Electric Field in the Environment of 110kV Power Line and its Impact on Biological Systems

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Abstract – ***The paper will present the influence of the electric field with an industrial frequency that originates 110 kV power line of the man who is in his immediate environment. The human model is composed of parallelepipeds representing the individual parts of the body and is located adjacent to the power line. The distribution of the electric field and the potential in the vicinity of the 110 kV power line is presented without the presence of a man under the power line obtained by the finite element method. The work is supplemented with certain standards regarding the maximum allowed values for the strength of the field and the allowed density of streams permeated into the human body.***

Keywords – ***electric field, potential, biological systems, induced currents.***

I. Introduction

With the rapid development of human society and the more advanced technological development, there is a need to increase the amount of electricity, which in turn leads to an increase in electromagnetic fields at the level of urban and working environment. In recent years, there is increasingly the opinion that electromagnetic fields derived in different ways, from energy lines to mobile phones, cause various diseases in people, including the most severe. In relation to this issue, due to insufficient knowledge, there is still no single position. A better insight into the real situation shows that potential health hazards, from electromagnetic fields, should not be ignored.

This paper deals with the aspect of the harmful influence of the electric fields in order to systematize the knowledge for estimating the electric field in the surrounding of the three-phase conductors. Knowing the values of the electric field and its distribution under and around the three-phase power lines is important for the protection of workers working in substations and the population living near the power lines.The paper contains an analysis of the electric field that originates 110 kV power line per person located in its immediate surroundings. The human model is composed of parallelepipeds representing the individual parts of the body. The method of finite elements is used to obtain the distribution of the electric field under and in the environment of the power line without and in the presence of man.The work is supplemented with certain standards regarding the maximum allowed values for the strength of the field and the allowed density of streams permeated into the human body.

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II. Mathematical model

The electric field in the vicinity of the power line is caused by the electrical charge of the phase conductors and the protective ropes. Phase conductors and protective ropes are modeled as infinitely long cylindrical conductors with a cross-section with finite dimensions. Considering that the earth is at zero potential, a mirror image method should be used to calculate the electric field generated by this system. Maxwell's postulate in a differential form is:

$$div\vec{D} = \rho \quad (1)$$

The connection between the vector of the electric field strength and the electrical induction is given by the expression:

$$\vec{D} = \varepsilon\vec{E} \quad (2)$$

The vector of the electric field strength expressed through the electric potential is:

$$\vec{E} = -grad\varphi \quad (3)$$

By connecting relations (2) and (3), the following partial differential equation is obtained:

$$-divgrad\varphi = \rho \quad \text{Or:} \quad -\varepsilon\Delta^2\varphi = \rho \quad (4)$$

Equation (4) can be applied to inhomogeneous regions and provides a solution for the electric potential and the strength of the electric field, under certain boundary conditions.

III. Distribution of electric field in the environment of 110kV power line

In Fig. 1 presents the cross-section of 110 kV power line with the corresponding dimensions of the distances between the phase conductors and protective ropes [1].

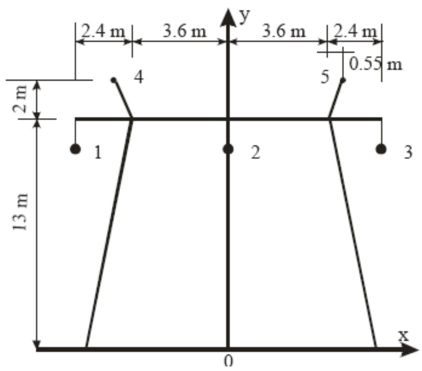

Fig. 1. Cross section of the conductors of the 110 kV power line

In Table 1, the dimensions of the 110kV transmission line are given, as well as the values of the voltage and current through the conductors.

Table 1. Coordinates and radius of phase conductors and protective ropes of 110 kV power line

	First phase	Second phase	Third phase	Rope 1	Rope 2
n	1	2	3	4	5
$x[m]$	-6	0	6	-4.1	-4.1
$y[m]$	12	12	12	15	15
U_n	$U_f e^{j0}$	$U_f e^{j\frac{2\pi}{3}}$	$U_f e^{-j\frac{2\pi}{3}}$	0	0
I_n	$I_f e^{j0}$	$I_f e^{j2\pi/3}$	$I_f e^{-j2\pi}$	0	0
a$[mm]$	8.74	8.74	8.74	5	5

The distribution of the electric field in the vicinity of the 110 kV power line in the absence of a person, obtained using the FEMM 4.2 program package is shown in Fig.2. of the power line.

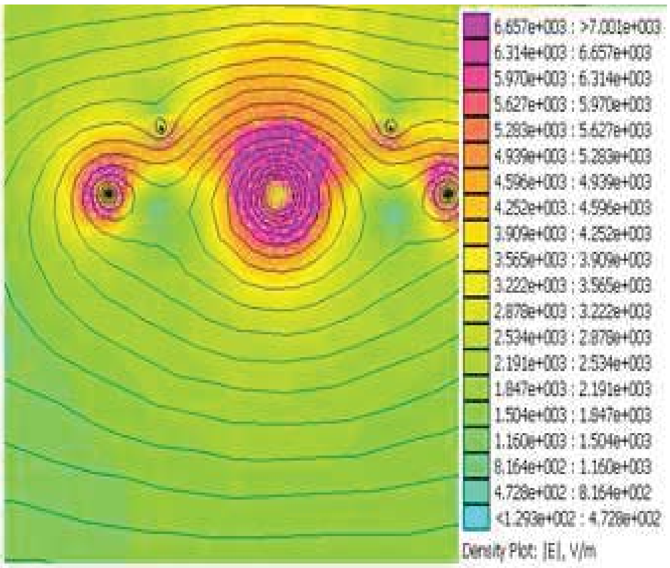

Fig. 2. Distribution of the electric field in the environment of the 110kV power line in the absence of a person

Fig.3. shows the distribution of the field per line vertical placed under the middle phase conductor perpendicular to the surface of the earth and in Fig.4. the distribution of the electric field per line parallel to the ground surface at height h = 1.5m and the length of x = -3m to x = 3m.

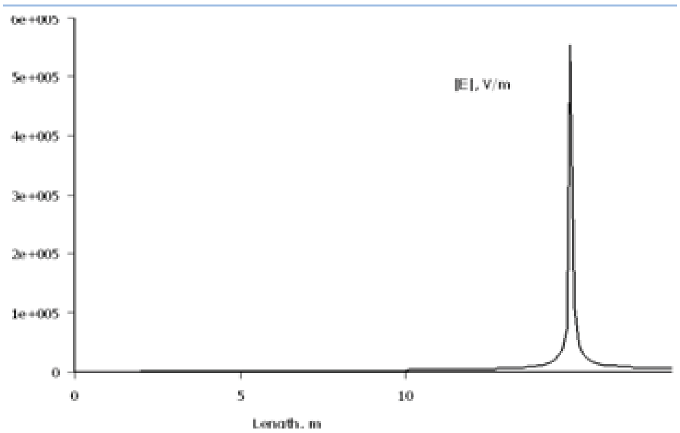

Fig. 3. Distribution of the electric field per line vertical placed under the middle-phase conductor perpendicular to the surface of the earth

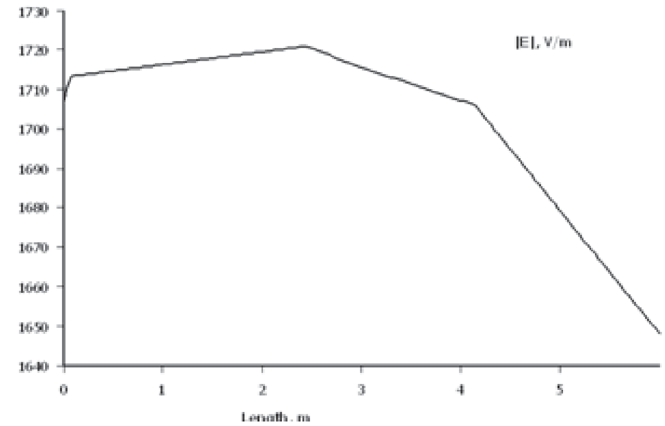

Fig.4. Distribution of the electric field per line parallel to the ground surface at height h = 1.5m and with a length of x = -3m to x = 3m

IV. Distribution of Electrical Field in the Environment of 110kV Power Line in the Presence of Man

Human tissue in an electromagnetic view acts as a non-homogeneous, paramagnetic semiconductor environment, whose specific conductivity σ and relative dielectric permeability ε_r very intensively with the frequency and is located in a wide range whose boundaries define the values of these quantities for fat tissue and blood. The dependence of the specific conductivity of the tissues of the frequency is such that with the increase in the frequency, the tissue conductivity grows, and the dielectric permeability decreases with the increase in the frequency. For an industrial frequency of 50Hz, for fat tissue $\varepsilon_r = 10^5$ and σ=0.02S/m, and for the blood $\varepsilon_r = 10^6$ and σ=1S/m.

The magnetic permeability of biological tissues is practically equal to the magnetic permeability of the free space $\mu_0 = 4\pi.10^{-7}$ H/m (the exception is the immediate proximity of microscopic magnetosomes), so that the biological tissues are non-magnetic.

When penetrating the electric field through human tissues, the intensity of the field is significantly reduced due to the electromagnetic properties of the biological tissues.

In order to simplify the analysis, the human body model has been chosen to be homogenous with average values for electromagnetic features. In the paper, using the FEMM 4.2 method, finite element method will show the shape of the potential and distribution of the electric field caused by an overhead 110 kV power line in the case when a human body model is placed under the very power line with hands lowered by the body.

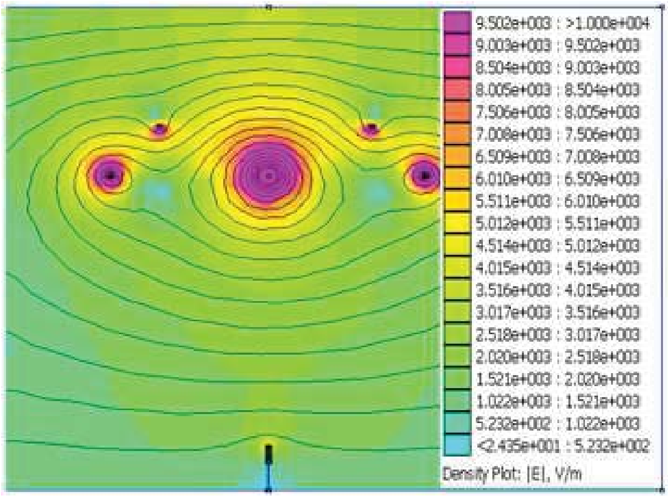

Fig.5. Distribution of the electric field below the 110 kV power line when a man with his hands is attached to the body under the very power line.

In Fig.6. is given detail from the previous image to show that the presence of a man under the power line causes deformation of the lines of the field. The intensity of the electric field around the head has a significantly increased value than that for the field without the presence of the human body, which is a potential danger.

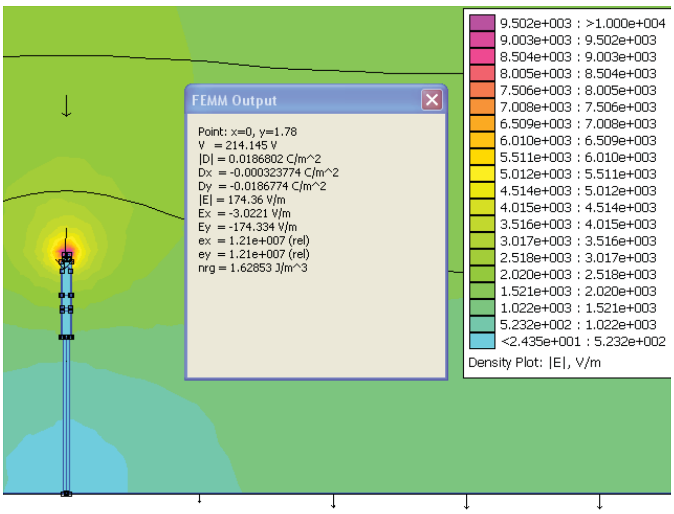

Fig.6. Distribution and intensity of the electric field in the environment of a man-model placed under the 110 kV power line in the presence of a man (detail from the previous picture)

Fig.7. Shows the distribution of the field per line vertical placed under the middle phase conductor perpendicular to the surface of the earth, at height h = 1.5m and the length of x = -3m to x = 3m when a human model is placed under the transmission line.

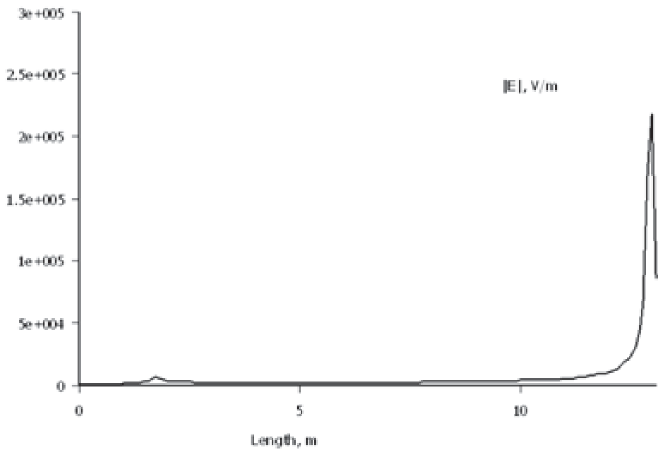

Fig.7. Distribution of field per line vertical placed under the middle phase conductor perpendicular to the earth's surface in the case when a human model is placed under the power line.

V. REGULATIONS AND STANDARDS OF THE AREA OF ELECTROMAGNETIC IMPACTS

The presence of electromagnetic fields with a wide range of frequencies in the work and environment and the inability of the human sensory organs to register them make these fields potential pollutants to the working and living environment.

With the problems of the ecology of the power lines of electricity in the high voltage circuits, a large number of institutions in the world are engaged.

The standards and recommendations of these institutions are the only criteria for harmfulness, while there are differences in permitted levels and time of exposure. [3]-[5].The status and background of each standard are related to several clear categories: there are real differences, which are dependent on the legal arrangements of individual states and factors influencing the establishment of standards. Political and social factors can play an important role as well as scientific factors. Other constraints are based on the position and structure of buildings in different countries.

International standards in this area are produced by the International Electrotechnical Commission IEC (International Electrotechnical Commission), within its Technical Committee.

Regional standars for Europa are produced by CELENEC (CLC), subclause SC111.

Recommendations for the permitted levels of exposure to electrical and magnetic fields have also been reported by the International Radiation Protection Association (IPRA) and the World Health Organization (WHO).

Limits of exposure to electromagnetic fields with industrial frequency according to the IPRA recommendations are given in Table 2.

In some countries (USA, Russia, Austria, Poland), by law or by other regulations, certain protection zones - "zones of safety" or "right-of-way zones" are located in the right-of - way directions under the power lines limited use of land for making living facilities, hospitals, schools, children's facilities, etc. Here, the upper permissible field strength of the zone or the edge of the zone is usually determined (usually from 1 [kV / m] to 10 [kV / m]) or the width of this zone is below the power lines (33 [m] to 115 [m]), depending on the voltage level and the state.

Florida was the first state to introduce magnetic induction into the ROW zone as a criterion for hazard assessment: in the vicinity of 500 [kV] power line, 20 [μT] and in the vicinity of 230 [kV] power line, 15 [μT]. Japan regulates the minimum height of the conductors below the power line of the earth, the minimum distance of the conductors from the objects and the strength of the electric field in the power line area. In many countries, there are no such regulations, but it is determined that the strength of the electrified and magnetic field under the power lines must not exceed the limits determined by the national standards.

Table 2 IPRA recommendations for exposure limits with electromagnetic fields with an industrial frequency

Characteristics of elongation	Electric field (kV/m)	Magnetic induction (mT)
In the workplace		
Full working day	10	0.5
Short-term	30 (E=80/ t)	5(max 2 hours)
Extremes	-	25
Population in general		
24 hours a day	5	0.1
Two hours a day	10	1

VI. Conclusion

Low-frequency electromagnetic fields are present everywhere in our environment. Their interaction with humans and other living organisms is expressed through direct action and through induced currents inside the tissues of the action of the external field. The importance of the properties of biological materials from which the tissues are made in the human body is great in determining the mutual influence. An important aspect of the interactions of NF fields that act on the human body in the air is that they do not heat the tissues more than basal metabolic processes in the body.

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