SIMULATION OF LIGHTNING OVERVOLTAGES WITH ATP-EMTP AND PSCAD/EMTDC

Violeta Chiş, Cristina Băla and Mihaela-Daciana Crăciun

Abstract. Currently, several offline digital simulation software tools are available, with varying degrees of modeling and simulation capabilities. This paper aims to compare the capabilities of two program packages for electric network simulation: ATP-EMTP and PSCAD/EMTDC for modeling lightning overvoltages.

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1. Introduction

The use of computer simulation tools is essential in power system studies. The number of tools suitable for transient analysis is increasing in the last few years. This paper aims to compare the capabilities of two program packages for electric network simulation: ATP-EMTP and PSCAD/EMTDC. The first one ATP is a universal program system for digital simulation of transient phenomena of electromagnetic as well as electromechanical nature. PSCAD/EMTDC is another popular tool in Electromagnetic Transients Program category which was developed at the Manitoba HVDC Research Centre.
Modeling of power components that take into account the frequency dependence of parameters can be currently achieved through mathematical models which are accurate enough for a specific range of frequencies. The simulation of transient phenomena may require a representation of network components valid for a frequency range that varies from DC to several MHz. Although an accurate and wideband representation of a transmission line is not impossible, it is more advisable to use and develop models appropriate for a specific range of frequencies [1]. Each range of frequencies will correspond to a particular transient phenomenon.

2.Simulation softwares PSCAD/EMTDC and ATP/EMTP

PSCAD is a powerful graphical user interface that integrates seamlessly with EMTDC, a general purpose time domain program for simulating power system transients and controls. Together they provide a fast, flexible and accurate solution for the simulation of virtually any electrical equipment or system. PSCAD/EMTDC represents and solves the differential equations of the entire power system and its controls in the time domain (both electromagnetic and electro-mechanical systems) [2].
The Alternative Transients Program (ATP) is considered to be one of the most widely used universal program system for digital simulation of transient phenomena of electromagnetic as well as electromechanical nature in electric power systems. With this digital program, complex networks and control systems of arbitrary structure can be simulated [3].
ATPDraw can be used as a simulation center, that provides an operating shell for other ATP-EMTP components. To solve the differential equations of system components in the time domain is used trapezoidal rule of integration [3].

3.Lightning overvoltages

Lightning strikes to overhead transmission lines cause travelling waves which propagate along the overhead line and enter substations where they cause overvoltages which can pose a risk to any items of equipment connected. The causes of overvoltages in power systems may be external (e.g., lightning) or internal (e.g., switching maneuvers, faults, ferroresonance, and load rejection), and may also occur as a combination of several events. Since their magnitude can exceed the maximum permissible levels of some equipment insulation, it is fundamental to either prevent or to reduce them.
Lightning surge voltages that arrive at a station, traveling along a transmission line, are caused by a lightning stroke terminating either on a shield wire, a tower, or a phase conductor [4].
The voltage magnitude and shape of these voltages are functions of the magnitude, polarity, and shape of the lightning stroke current, the line surge impedance, the towersurge impedance and footing impedance, and the lightning impulse critical flashover voltage (CFO) of the line insulation.
For lines that are effectively shielded, the surge voltages caused by a backflash are usually more severe than those caused by a shielding failure; that is, they have greater steepness and greater crest voltage [5].

4.Case study

Consider a transmission line (220 kV, 100 MVA) with towers that are 40 m tall and spaced 280 m apart. Assume that there is a single shield wire with a characteristic impedance of 520 ohm and that the tower ground strap has a characteristic impedance of 135 ohm. The tower has a footing resistance of 30 ohm. Assume a propagation velocity of the speed of light for the ground wires and 0.85 times the speed of light for the tower ground strap. The phase conductors are 75% of the way up the tower and the ground wire is segmented and open at the top of each of the adjacent towers. For modeling lightning overvoltages it was used ATP-EMTP and PSCAD/EMTDC.
Shield wires and phase conductors of the transmission line can be modeled by several spans at each side of the point of impact. For lightning overvoltage calculations, a constant-parameter line model can be accurate enough, and parameters are usually calculated at 400-500 kHz [5]. A line termination at each side of this model is needed to avoid reflections that could affect the simulated overvoltages around the point of impact. This termination must be represented accordingly to the model chosen for the line spans.
Several models have been proposed to represent transmission line towers (single-phase vertical lossless line model, multiconductor vertical line model, multistory model); they have been developed using a theoretical approach or based on an experimental work [6]. The simplest representation is a lossless distributed-parameter transmission line, characterized by a surge impedance and a travel time.
Travelling waves propagate in air or gaseous insulants at the velocity of light c. In the case of exposed conductive parts with solid insulation (for example, cables), the speed of propagation is and depends on the level of the relative dielectric constant ε_r.

$$\nu = \frac{c}{\sqrt{\varepsilon_r}} \tag{1}$$

The surge impedance Z describes the high-frequency behaviour of the items of equipment and can be calculated with the relationship:

$$Z = \frac{1}{\mu \cdot C'} \tag{2}$$

where

$$Z = \sqrt{\frac{L'}{C'}} \tag{3}$$

$L^{'} = inductance\, per\, km$
$C^{'} = capacitance\, per\, km$

For overhead lines and overhead earth wires, the resultant surge impedance can be calculated with the relationship:

$$Z = 60 \cdot \ln \frac{2h}{r} \tag{4}$$

where h describes the suspension height above ground, and r is the equivalent radius of the conductor. Grounding modeling is a critical aspect. A nonlinear frequency-dependent representation is required to obtain an accurate simulation. Since the information needed to derive such a model is not always available, a lumped circuit model is usually chosen for representing the footing impedance, although it is recognized that this model is not always adequate.

A lightning stroke is represented as an ideal current source whose parameters, as well as its polarity and multiplicity, are randomly determined according to the distribution density functions recommended in the literature [5]. It was considered the case of a lightning strike where the current rises to 40 kA in 2 μ s and falls to 20 kA after 40 μ s (Figure 1).

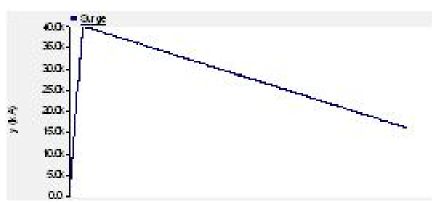

Figure 1: Lightning current in PSCAD

Because PSCAD requires a terminating impedance at the end of a line, it can't be open circuited, a very large resistance has been placed at the end of the line. The Bergeron model is based on a distributed LC parameter travelling wave line model, with lumped resistance.

After simulation the peak voltage at the tower top, the bottom of the tower and at the conductor height was obtained. (Figure 3, Figure 5).

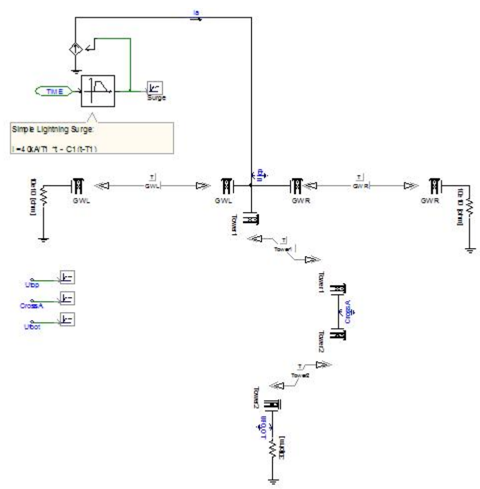

Figure 2: Electric diagram implemented in PSCAD

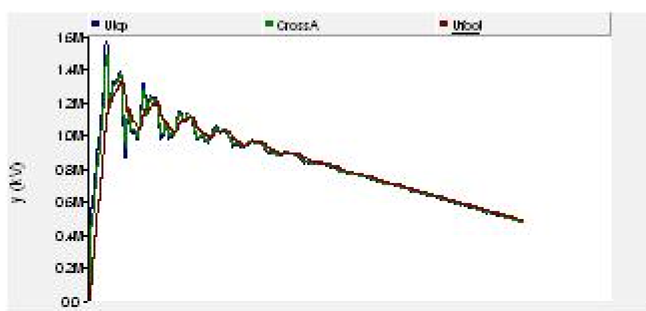

Figure 3: Voltages at tower top, cross arm and footing resistance in PSCAD

The results obtained with PSCAD/EMTDC and ATP were compared with Mathcad (Figure 6, Figure 7, Figure 8).

After the simulations performed with PSCAD/EMTDC and ATP-EMTP were obtained very close results.

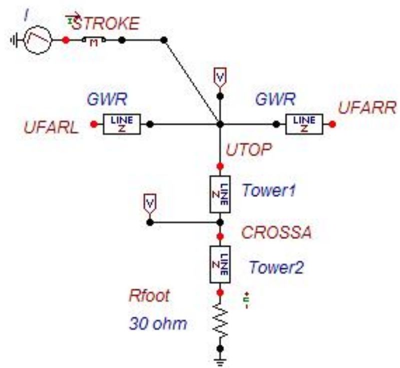

Figure 4: ATP Draw Circuit Diagram

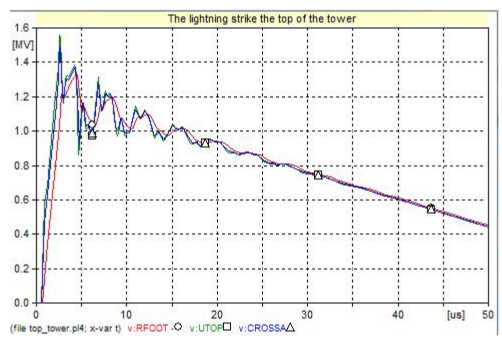

Figure 5: Voltages at tower top, cross arm and footing resistance in ATP

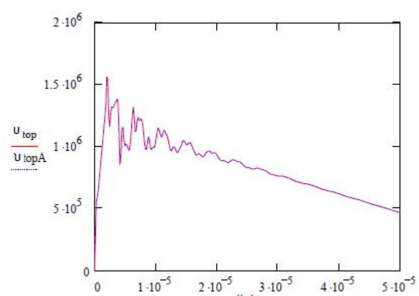

Figure 6: Tower top voltages

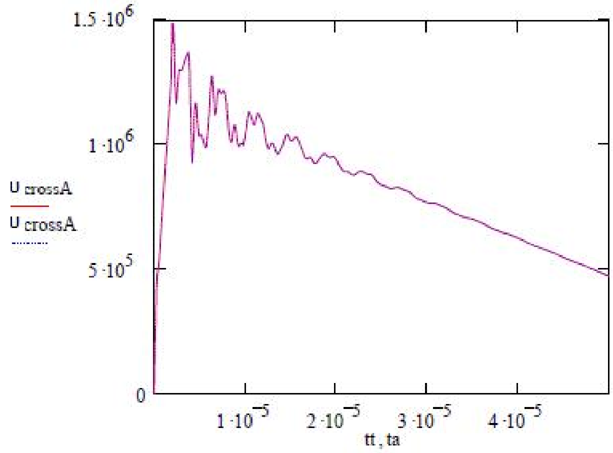

Figure 7: Voltages at the crossarm

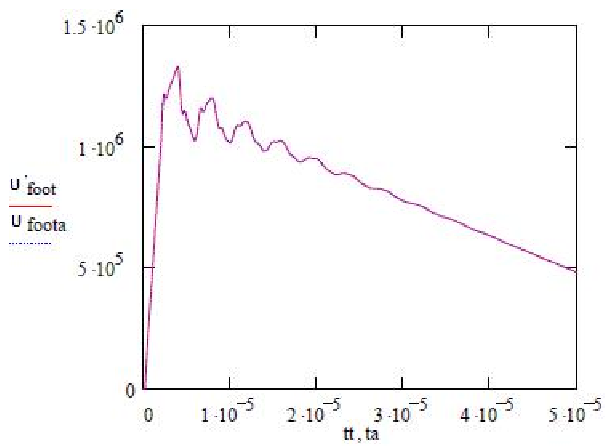

Figure 8: Voltage at footing

6. Conclusion

Calculation of lightning overvoltages necessitates simulation of the electrical equipment, such as for example overhead transmission lines, cables, towers and substations as travelling wave model.
In order to analyse wave processes within power lines due to lightning discharges there are various computer techniques including software packages (eg EMTP Electro-Magnetic Transients Program) or special processing programs. Computer analysis of overvoltages in this paper has been carried out using processing program ATP-EMTP and PSCAD/EMTDC.
The accuracy of results of simulation is extremely influenced by the accuracy of the input data.

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