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Electrical Field Distribution Analysis on Human Being Placed under High Voltage Lines

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The paper presents the interaction between electric field of a high voltage line and the body of a human being placed near the line, for normal situation, when human being is placed on the ground or in accidental situation when the human being is placed near the line. The research is based on a simplified model of human being solved by finite elements method. Both aspects as field measure (as a disturbance for human being) and energy one has been pointed out and, finally, forces via weighted tensor developed between field and human being. The work results, developed in this paper, may be successful used in the order to improve the normative exigencies for different practice field interactions.

Keywords: *FEM analysis, electric field, electromagnetic compatibility, high voltage lines.*

1. Introduction

Currently, the issue of electromagnetic compatibility is a particularly and complex one due to the addressing in both types of global interaction as: device-device interaction [1], [2] and the interaction device-biotic environment [3], [4], [5]. From the device-biotic environment interactions group, human-machine interaction emerges as being of great importance in the context of modern society. The human being is viewed as the top of everything that is found together under the term "biotic environment." For this reason, most research studies - united under the concept of electromagnetic interactions - addressed special issues related to the interaction of the electromagnetic field with the special biological body represented by the human being.

The mathematical modeling of such interactions occurs again, barriers related to the insufficient knowledge of how the body's internal subsystems human operator which concurs each other to ensure in the normal ambient conditions, the har-

monious working of the entire body (an integrated subsystems of structurally inhomogeneous). A disharmony in the working of the human body is immediately associated with a disease state by modern medicine. Such inharmonic operation occurs in the electromagnetic field interaction with the human body. So, by extrapolation, it may be concluded that the effect of such interaction, during on, for magnitude and frequency reduced of electromagnetic interference fields, is reflected by a disease of human being.

Visualization of such interactions, even with the use of simplifying assumptions to the homorfe modeling (close to reality) is particularly useful in raising awareness, primarily human operators and, secondly, for the opening of research for investigation of these classes of interactions. Starting from this idea, in this paper is approached by simplifying mathematical models, only electric field - body being interaction. Such interactions may occur in practice, where the human being is close to the high-voltage power lines (which may be accidentally around or under the conditions of carrying out interventions on these lines, when power supply is connected on high voltage lines

2. Modeling of electric field-human being interaction

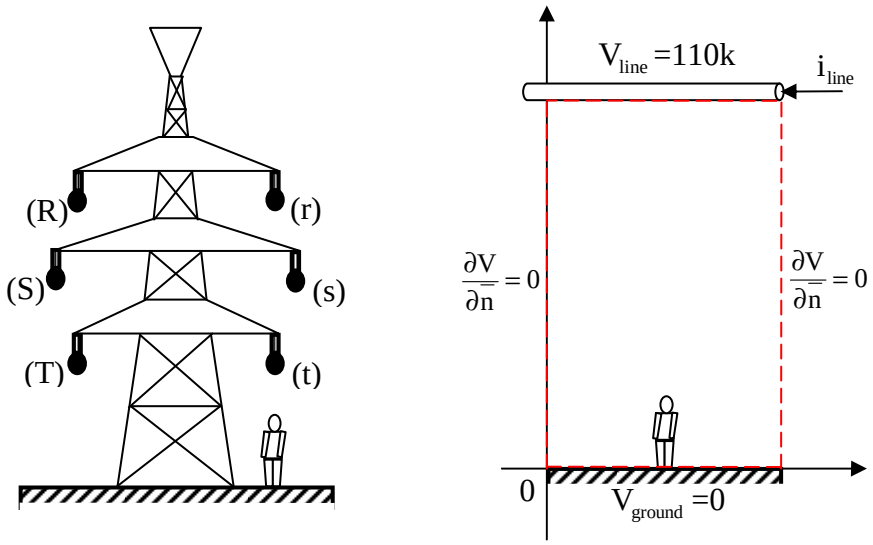
The human body can be approached, in the analysis of complex electromagnetic field interaction, with the entity generally electric field, in particular, using various analogies, which is specific to some representation - scales. In essence, the human body is a physical-chemical, extremely complex, and multiple internal interactions at the intimate molecular level. Such an overall approached is difficult to use for viewing the macroscopic effects of the interaction of interest, which is, ultimately, a field-matter interaction. Macroscopic treatment of what is found in the above "substance" requires the use of simplifying hypotheses and implicitly adopting a new macroscopic model for human operator's body. Thus, in the simplest version, the body can be formed by a sphere filled with saline [1], so the use of a model in which the interaction is neglected multiple internal, selecting an ideal form, with a homogeneous structure.

Of course, an increase in accuracy can be obtained by refining the model, accepting a human organism as an integrated system composed of several subsystems of structurally inhomogeneous and shape, but without taking into account the interactions between these subsystems. However, in order to obtain, in this case, the quality of the uniqueness of the human body as a system integrator, using the case of a "tire" unit represented by the external surface of the body which is accepted as a balancing surface. For the case of concrete interaction, in this work is using such a simplified model for the human operator's body structure, identified this area as equipotential surface equilibrium (constant potential). This feature is considered as a final result which is obtained after the extinction of many transients that can occur both as a result of electric field-matter interaction and of the multiple effects under avalanche of specific components at national level.

Therefore, accepting the steady state model for the human body (body operator), we analyzed the interaction electric field - man in two cases:

- Human operator - with a height of 1,80 m - found on earth as a conductor lines 110 kV (accidental penetration);
- Human operator - with a height of 1,80 m - in the immediate vicinity of the 110 kV line (active participant intervention to ensure the proper functioning of the line).

In the order to solve the computing field problem, by finite element method, has been used a method performed by FEM software.
Integration field areas for the two subject cases are shown in Figure 1a.



a. b.

Figure 1. High voltage lines and human being exposed to electric field action

The high voltage is a three phase one and has double circuit with the phase respects the notation as: R-r for phase one, S-s for phase two and T-t for the third one. The man is placed under line. The construction of the pillar respects the current standards.

The field area for modeling approach has been separated by the area of medium denoted by Ω and the one for human being by Ω_H. Based on this 2D approach and according to domain field limits, several boundary conditions have made ($\partial\Omega$, respectively, $\partial\Omega_H$). For domain considerate the boundary condition has been depicted in belongs Figure 1b. The mathematical model used for the analyzed system is described by:

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}=0,\ V\in\Omega/\{\Omega_H\} \tag{1.1}$$

$$\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}=-\frac{\rho}{\varepsilon},\quad V\in\Omega_H \tag{1.2}$$

$$V=100[kV]=cst.,\ V\in\partial\Omega \tag{1.3}$$

$$V=1[kV]=cst.,\ V\in\partial\Omega_H \tag{1.4}$$

$$V=0[kV]=cst.,\ V\in\partial\Omega \tag{1.5}$$

$$\frac{\partial V}{\partial \bar{n}}=0,\ V\in\partial\Omega \tag{1.6}$$

Based on this electric field permittivity of various part of human being, in this paper was considerate only three important parts that have the next values presented on Table 1:

Table 1. The electric permittivity of different parts of human body

Human Body Part	Relative Electric Field Permittivity
Arms and legs	6e4
Head	1.7e5
Neck	6e5
Bust	4.35e5

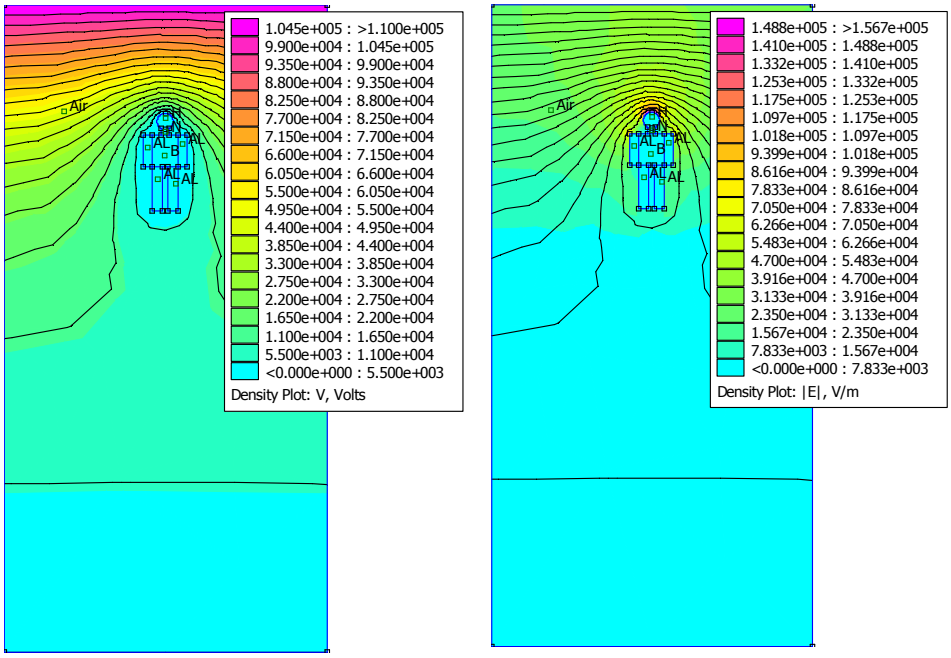
The electric field permittivity of various part of human being has the some values in all 2D directions due to the fact that the body of human being was considerate as an anisotropic media in each part.

In the order to obtain a complete image about electric field interaction with human being, several simulation tests were done. Finally, the results are approached on the force via weighted tensor and energy stored of human being. This kind of study approach based on electric field and energy and forces is made in the order to generalize the impact of high voltage on the health of human being.

Case 1. *Human being placed near of voltage line*

This situation occurring in practice for normal situation when human operator does some on-line intervention in a high voltage line in exploitation regime for real works of maintenance process.

The distributions of electric potential on all domains and equipotential lines are depicted in Figure 2a.



a. Potential distribution and echipotential lines

b. Electric field distribution and echipotential lines

Figure 2. Numerical results on case 1

From the above figure can be observed an increasing of electric potential in the high part of the head human. The lowest values of electric potential can be founded near the ground (where was considerate as a reference one. The distribution of electric potential is a symmetrical one beside a middle line of the domain field considerate.

The electric field distribution is depicted in Figure 2b. Due to isotopic media considerate in mathematical models, the electric field distribution is the same as the one of potential (but on the other scale) where head human is the biggest stress part. Moreover, as can be seen from the least figure, the boundary surface has the same behavior as Michel Faraday Cage. This result has a great importance for practical situation occurring in practice because based on this can be predicted the real dangerous situation.

The electric field distribution in the head surface is presented in Figure 3.

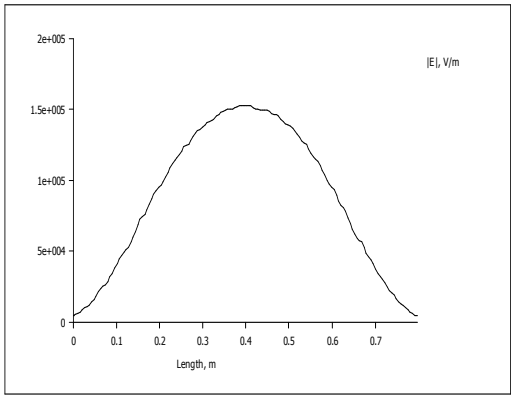


Figure 3. Absolute value of electric field on the human head surface

A complete representation of surface absolute electric field per length for various human parts is depicted in Figure 4.

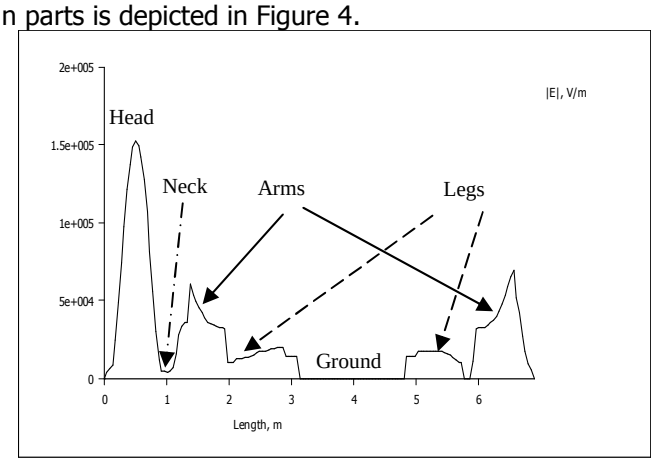


Figure 4. Absolute values of surface electric field per length in various parts of human being

According to energy transfer by electromagnetic field, an energy stored will be performed in different media. The energy stored in various parts of human being is presented in Table 2.

Table 2. The stored energy and average electric field

Human Body	Stored Energy (J)	Average Electric Filed on the Volume (V/m)	
		E_x	E_y
Head	1.20733e-029	1.56751e-013	3.73958e-013
Neck	1.10539e-029	5.58647e-013	-2.12747e-013

Bust	9.64991e-030	-3.10521e-013	-7.55028e-014
Arm	3.69177e-031	1.25959e-012	7.78063e-014
Leg	1.46065e-031	5.35714e-014	-3.64622e-014

As a consequence of the maximal value of surface absolute electric field obtained in head surface, the stored energy is obtained in head volume. In all the other parts is obtained decreased values of energy stored. The components values of average electric field over volume for different parts of human body are also presented in Table 2.

Summarized global field, energy stored and stress are presented in Table 3. The analyzed global quantities have different values of the 2D axis due to the fact that human body geometric dimensions are different.

Table 3. The stored energy Global field, energy stored and stress

Quantity	Values	
	x-axis	x-axis
Stored Energy (J)	0.0515217	
Average Electric Field over Volume (V/m)	-3.05059	-9166.67
Force via Weighted Tensor (N)	1.637834e-018	5.731796e-019

Case 2. *Human being placed on the ground*

A frequent case, that occurring in practice, is the situation when the human being is placed on the ground. In this kind of situation the foot of human being is considerate at the ground potential (as a reference one).

Based on the same analyses as one done for the case 1, absolute values of surface electric field per length in various parts of human being respects the distribution, but on the other scale (Figure 5).

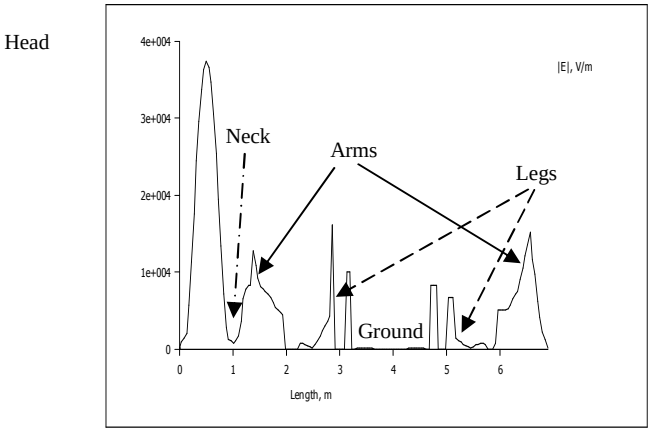


Figure 5. Absolute values of surface electric field per length in various parts of human being

On the ground (Table 4), the stored energy is increasing due to human body ground contact.

Table 4. The stored energy and average electric field

Human Body	Stored Energy (J)	Average Electric Filed on the Volume (V/m)	
		E_x	E_y
Head	1.32493e-018	1.82725e-007	-8.74563e-007
Neck	1.10643e-015	-8.73435e-007	-0.000126171
Bust	8.38465e-012	-7.26472e-005	-0.00117035
Arm	8.60764e-014	0.00168688	1.16396e-013
Leg	0.181015	-78.125	-1250

As a consequence of the energy stored increasing, a more significant increasing is founded on the values components of average electric field over volume for different parts of human body (Table 4)

And finally, global field, energy stored and stress have increasing values (Table 5).

Table 5. The stored energy and average electric field

Quantity	Values	
	x-axis	y-axis
Stored Energy (J)	0.463262	
Average Electric Field over Volume (V/m)	-35.2926	-35.2926
Force via Weighted Tensor (N)	-3.629639e-006	-3.629639e-006

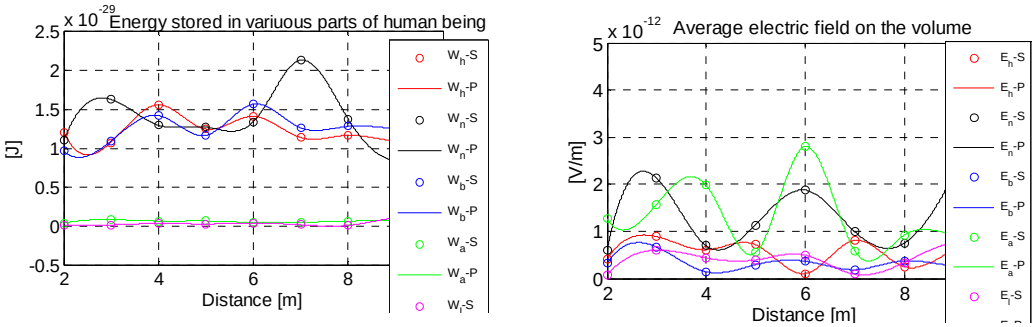
An important remark, based on the comparison on above results, is about the average electric field over volume, which has bigger values for the case when the human being is placed on the ground. Those aspects occurring in many practical situations for the man placed in neighbor of high voltages lines while and those situations need adequate equipment for ground insulation.

3. Results and discussions. Generalized results

In the above cases study has been proved that in the human body – high voltage line interaction the distance has an important role and electric field stress is dependent on this. The limit cases are described by the situations when human body is near the line, respectively, on the ground.

In the order to generalize the above study, is performed different numeric simulation tests from meter by meter distance. The obtain point results (P) are graphically interpolated in majority of cases by spline function (S). As can be seen from Figure 6a, the most stored energy in human being parts by electric field is

represented by neck, head and bust (W_n, W_h and W_b) and the easier parts are arms and legs (W_a and W_l) . The average electric field on the volume of different parts of human being is presented in Figure 9b (denoted by E).



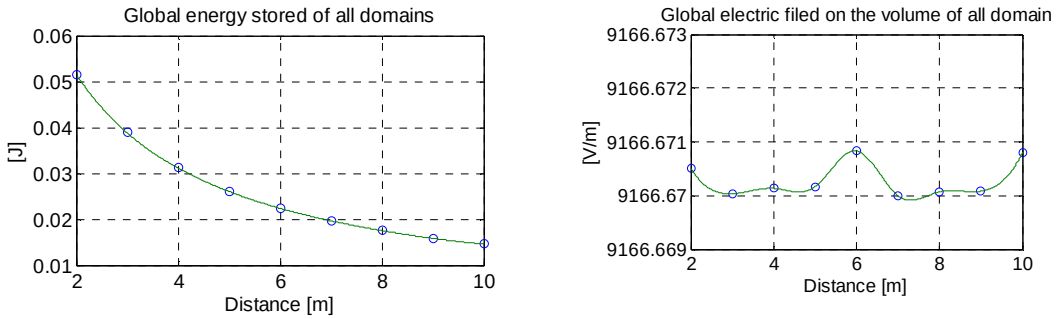
a. Force via weighted tensor of human being

b. Average electric field on the volume of different parts of human being

Figure 6. Energy stored and average electric field

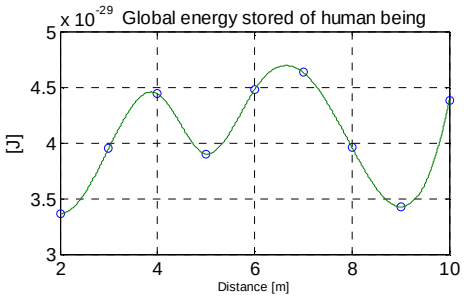
In this case the most stressed human part is represented by neck and arm and the easier by the all the other parts.

Global energy stored of all domains is represented in Figure 7a. This curve has a decreasing behavior via distance.

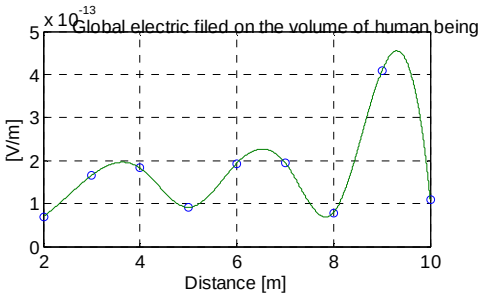


a. Global energy stored of all domains

b. Global electric field on the volume of all domains



c. Global energy stored of human being



d. Global electric field on the volume of human being

Figure 7. Global results of simulations

In the Figure 7b is represented global electric field on the volume of all domains. This curve has a quasi-constant variation via distance.

The global energy stored in the body of human being is represented in Figure 7c The variation of this curve is located in small range. The global electric field on the volume of human being is represented in Figure 7d. This curve has a variation which depends on distance and, thus, at big distance there appear some peaks.

A final graphical representation has been done for force via weighted tensor of human being (Figure 8).

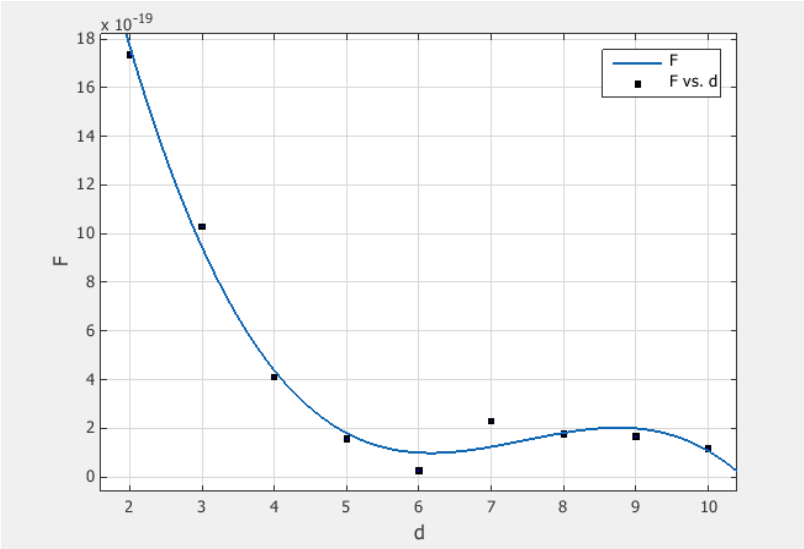


Figure 8. Force via weighted tensor of human being

Due to the fact that force via weighted tensor of human being has a great importance for practice, an adequate interpolation function was used.

4. Conclusion

The electric field interaction, generated by high voltage lines, with human being is a complex problem and depends by multiple aspects. Numerical simulations show, for human stand up, that there is a distribution of electric field and the head is the biggest stressed human part by this field.

An important idea, based on this work paper, is about the stress that may have important values when the human being is no insulated beside the ground. So, more dangerous are the situations when the human being is placed on the ground and have no insulation beside the ground, despite the other situations when is placed near the line. The used model respects the theoretical considerations of Faraday cage.

Those situations are occurring in practice and need special attention in the order to ensure human being safety.

Future works include the researching of high voltage when additional effects as atmosphere discharges are performing influences.

References

[1] Bizon N.N., Dimitris V.C., *Fundamentals of Electromagnetic Compatibility. Theory and Practice,* Matrixrom Publishing House, Bucharest, 2007.

[2] Ignea A., *Intoduction in Electromagnetic Compability, Publishing House of West*, Timisoara, 1998.

[3] Morega M., *Bioelectromagnetism*, Matrixrom Publishing House, Bucharest, 1999.

[4] Golovanov I.C., *Measuring of Electric Measure in Power Electric Plants,* Romanian Academy – AGIR Publishing House, Bucharest, 2009.

[5] Hortopan G., *Principles and Techniques of Electromagnetic Compatibility,* Technical Publishing House, 1998.

[6] Stuchly M. A., *Interaction of Low-Frequency Electric and Magnetic Fields with the Human Body,* Proceedings of the IEEE Volume: 88, Issue: 5, May 2000.

[7] Okoniewska E., Stuchly M.A., Okoniewski M., *Interactions of electrostatic discharge with the human body - Microwave Theory and Techniques*, IEEE Transactions, Volume: 52, Issue: 8, Aug. 2004.

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