

Comparison of Power Transmission Line Models with Finite Elements

C. K. Arruda¹, A. A. Silveira¹, F. C. Dart¹

¹CEPEL, Rio de Janeiro, RJ, Brazil

Abstract

The growing demand for efficient transmission (1), including refurbishing of existing lines, requires technological advances beyond the actual methodologies, basically electric parameters and electromagnetic fields estimation.

Some analytical models developed at CEPEL (2, 3) provide reliable data for projects of transmission lines in extra-high voltage (EHV) and the proposed ultra-high voltage level (> 800 kV in AC systems).

This paper presents an application of finite element (FEM) models developed in COMSOL Multiphysics® software, compared with analytic models. The application of FEM is common in high voltage engineering (6, 7, 8), the present approach relies in less explored issues, such as the influence of the ground (4, 5) - most methods considers an ideal ground (infinite conductivity), a reasonable premise in some models, e.g. direct-sequence impedance and admittance, but lacking precision regarding other aspects, e.g. unbalanced currents or electric fields at ground level.

Other aspects are the electric field at the conductor surface (Figure 3), a limiting factor for EHV projects due to the corona effect, and the skin effect at high frequencies (Figures 1 and 2), another important aspect, applied in the transient response such as lightning and switching phenomena.

The COMSOL model applies the AC/DC Module (Electrostatics and Magnetic Fields physics interfaces) for the calculation of electric fields, current density and equivalent electric parameters (impedance and admittance), using 2D approximation, being a reasonable premise for the present study. A parametric sweep was applied at the ground conductivity, to compute the influence in the impedance matrix and compare with models e.g. Carson (4) and Deri (5).

The mesh generation demands a good representation of each conductor, including the steel core, due to the necessary precision at the conductor surface for determination of the electric fields. Also the boundary layers refinement was applied in one conductor, for a correct representation of the skin effect at high frequencies.

The models are made both in phasor (frequency domain) and in time dependent simulation, basically for the effects of each phase in the electric field at ground level. Figure 4 shows the

electric field ellipsis, an aspect evident only in a time dependent simulation (9).

The validation are made in a AC transmission line concept with an expanded bundle, at 500 kV, using 6 conductors per phase, each one made of aluminum with steel core (ACSR). The ground cables and a ground with finite conductivity also are represented, using both normal (balanced) and unbalanced conditions (mainly for a single phase short-circuit simulation).

The results obtained are compared with analytic models, which limitations are determined by empirical data (e.g. Carson approximation of the return ground impedance, in COMSOL the ground was considered as an additional conductor) or simplified assumptions (e.g. consider a cable as an ideal cylinder, which in COMSOL was possible represent each wire inside the cable). The FEM model, although not absolute, can be used for further discussion of the general validity of the TLs models.

Reference

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Figures used in the abstract

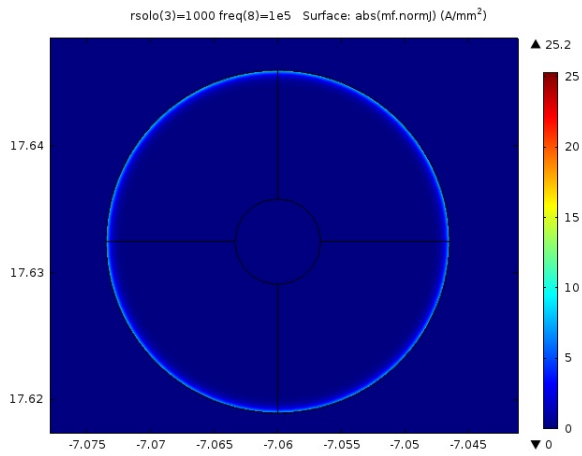


Figure 1: Current density in an aluminium cable with steel core (ACSR) at 100 kHz (skin effect).

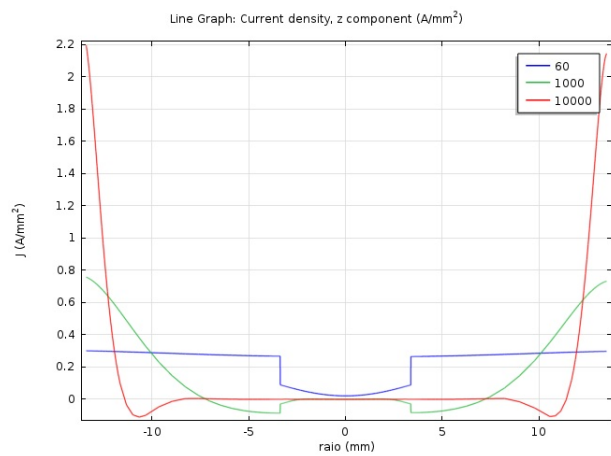


Figure 2: Transverse profile in an ACSR cable, showing current density for a range of frequencies (up to 10 kHz).

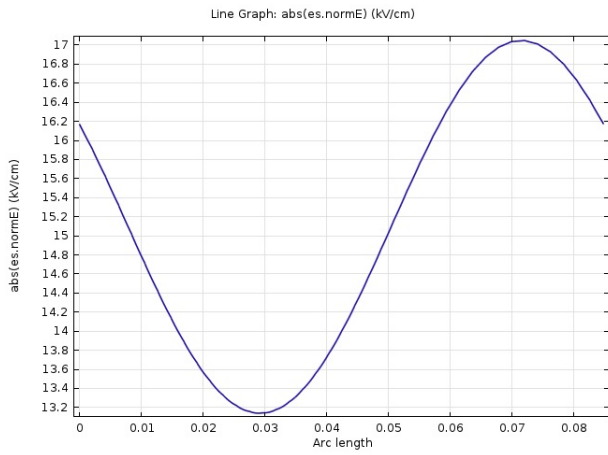


Figure 3: Surface electric field around one cable, showing difference due to proximity of other cables and phases.

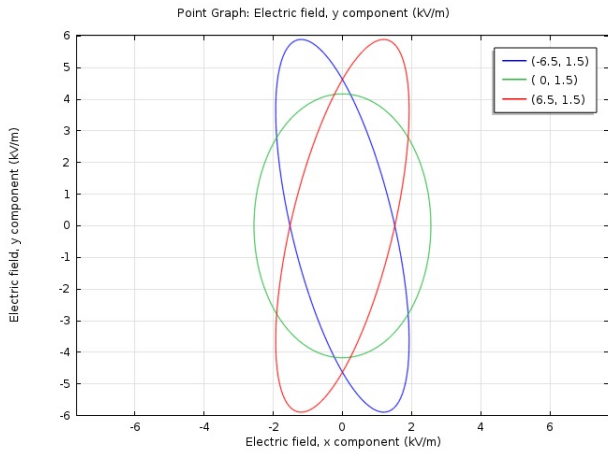


Figure 4: Electric field near ground (1.5 m height) below each phase, time dependent simulation, showing the ellipsis due to the triphase composition.