Transmission Line Modeling Method Applied to Evaluate Effective Length of Impulsive Grounding Electrodes

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Abstract — This paper presents a study about the effective length used to dissipate current to the earth proceeding from a lightning surge injected in a horizontal grounding electrode. An algorithm based on Transmission Line Modeling Method (TLM-1D) was developed in order to evaluate the transitory behavior of the grounding. Variations of soils properties as resistivity and permittivity were taken into account. The simulation results show that a significant part of the electrode is not effectively used to scattering the surge current to the soil.

I. Introduction

In the project stage of a Lightning Protection System (LPS), grounding schemes must be taken into account in order to ensure the best current dissipation to the earth. In this task, the numerical simulation can provide valuable information about the grounding behavior before the electrodes are physically deployed on the soil. This practice may provide optimized performance of the LPS both the standpoint of personal safety as in the protection of the equipment electrically sensitive.

In recent years, numerical methodologies used to solve electromagnetic compatibility problems in a general manner as The Finite Element Method, The Moments Method, The Finite Difference Time Domain Method and The Transmission Line Modeling Methods (TLM) had been developed and adjusted for grounding systems analysis [1]-[3]. The TLM is between the most studied and developed in recent years, being able to be used for Maxwell's equations solution for electromagnetic waves propagation. Complex geometries, non-homogeneous medium with losses, materials with changeable parameters can be modeled with the TLM [4].

A typical impulsive grounding used in electric power systems, as towers in transmission and distribution lines, consists in a single horizontal electrode or counterpoise that must dissipate the current proceeding from a lightning surge. Usually, in the project of this kind of LPS, only safety criteria for people and equipment are taken into account and there are not studies about the electric efficiency of the electrode.

An electrode effective length can be stated as the length, above which the reflection voltage from the receiving end does not affect the peak value of the sending end voltage [5]-[6].

In this context, the goal of this paper is present a study about the effective length of counterpoise conductors or the length of the electrode that really is used in the current dissipation process to the earth. Several simulations using a TLM-1D (one dimension algorithm) considering short and long horizontal electrodes were performed in order to analyze the influence of the soil parameters as resistivity and permittivity in the effective counterpoise length.

II. Transmission Line Modeling Method

The TLM is a differential numerical technique having implementations in both time and frequency domain. In this method, Maxwell's equations are solved by analogy with Transmission Line Theory.

This technique involves the division of the solution region in a set of transmission lines (segments). Junctions are formed where the lines cross to form impedance discontinuities. The comparison among the transmission lines equations and the Maxwell's equations allow establishing equivalence between the voltages and currents in the lines with electromagnetic fields in the solution region [7].

In the case of horizontal electrodes a TLM algorithm in on dimension can be used to analyze the grounding behaviour presenting good accuracy to estimate current, voltages and field along the electrode [8].

In this technique, the impulsive response and the behavior in the time of a system can be explicit determined and there are no problems with convergence, stability or spurious solutions. Additionally, the non-linear soil ionization phenomenon can be incorporated to the model [9]-[10].

III. Results

In order to evaluate the effective length of a horizontal electrode, a TLM-1D model was developed with less than 200 lines of MATLAB code. In the results presented here a transient impulse, representing by a double exponential function 1 kA (1 x 10) μs was injected in on extremity of a 100 m long counterpoise with 7.5 mm of radius buried at h = 0.5 m depth in homogeneous soil. In the simulations the soil resistivity and permittivity ranges from 10 Ωm to 1000 Ωm and 1 F/m to 100 F/m respectively.

Fig. 1 shows a 3-D plot representing the current dissipation along the electrode (y axis) considering different values of soil resistivity. In the xz axis can be seen the current propagation in time for a specific point along the electrode.

It can be observed in these curve surfaces that for all values of soil resistivity a significant portion of the electrode is not utilized to dissipate de current. However, the resistivity had a proportional relation, with the effective electrode length.

Fig. 2 shows again a 3-D plot presenting the current dissipation along the electrode (y axis) and current propagation in time for a specific point along the electrode (xz axis). In these simulations, different values of soil permittivity with a constant value of soil resistivity were taken into account.

Again observing these results, it can be seen that a part of electrode length is not effectively utilized to dissipate de transient current for all values of permittivity soils. However, differently of resistivity, the change of permittivity doesn't affect de current propagation along the electrode.

IV. Conclusions

Some simulations based on TLM-1D algorithm are performed in order to evaluate de effective length of a horizontal electrode. The results show that a significant part of a long grounding counterpoise is not effectively utilized to dissipate de transient current to the earth. The soil resistivity affects directly the effective electrode length while the change of media permittivity doesn't present relevant influence on the scattering current along the grounding conductor.

V. References

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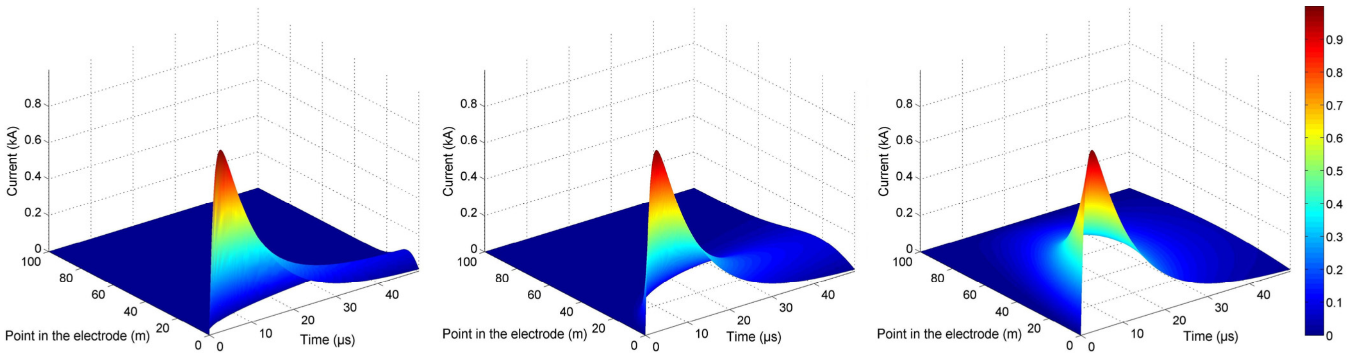

Fig. 1. Current dissipation along the horizontal grounding electrode considering constant value of soil permittivity (10 F/m) and different values of soil resistivity.
Left to right: 10 Ωm, 100 Ωm, 1000 Ωm.

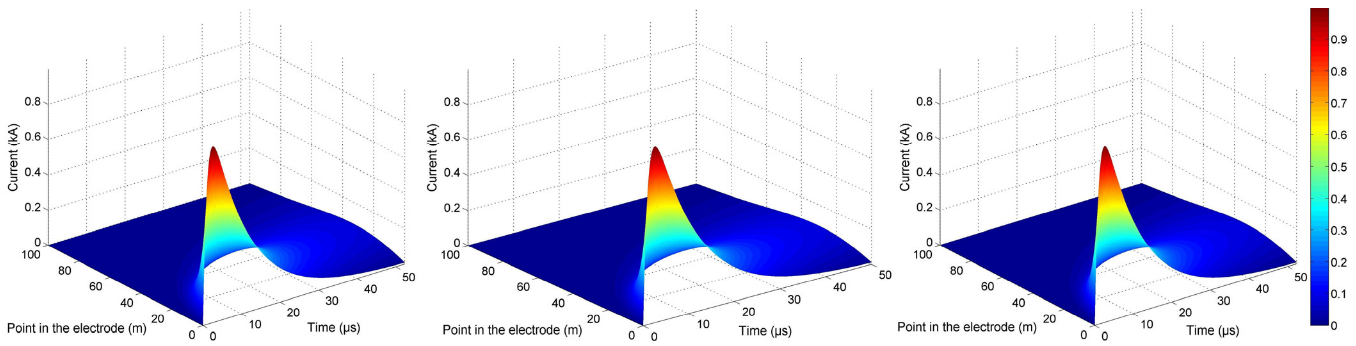

Fig. 2. Current dissipation along the horizontal grounding electrode considering constant value of soil resistivity (200 Ωm) and different values of soil permittivity. Left to right: 1 F/m, 10 F/m, 100 F/m.