Numerical modeling of standard lightning impulse on overhead lines

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Summary: The paper approaches the topic of the numerical modelling of the electromagnetic disturbances that occurs on HV lines. Being broadband signals, an accurate evaluation of the disturbances propagation on HV lines requires that the transmission lines model to be taken into consideration. Therefore, in the first part of the paper the principles of modelling using non-uniform transmission lines are emphasized. Then the per-unit-length parameters computation is detailed, with the terms which take account of the influence of a lossy ground. In the second part of the paper the numerical computation algorithm implemented is presented. In the last part of the paper there are presented several examples using a concrete HV line to which several standard test signals have been applied.

1 Introduction

The principle of modeling the non-uniform transmission lines is based on the idea of dividing the line into multiple pieces of uniform lines with the length very small in comparison with the wavelength.
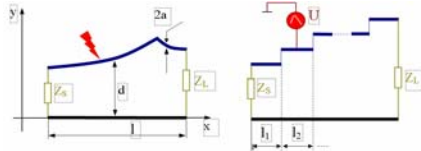
Fig. 1. Modelling using non-uniform transmission lines

The numerical modelling of the electromagnetic disturbances propagation on HV lines can be achieved using professional software packages designed for circuits' numerical analysis. In this paper the PSPICE software that is included in the ORCAD 9.2 package was used. The general flowchart of the numerical algorithm implemented in accordance with the details outlined in the above paragraphs is presented in Fig. 2.
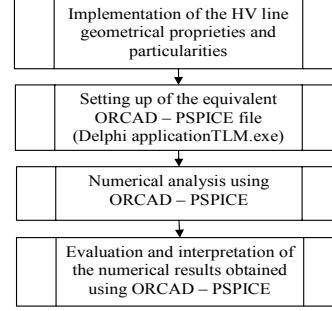
Fig. 2. General flowchart structure of the numerical analysis algorithm implemented

2 The per-unit-length parameter

The HV line per-unit-length parameters are computed according to Carson's theory and approximations for wave propagation above loss ground.

Self impedance includes three components:

$$Z_{ii} = j\omega L_{ii} + Z_c + Z_g \quad (1)$$

The loop inductance is:

$$L_{ii} = \frac{\mu_0}{2\pi} ln \frac{2h_i}{r_i} \quad (2)$$

The internal impedance:

$$\underline{Z}_c = R_c + jX_c = \frac{\rho\gamma}{2\pi r} \frac{I_0(\gamma r)}{I_1(\gamma r)} \quad (3)$$

in which the material constants μ and σ respectively the propagation constant $\gamma = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$.

The mutual impedance Zij of two conductors i and j, both parallel to the ground, with their respective heights above the ground being hi and hj have two components:

$$Z_{ij} = j\omega L_{ij} + Z_{gm} \quad (4)$$

The mutual inductance Lij is:

$$L_{ij} = \frac{\mu_0}{2\pi} ln \frac{D'_{ij}}{D_{ij}} \quad (5)$$

The impedance of the ground return path Zgm is:

$$Z_{gm} = R_{gm} + jX_{gm} \quad (6)$$

In the computation of the capacitance of transmission line accepts two factors: the length is larger then the dimensions of the circuits, the environment is uniform (air), the conductors have a cylindrical configuration.

The impedance of the earth return path is represented by Carson's correction terms for the self and mutual impedances.

3 Numeric simulation results

This paper presents several numerical applications of the developed algorithm. The examples focus on a 110 kV LEA. For the LEA parameters modeling, existing towers in the National Energetic System are used. Consider the case of an overhead power transmission line, at the left end one apply the lightning pulse voltage 1.2/50 μs. The line parameters are computed at frequency 50Hz and the ground is characterized by ρ=100 Ωm. The response wave presented in Fig. 3 is the signal at the open load end of the high voltage line obtained with the proposed software module.
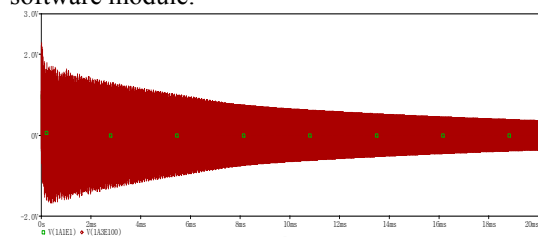
Fig. 3. Lightning pulse voltage, signal on load– proposed software

To validate the results obtained with the modul software proposed, in Fig. 4 is presented the result obtained with ATP.

In case when the parameters are evaluation at 500 KHz frequency, we can see the wave shape of signal in Fig.5 and when the ground is characterized by ρ=1000 Ωm the result is in Fig.6.
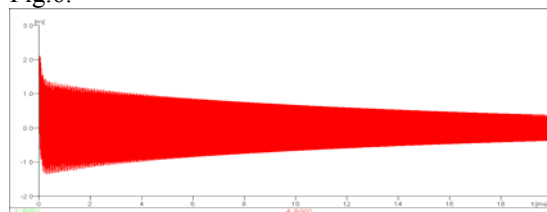
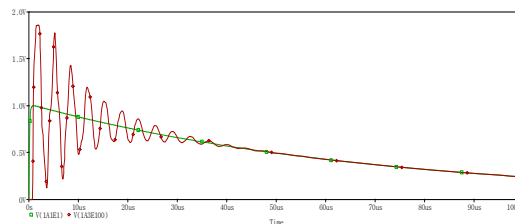**Fig. 4.** Lightning pulse voltage, signal on load-phase 1 with defect –ATP

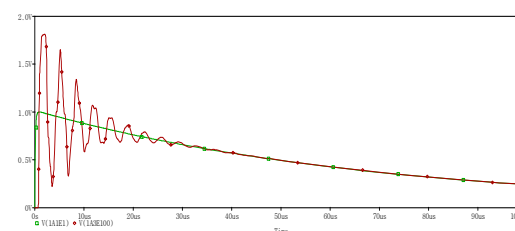**Fig. 5.** Lightning pulse voltage, signal on load – proposed software

Fig. 6. Lightning pulse voltage, signal on load – proposed software

The conclusion of analyses performed is that the appearance of a lightning pulse on one phase of the HV line conductors generates significant over-voltages and over-currents, while the waves shape is essentially influenced by the geometrical properties of the line.

References

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