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Assessment of Electric and Magnetic Field Exposure Near Overhead Transmission Lines Using 2D Finite Elements Method

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1 Introduction

Electric and magnetic fields near power lines are of particular interest in safety analysis related to effects on the environment, human exposure and electromagnetic disturbances on adjacent systems. Electromagnetic modeling is an efficient procedure to assess their effects in different scenarios.

In this paper we perform numerical analysis of the distribution of electric and magnetic fields in the vicinity of 110 and 400 kV overhead transmission lines using the open source software FEMM 4.2. The modelling procedure is briefly described and the results are verified using full-wave electromagnetic model based on the method of moments. Different configurations of transmission lines and the effects of phase sequence transposition are considered. Calculated electric and magnetic field levels are then compared to exposure limits established by ICNIRP [1]. Using the magnetic field, the induced currents within fictional human tissue are also estimated.

2 Implemented models in FEMM

The overhead transmission lines of interest are 110 kV single-circuit, 110 kV double-circuit and 400 kV power lines. Following the procedures provided in [2], electric and magnetic field levels are calculated at height of 1 m above ground, within a profile that is perpendicular to the transmission line.

In FEMM 4.2, the calculated fields are provided as instantaneous values, not as a phasors. To compute the RMS values, we sample the values of each phase at multiple time instants over one period of 20 ms [3]. Our verification has shown that 40 equally time-spaced samples provide good estimate of one period. To automate this process for all considered cases, we used the Lua scripting language which is incorporated in the FEMM 4.2 software. Computation of the electric field and the electric potential is done using the "Current Flow" module of FEMM 4.2, while computation of the magnetic field and magnetic potential is done using the "Magnetics" module.

3 Estimation of the induced current density in human tissue

The presence of the magnetic field in the vicinity of transmission lines causes induced electric field in biological tissues. Calculation of the internally induced electric field in human heart and brain tissue based on the Faraday's law is performed. In the process, the average characteristics of human tissues are considered. Furthermore, the endogenous current densities of the heart and brain are estimated at a minimal value of 10 mA/m^2 and 1 mA/m^2, respectively [4].

4 Results and discussion

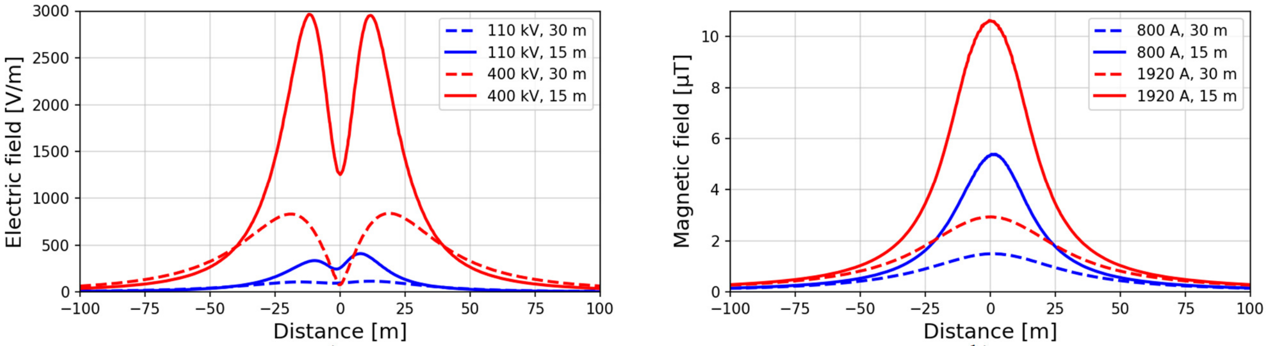
In Fig. 1 the results of the electric and magnetic fields for the single-circuit systems are shown. It is observed that the maximum value of the electric field for the 400 kV tower is 1.68 times lower than the exposure limit and for the 110 kV tower it is 12.2 times lower for the h_g = 15 m case. In comparison, the values are further lowered by a factor of 3.54 for the h_g = 30 m case. In practice, the height of the conductors may be lower along the power line, and therefore 400 kV tower can be considered as a possible health risk factor.

The maximum value of the magnetic field for the 400 kV tower is 18.8 times lower and for the 110 kV tower it is 68 times lower than the limit for the h_g = 15 m case. For the h_g = 30 m case, there is a further decrease by a factor of 3.6.

In Fig. 2 the results of the electric and magnetic fields for the double-circuit towers are shown. The maximum values for both the electric and magnetic fields appear when the phases are untransposed. It is observed that the maximum value of the electric field for the untransposed case is 7.5 times lower, and for the transposed case is 21.2 times lower than the exposure limit for h_g = 15 m. The maximum value of the magnetic field for the untransposed case is 80 times lower, and for the transposed case is 145.77 times lower than the exposure limit for h_g = 15 m. For h_g = 30 m, more than 3 times lower values are observed.

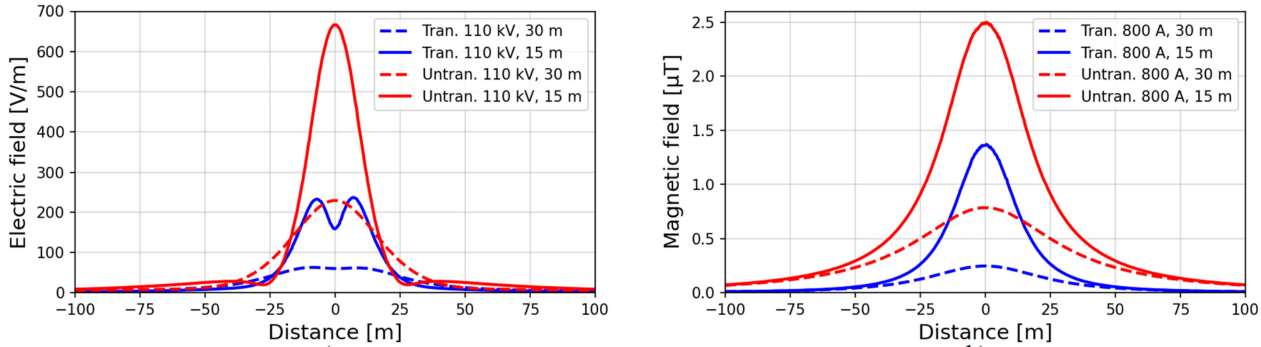
The results show that the magnetic field originating from the modelled towers causes induced currents that are more than 385 times lower than the heart's endogenous currents and more than 45 times lower than the brain's endogenous currents. It should be noted that the estimated maximum values were obtained by using the highest value of the time derivative of the magnetic field $\partial B/_{\partial t}$ in one full period.

Some of the results of the implemented models in FEMM 4.2, have been verified with an independent approach based on the method of moments [5] where less than 3% error was observed.



a) b)

Fig. 1 RMS Electric field a) and RMS magnetic field b) for single-circuit towers.



a) b)

Fig. 2 RMS Electric field a) and RMS magnetic field b) for double-circuit towers.

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References

[1] International Commission on Non Ionizing Radiation Protection, (2010), "Guidelines for Limiting Exposure to Time-Varying Electric and Magnetic Fields (1 Hz - 100 kHz)", *Health Physics*, **Vol**. 99, No. 6, pp. 818-836.

[2] EN 62110:2009 - Electric and magnetic field levels generated by AC power systems - Measurement procedures with regard to public exposure, CENELEC, Brussels, (2009).

[3] E. Lunca, S. Vornicu, A. Salceanu, O. Bejenaru, (2018), "2D Finite Element Model for computing the electric field strength-rms generated by overhead power lines." *Journal of Physics: Conference Series*, **Vol**. 1065, No. 5, 052024.

[4] J. Bernhardt, (1979), "The direct influence of electromagnetic fields on nerve- and muscle cells of man within the frequency range of 1 Hz to 30 MHz", *Radiation and Environmental Biophysics*, **Vol**. 16, pp. 309–323.

[5] B. Markovski, L. Grcev, V. Arnautovski-Toseva, (2021), "Fast and Accurate Transient Analysis of Large Grounding Systems in Multilayer Soil", *IEEE Transactions on Power Delivery*, **Vol**. 36, No. 2, pp. 598-606.