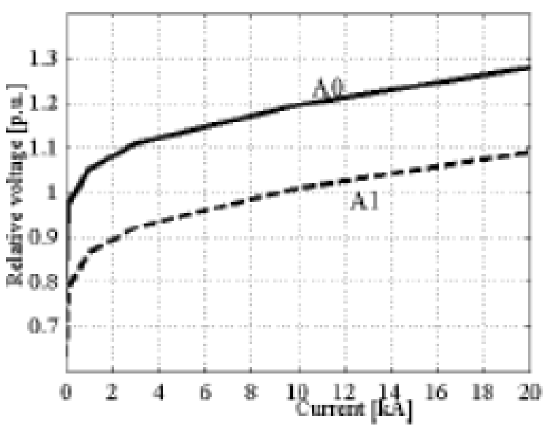


Figure 3. Characteristics of nonlinear elements A_0, A_1 of IEEE arrester model

The detailed analysis of different varistor model advantages and disadvantages is given in [4].

The overhead distribution lines are represented by distributed parameter model, using the JMARTI frequency dependent model which are the most accepted model for transient study [5,6]. The transformer are represented by BCTRAN model with parameters determined on the basis of evidence and rating data.

As an example we analyze real circuit shown as a ATP model on Figure 4 This is an initial model and it was extended of line surge arresters. Results shown on Figure 5 indicates reduction of overvoltage stress due to applying line surge arresters.

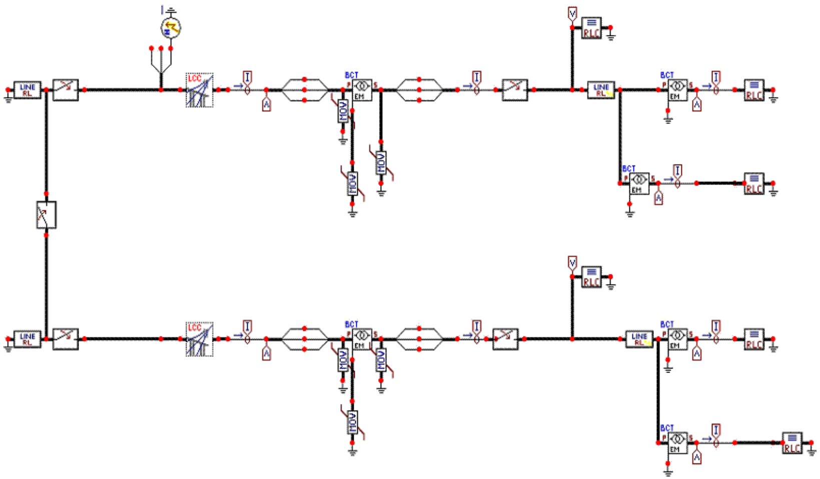
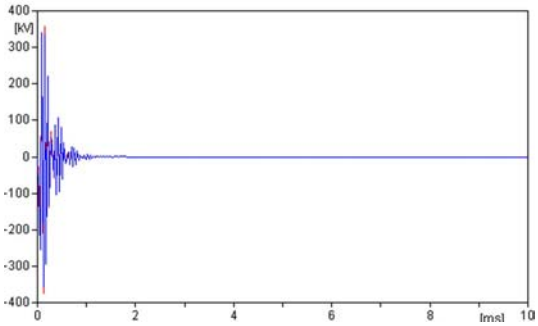
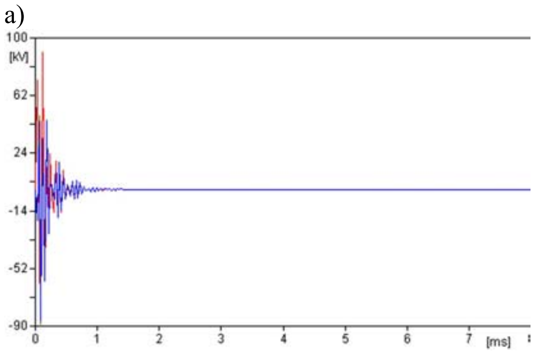
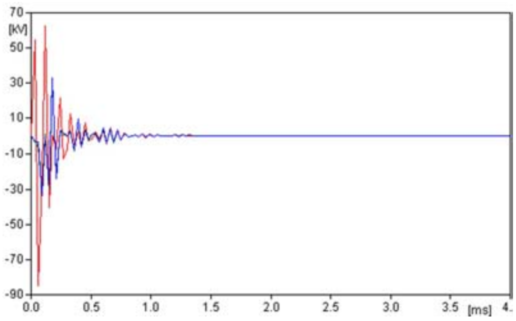


Figure 4. Initial model of analyzed circuit



a)





b) c)

Figure 5. Simulation results a) system without arresters, b) system with arresters installed with transformer, c) system with line arresters

CONCLUSIONS

Applying of line surge arresters have led to means of significantly improving line lightning performance. But, this does not necessarily mean that the transmission line with line arresters will have satisfactory outages performance. It is because surge arresters have been installed on distribution lines in high density, in order to decrease outages caused by lightning. As a result, outages due to flashover at insulators on distribution lines have been gradually decreasing. However, as the number of surge arresters installed increases, surge arrester outages may increase as a proportion of total distribution line equipment outages.

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