Modeling of Grounding Systems Considering the Soil Ionization Effect Using COMSOL Multiphysics® Software

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Abstract

Introduction: The soil ionization is an important phenomenon to be considered in the analysis of grounding electric systems. When lightning strikes a grounded structure, the electric field associated with the high impulsive current injected into the grounding conductors may cause the soil around them to breakdown (see Figure 1). This phenomenon causes a decrease in the electric potential in the area of soil ionization and consequently reduces the value of the ground impedance [1, 2]. Several mathematical models have been proposed to take into account the dynamic effect of soil ionization on grounding systems submitted to lightning currents. Some of them, like the Dynamic Model (DM) and the Energy Balance Model (EBM) make use of analytical functions to represent the space-time variation of the soil resistivity [3, 4]. In this way, the main goal of this work is to use the COMSOL Multiphysics® software as a modeling tool for grounding topologies subjected to lightning currents, taking into account the soil ionization effects predicted by the DM and EBM methods. Although COMSOL has been used successfully for many years in solving a lot of physical and engineering problems, apparently it has not been used in applications involving the transient behavior of grounding systems. Then, another objective of this work is to demonstrate that this software appears as an attractive alternative to be used as a computational tool in studies related to this subject matter.

COMSOL Multiphysics Utilization: To perform the time domain simulations, the AC/DC Module was used. The 3D domain was discretized using ExtraFine adaptive meshes. Figure 2 show a flowchart of the algorithm of the proposed procedure developed to implement the soil ionization methods using LiveLink™ for MATLAB®.

Results: As example in this abstract, the modeling and simulation results for a concrete pole base acting as a grounding topology for overhead power distribution lines are shown. The geometric and mesh characteristics used to model a "Double T" type concrete pole base are presented in Figure 3. The distribution of the equipotential lines is shown in Figure 4a. Furthermore, Figures 4b and 4c show the voltage at the injection point and the transient ground impedance obtained for the DM and EBM models, respectively.

Conclusions: This work has proposed a procedure that allows modeling grounding systems with COMSOL Multiphysics® and MATLAB® taking into account the soil ionization effects

according to the Dynamic and Energy Balance models. Comparisons between calculated results and those reported in the technical literature showed a satisfactory agreement. In the full paper more simulations showing the behavior of both ionization models for some typical grounding topologies used in electric distribution systems will be presented.

Reference

[1] V. Cooray, "Lightning Protection", IET Power and Energy Series, Vol. 58, 2010.

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[3] G. Ala; P. L. Buccheri; et al, "Finite difference time domain simulation of earth electrodes soil ionization under lightning surge condition", IET Science, Measurement and Technology, Vol. 2, No. 3, pp. 134-145, 2008.

[4] S. Sekioka et al., "Current-Dependent Grounding Resistance Model Based on Energy Balance of Soil Ionization", IEEE Transactions on Power Delivery, Vol. 21, No. 1, pp. 194-201, Jan. 2006.

Figures used in the abstract

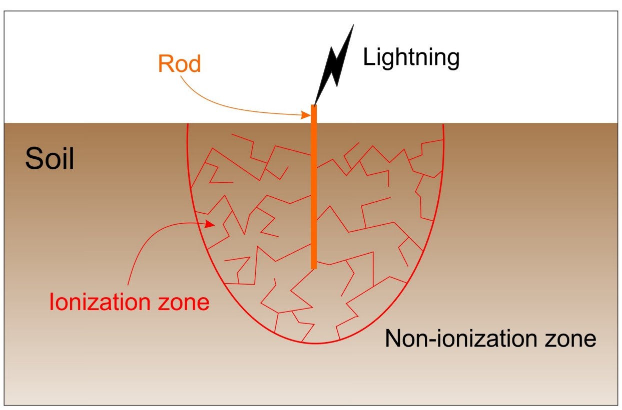

Figure 1: Ground electrode associated with soil ionization.

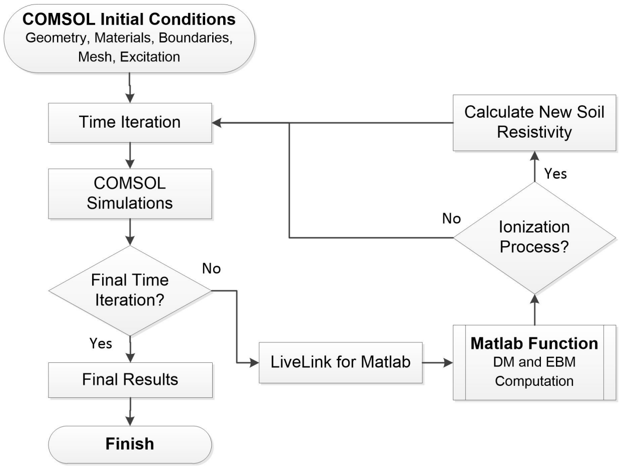

Figure 2: Flowchart of simulation procedure.

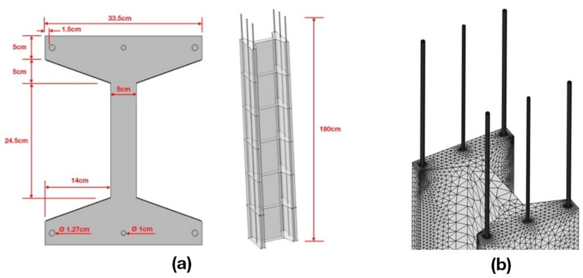

Figure 3: Geometric dimensions of the simulated concrete pole base.

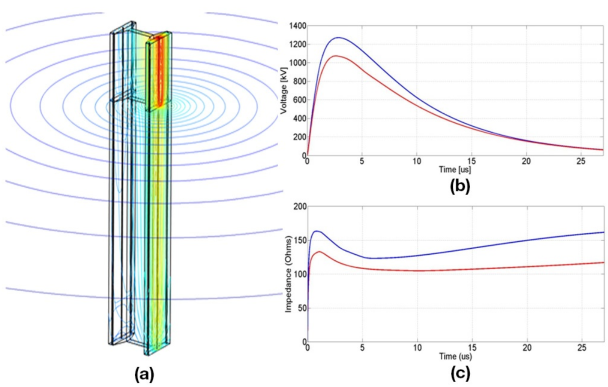

Figure 4: Simulation results: a) distribution of the equipotential lines for a concrete pole base; b) voltage at the injection point (DM-blue and EBM-red); c) transient ground impedance (DM-blue and EBM-red).