ELECTROMAGNETIC FIELD MODELLING IN VICINITY OF A POWER LINE

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Abstract: *The electromagnetic field distribution in vicinity of a power line has been studied in the paper. The problem was considered as time-harmonic, 2D plane-parallel and field distribution has been numerically modelled using finite element method and software package QuickField 5.6. The three-phase power line consists of three conductors of circular cross section with time varying currents, shifted in phase by* 120^0*. The study was carried out for different distances between the conductors. The results for current density distribution in the conductors and magnetic field in points with specified coordinates have been obtained for different currents of 50 Hz frequency.*

Keywords: *electromagnetic field modeling, power line, finite element method*

1. INTRODUCTION

The creation of high technology, energy-efficient and reliable electromagnetic devices and systems that do not harm the environment is of significant importance for our new and modern society. Nowadays, special attention has been paid to the possible harmful effects on the environment arising from the electromagnetic fields generated in the vicinity of power lines [1], [2], [3].

Transmission of electricity is accompanied by the generation of low-frequency electromagnetic fields. These fields can affect both the reliable work of electrical and electronic equipment and devices that are close to them and also to have a significant impact on variety of living organisms. The good understanding of these effects allows predicting and therefore avoiding the negative consequences both for equipment and for living organisms [4]. It is important to know that there are many studies that examine the impact of induced currents in living organisms and in particular on the human body. According the studies maximum allowable magnetic field is 0.04μT [5].

The main goal of the presented work is investigation of electromagnetic field distribution in vicinity of a power line. The aim is field modelling in points with specified coordinates in vicinity of line. Since the field distribution depends on line currents, geometry of the lines and distances from the conductors the study is carried out for different currents of 50 Hz frequency and for different distances between the conductors.

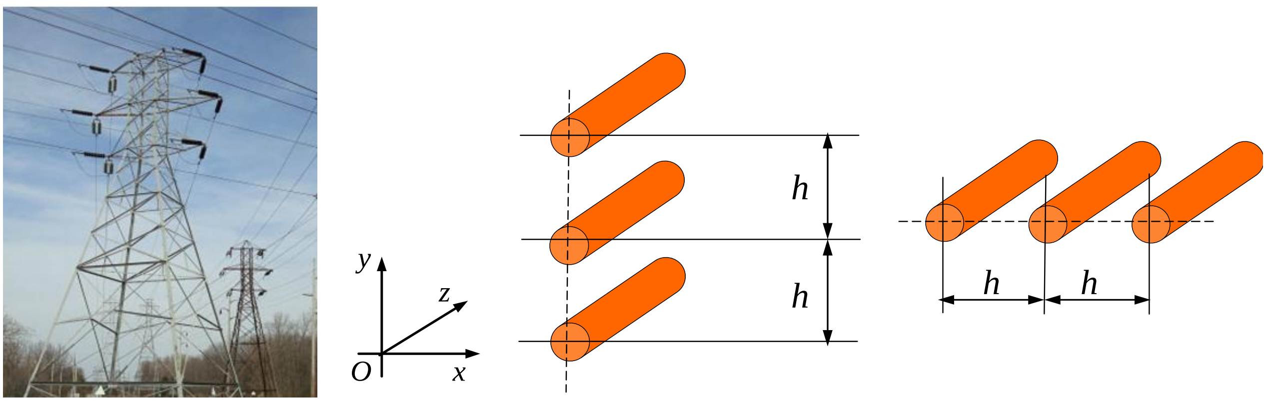
In many papers similar problem has been studied using analytical expressions, based on the Biot-Savart law and superposition of the fields. This approach involves a lot of idealizations and does not allow examining the real environment, taking into account the existence of other material objects in the investigated regions.

In the presented work field distribution has been numerically modelled using finite element method (FEM) and commercial software package QuickField 5.6. Using this numerical method for solving of the task, makes it possible to take into account of the real environment and distortions of the field distribution due to the presence of objects with different material properties. The field quantities and characteristics can been easy obtained in any point of observation.

2. DESCRIPTION OF THE STUDIED PROBLEM AND MATHEMATICAL FORMULATION

2.1. Investigated power line

The principal geometry of the investigated system is shown in Fig. 1. Two main design variants of the power line have been considered in the presented work – vertical (Fig.1a) and horizontal (Fig.1b). In the both variants the three-phase power line consists of three conductors of circular cross section with time varying currents, shifted in phase by 120^0. The study is carried out for different distances ***h*** between the conductors (***h*=2*m*÷** 6m) and for different 50 Hz currents ***I*** (***I*=5*A*÷** 15A). The field distribution has been observed in control points with specified coordinates.



a) vertical b) horizontal

Fig. 1. Two main variants of possible geometry of the investigated system

2.2. Mathematical formulation

The problem of electromagnetic field distribution of the power line is considered as time-harmonic, two-dimensional, plane-parallel in plane *xOy*. The problem is formulated and solved for the complex amplitude of vector magnetic potential $\vec{A}$, where

$$\vec{B} = rot\,\vec{A}, \tag{1}$$

– $\vec{B}$ is a vector of magnetic flux density.

The flux density lies in the plane of model (*xOy*), while the vector of electric current density $\vec{J}$ and the vector potential $\vec{A}$ are orthogonal to it and have components only in z-direction J_z and A_z. The electromagnetic field is modelled using complex magnetic potential $\dot{A}_z$ by equation:

$$\frac{\partial^2 \dot{A}_z}{\partial x^2} + \frac{\partial^2 \dot{A}_z}{\partial y^2} - j\omega\mu\sigma \dot{A}_z = -\mu \dot{J}_z \qquad (2)$$

where σ is electric conductivity, μ is magnetic permeability and $\dot{J}_z$ is the complex of the current density z-component J_z.

3. FEM MODELLING OF A THREE-PHASE POWER LINE

Numerical investigations of electromagnetic field distribution have been made using FEM and QuickField 5.6 software package [6].

Study was carried out for different design parameters, shown in Table 1, like distances between conductors and values of the phase currents. The field in special control points has been determined. Analysis of the results gives possibilities to estimate field values according their possible effects on the electrical equipment and living organisms and make reasonable choice in order to avoid negative affects.

The finite element mesh, used for the analysis of vertical variant of power line is shown in Fig. 2.

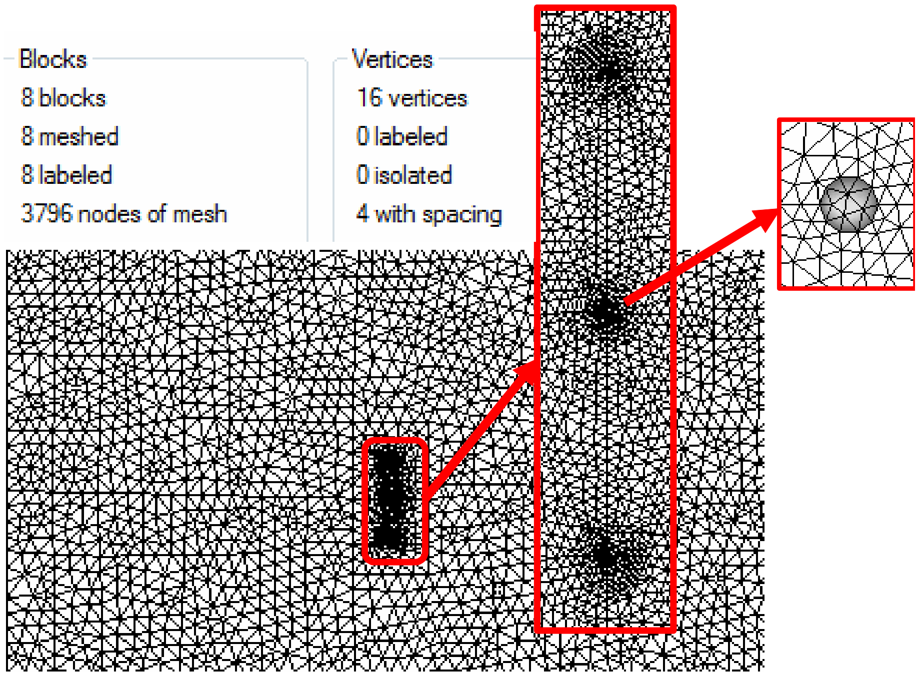


Fig. 2. Finite element mesh, used for the analysis of vertical variant of power line consists of 3796 nodes

The magnetic field distribution for the vertical and horizontal line geometry are shown in Fig. 3 and Fig. 4, when design parameters are: distance h=5m and current is I= 10A. In Fig. 5 and Fig.6 current density distribution is shown for the same variants of investigation. These figures also illustrate determination of the total current in conductors - the current of the first phase (I=10A, $\varphi = +120^0$)in Fig.5 and in Fig.6 determination of the current density distribution in case of vertical geometry and total current in the current of the third phase (I=10A, $\varphi = -120^0$)

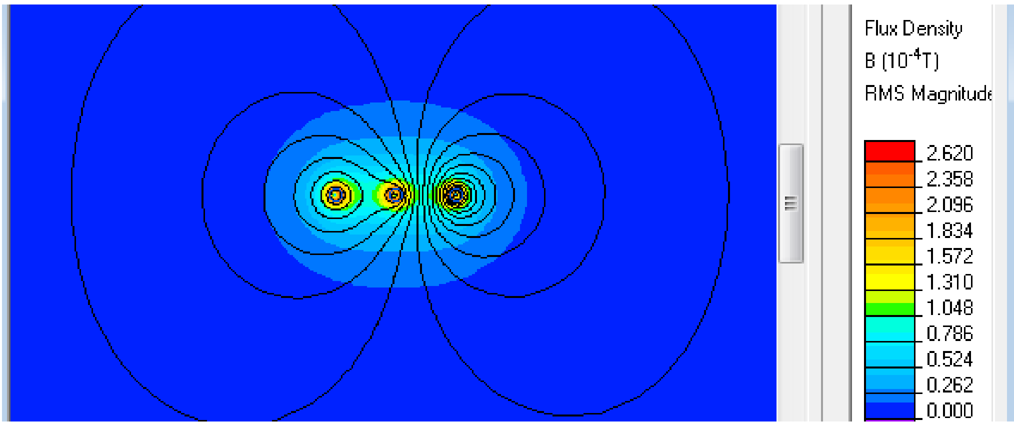


Fig. 3. Magnetic field distribution in the vicinity of a power line in case of horizontal geometry

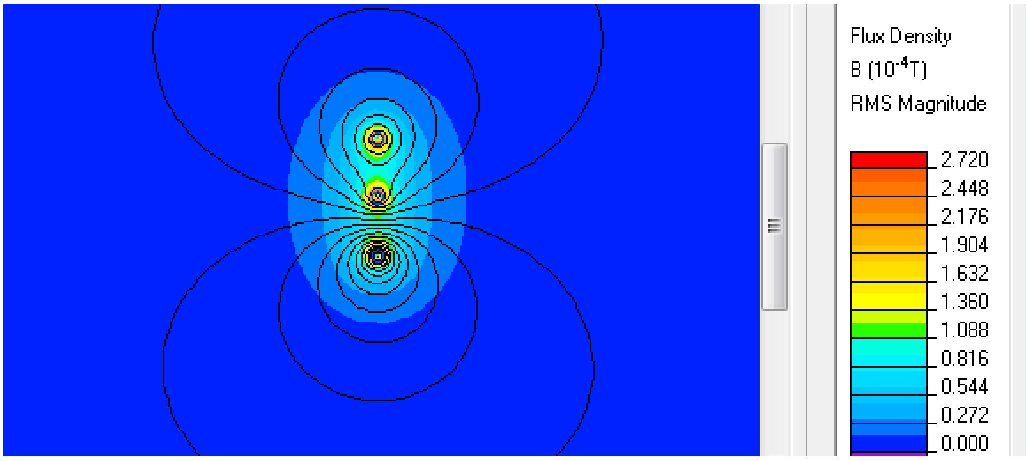


Fig. 4. Magnetic field distribution in the vicinity of a power line in case of vertical geometry

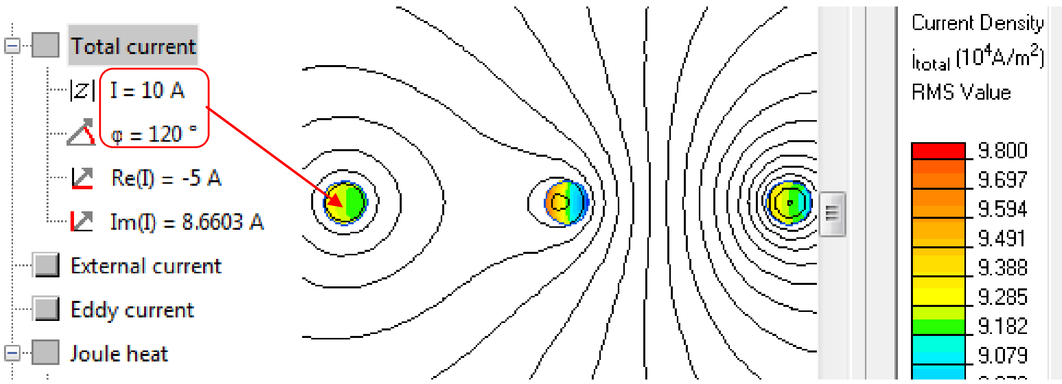


Fig. 5. Determination of the current density distribution in case of horizontal geometry and total current in the current of the first phase

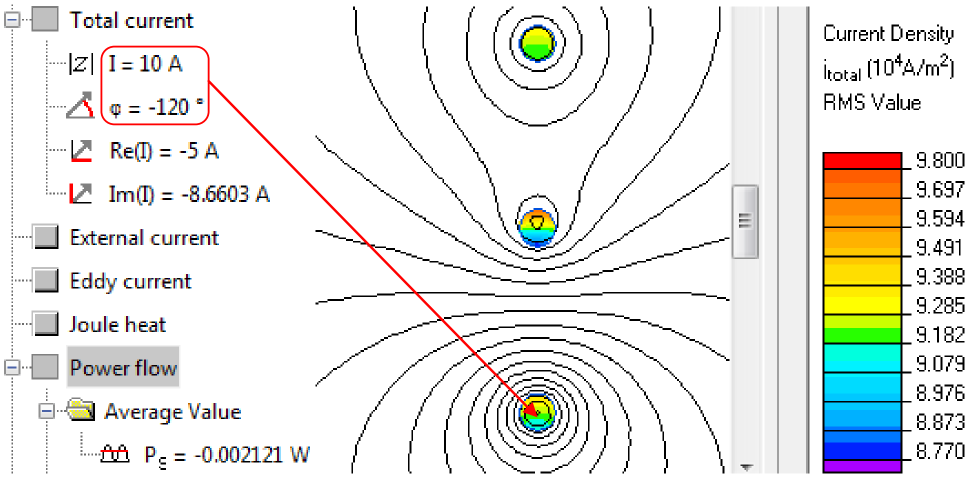


Fig. 6. Determination of the current density distribution in case of vertical geometry and total current in the current of the third phase

The main goal of the analysis of obtained results is field modeling in the vicinity of power line. The results for magnetic flux density values in points with specified coordinates are shown in Fig. 7 and Fig. 8 for two different distances between conductors.

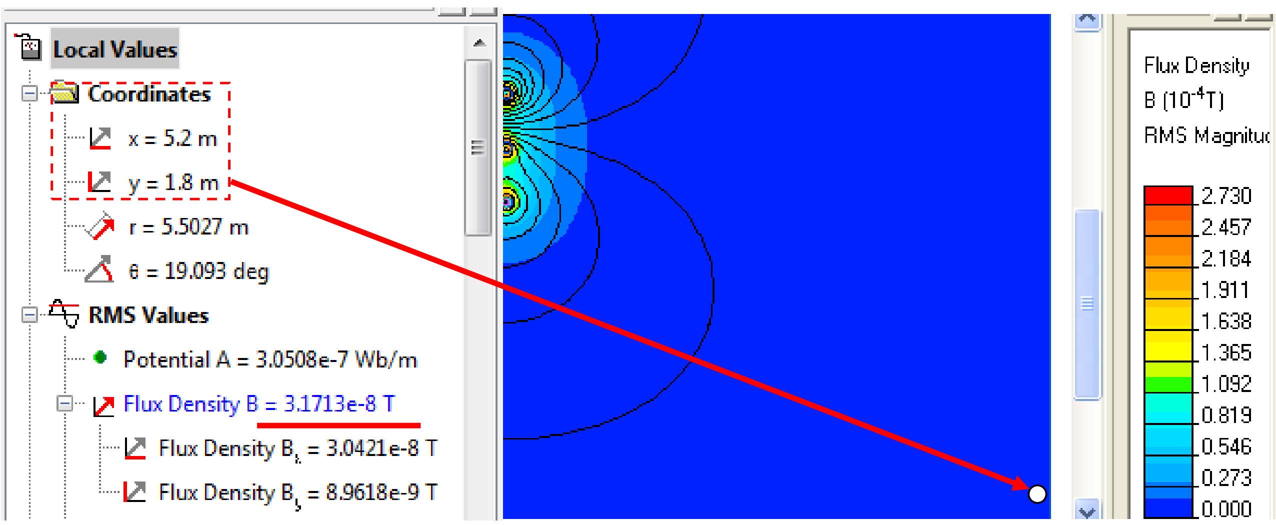


Fig. 7. Magnetic field distribution in the vicinity of a power line and magnetic flux density values in points with coordinates x=5.2m, y=1.8m

4. CONCLUSION

In this work detailed investigation of electromagnetic field distribution in vicinity of a power line has been done for different values of phase current, line geometry and distances between the conductors. The aim of the study is field modelling in points with specified coordinates in order to estimate field values according their possible negative effects on the electrical equipment and living organisms. It gives possibilities for reasonable choice of the line parameters in order to avoid harmful affects.

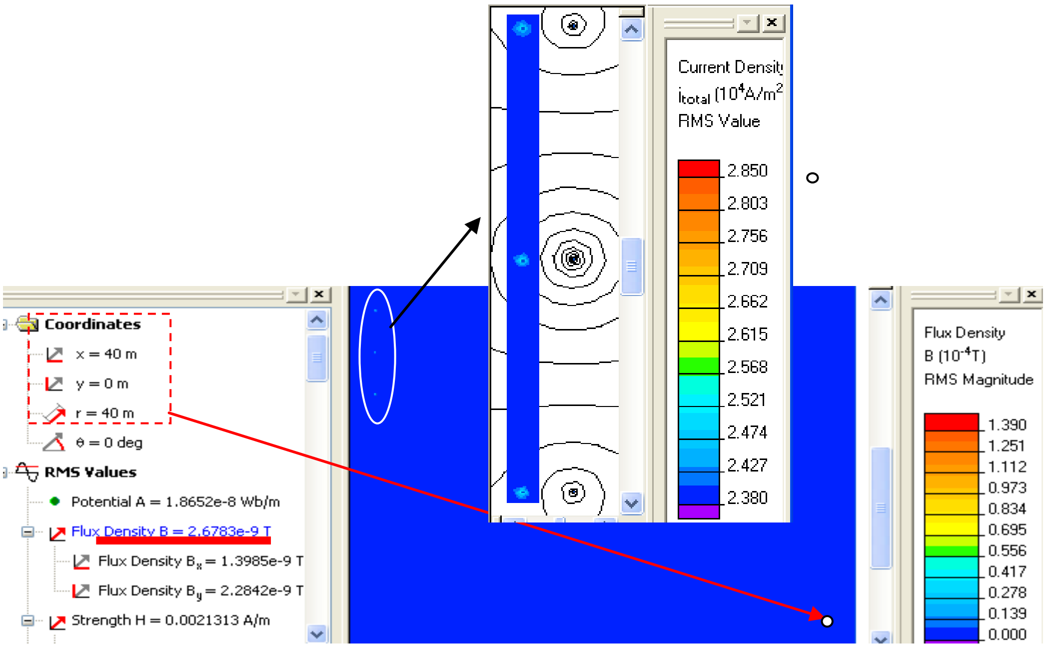


Fig. 8. Magnetic field distribution in the vicinity of a power line and magnetic flux density values in points with coordinates x=40m, y=0m

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