Two Dimensional Model of OTL with including of Human Body Model Using Comsol-Multiphysics analyzing the Electromagnetic Fields

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***Abstract*— The high voltage transmission and distribution lines are source of electromagnetic fields, it can produce a Biological effects on the human body, animals and plants which have been a subject of scientific interest for the risk on the living organisms such as blood leukemia, cancer and others. The present paper evaluates the electromagnetic field induced by the high voltage overhead transmission line OTL and their effects on the human body, by numerical modeling in COMSOL Multiphysics software using finite elements method. In addition, the sensitivity of the results when considering the human body with its internal organs is estimated.**

***Keywords*— COMSOL Multiphysics, Electromagnetic fields, Human body, Time dependent, Transmission line.**

I. Introduction

The emission of electromagnetic fields waves can affect on the living beings, when it can cause the cancer and leukemia [1]-[3]. Several studies have been carried out on the possible effects of electromagnetic fields on humans, animals, plants and cell or tissue cultures as the biological effects [4]-[15]. Many studies have carried out to evaluate the electromagnetic fields under different power transmission lines, where the magnetic field is the major sources of induction, under single and parallel transmission lines [14]-[22].

The present paper investigates the effect of electromagnetic field intensity on human body using COMSOL Multiphysics software to simulate the distribution of the electric and magnetic fields below the AC 220kV overhead transmission line (OTL) where the human body model is presented in 2D and grounded for under bundle conductors in AC three phase systems. Two scenarios are treated in this study: at the conductors center level and at the human head in case of its position under the central conductors of OTL three-phase system. Scenarios are modeled in the COMSOL Multiphysics software using the finite element method to solve the Maxwell differential equations

II. Transmission Lines Modeling

The OTL is modeled as AC 3 phase system of bundle conductors with 1.144 cm of radio placed at 20.2m under the ground, for a voltage level of 220kV, as shown in Fig. 1, where:

- Each phase consists of two conductors each one have diameter of 1.144 cm and spaced by 40 cm.
- The distance phase conductor to the ground is 20.2 m.
- The distance guard cable to the ground is 24.8 m.
- Separation between each two adjacent phases is 10 m.

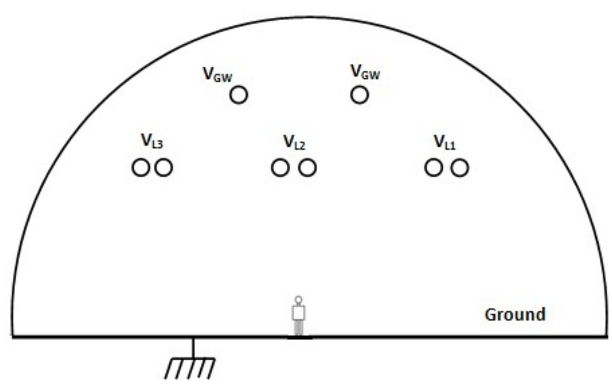


Fig. 1. 2D-Space model of AC transmission line including the human body model.

Table 1 documents the specific parameters of the simulation model. This paper focuses on the electrical field at the tower and the surrounding area. COMSOL, which makes use of the FEM method, is used for the investigations. The software utilizes Maxwell's equations for steady state and transient calculations.

TABLE 1. PARAMETERS OF THE SIMULATION MODEL.

220 kV, AC System	$V_{L1} = 220\sin(\omega t + 2\pi/3)[\mathrm{kV}]$ $V_{L2} = 220\sin(\omega t)[\mathrm{kV}]$ $V_{L3} = 220\sin(\omega t - 2\pi/3)[\mathrm{kV}]$
Ground Wire	$V_{GW} = 0[\mathrm{kV}]$

III. THE HUMAN BODY MODEL AND DIELECTRICS PROPERTIES OF TISSUE

The human body Model is suitable not only to calculate the strength of electric field and magnetic field in tissues but also for applying finite element method by COMSOL Multiphysics. The model in 2D for the human Body is developed and considered as model takes into account the presence of some relevant tissues like brain and heart. The actual body model accounts for four organs (brain, lungs, liver and intestines) with the 1.760 m is human height being placed under overhead transmission lines above the ground and represented as depicted in Fig. 2.

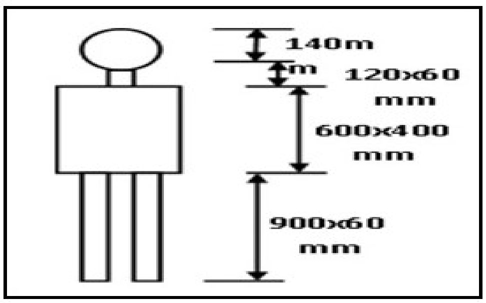


Fig. 2. The Human body geometry and model.

The relative dielectric constant of the various organs are obtained from the literature [15] and listed in Table 2.

TABLE 2. ELECTRIC CONDUCTIVITY OF HUMAN BODY [22].

Material/Organ	**Relative dielectric constant (permittivity) $\varepsilon_r = \varepsilon/\varepsilon_0$**
Brain	0.7
Lung and Liver	0.1
Digestive organs	0.03
Legs(muscle)	0.1
Other tissue	0.02

The value will be inserting and including in modeling of human block model for each material part of human body are: the dielectric constant of tissue and material (Table 3) [22].

TABLE 3. RELATIVE DIELECTRIC CONSTANT OF HUMAN BODY MATERIAL [22].

Material/Organ	**Relative dielectric constant (permittivity) $\varepsilon_r = \varepsilon/\varepsilon_0$**
Brain	1.21E7
Lungs	5.76E6
Liver	1.83E6
Leg	1.77E7
Other tissue	1.11E7
Digestive organs	1.68E7

IV. EXPRESSIONS OF ELECTROMAGNETIC FIELDS IN THE HUMAN BODY

The expressions of electromagnetics in the human body can be obtained by the resolution of Maxwell equations based on the application of the coupling between electrostatic and magnetic fields E and H using the AC/DC study in COMSOL Multiphysics software v.5.1.

$$\overrightarrow{rot}\vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (1)$$

$$\overrightarrow{rot}\vec{B} = \vec{J} + \frac{\partial \vec{D}}{\partial t} \quad (2)$$

$$\overrightarrow{rot}\vec{E} = -\frac{\partial \vec{B}}{\partial t} \quad (3)$$

$$div\vec{D} = \rho \quad (4)$$

$$div\vec{B} = 0 \quad (5)$$

$$\vec{B} = \mu_0\, \mu_r\, \vec{H} \quad (6)$$

$$\vec{B} = \sigma\, \vec{E} \quad (7)$$

$$\vec{D} = \varepsilon\, \vec{E} \quad (8)$$

Electric field near the transmission lines is generally measured in kV/m and magnetic fields are in micro Tesla [μT]. Thus ε_r is the relative permittivity, σ the electric conductivity [$\mathrm{Sm^{-1}}$], μ_r the relative permeability, k thermal conductivity [$\mathrm{Wm^{-1}\ K^{-1}}$], ρ density [$\mathrm{kgm^{-3}}$], Cp the heat capacitance [$\mathrm{Jkg^{-1}\,K^{-1}}$].

V. STEPS IN COMSOLMULTIPHYSICS SIMULATION

The numerical simulation is performed by the COMSOL Multiphysics software v.5.1 version in 2D. An electrostatic and magneto-static modules of COMSOL have been used to determine the distribution and variation of the electric and magnetic fields. The steps for calculation are described as follow:

1. Create the geometry of the model.
2. Description of study domain.
3. Allocation of physical parameters.
4. Triangular mesh of the study domain.
5. Solve using COMSOL Modules for electric field intensity/magnetic flux density.

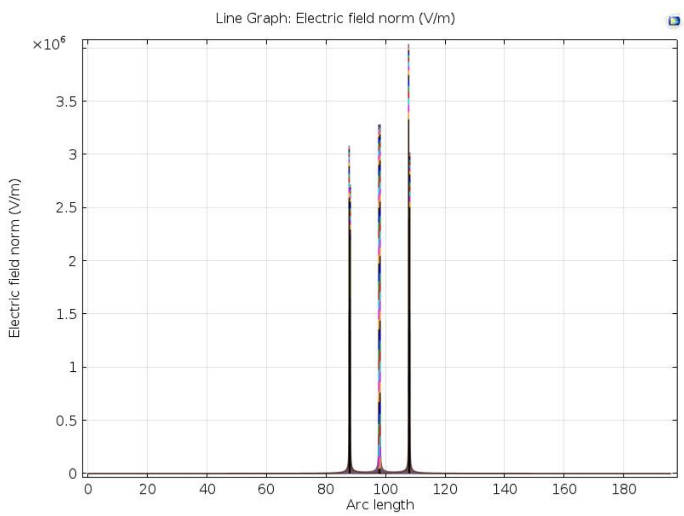
VI. RESULTS OF SIMULATION

This paper studies numerically the electric and magnetic fields distributions of overhead 220 kV power lines operating at a frequency of 50 Hz of the transmission network for the overhead power lines. The results are taking for two scenarios: at the conductors level and at the head level (1.76 m). The current circulates in the conductors of the power line is equal to 760 A.

A. Electric field

To investigate the influence of the electric fields under transmission lines, three simulations are carried out: without presence of human body model, with including of human body under the tower and at 6m near the tower centre.

A detailed view of the electrical field at the line conductors level and at 1.76 m which present the human head level, above the ground is shown in Fig. 3 (*a* and *b*) for the transmission tower with three AC systems without including the human body model. The meshed surface is a result of the superposition of discrete time points.



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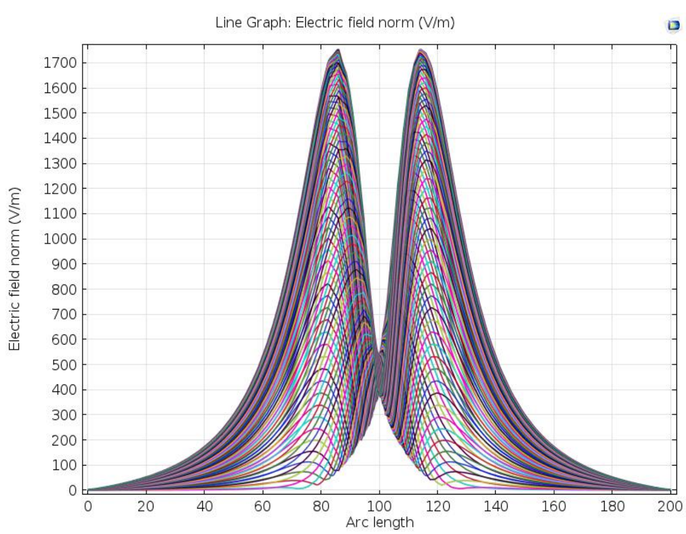
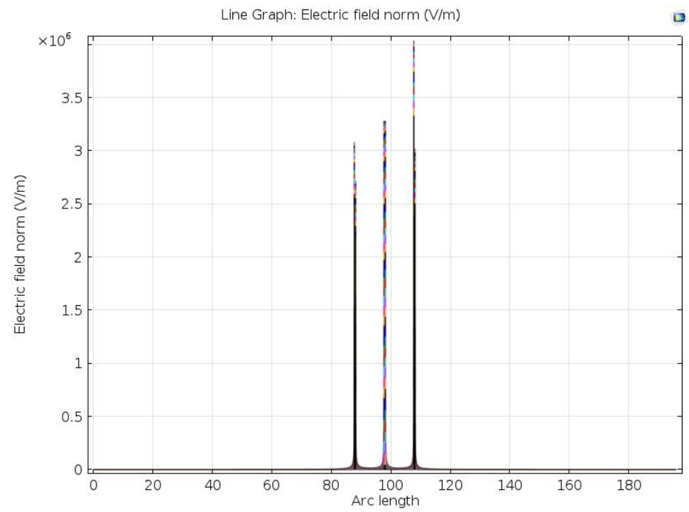


b-

Fig. 3. Electric field distribution, without including of human body.

The electrical field of the AC transmission line with presence of human body model is shown in Fig. 4, for two scenarios at the line conductors level and at 1.9 m above the ground.



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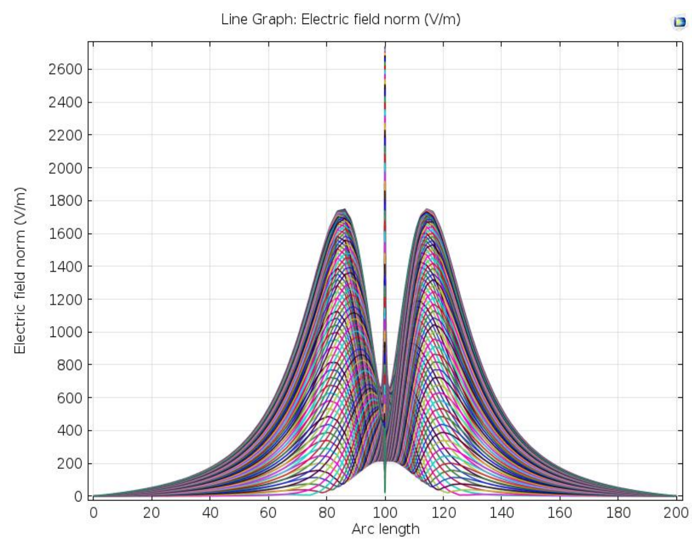

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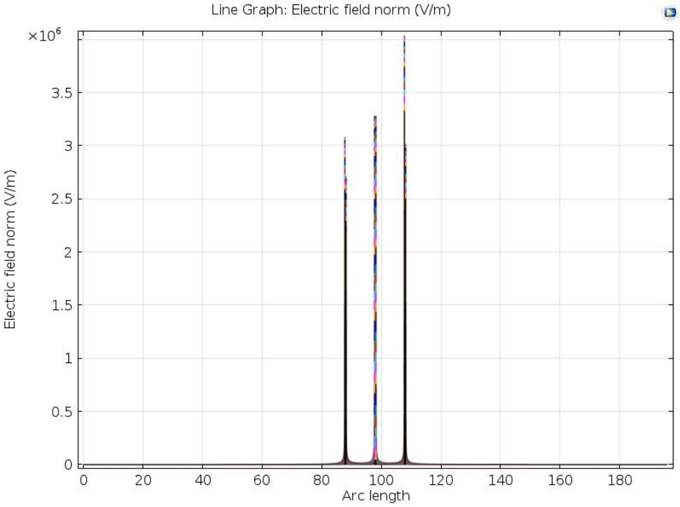
Fig. 4. Electric field distribution, with including of human body.

Furthermore, the influence of lateral distance between human body model and the phase conductors of a AC-System on the electrical field will be investigated. For this investigation, the distance is chooses at 6m near the line center. The results are shown in Fig. 5.



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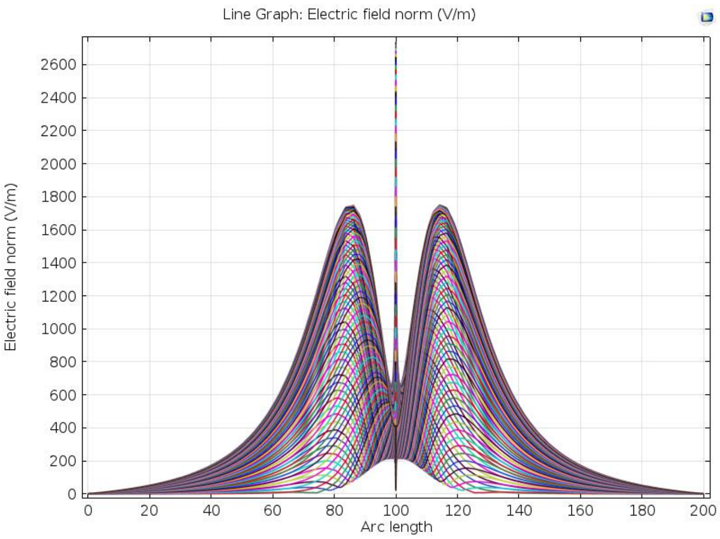


b-

Fig. 5. Surface electric field distribution with including of human body at 6m.

Comparing the results from the Fig (*a*) in 3 to 5, it can be seen that they are nearly identical.

The electrical field in figures (*b*) in 3 to 5, with and without presence of human body model are different, Fig. 4 and Fig. 5 have a higher amplitude under the HVAC system compared with the pure AC transmission line (without human model).

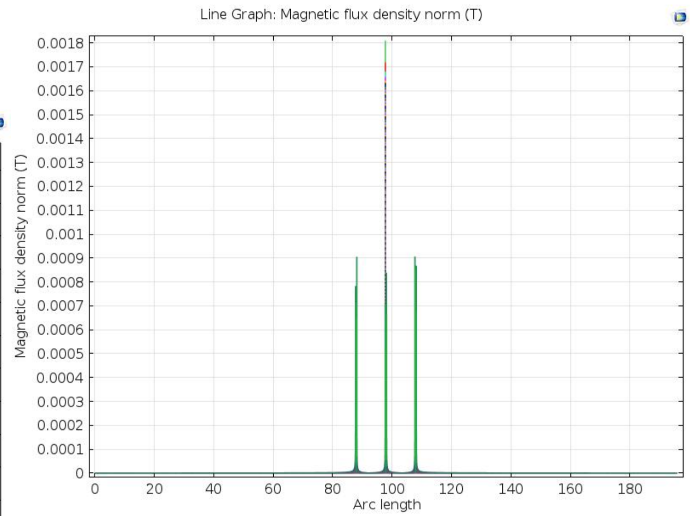
This intense values of incidental electric field can cause the biological effects in tissues and the head of human body where it is exposed to this extremely strong electrical field [1]-[3].

This conclusion has been found from the values of this field selected in reference [1-3, 22].

B. Magnetic field

The current circulates in the conductors of the power line is equal to 760 A. To evaluate the magnetic field near the HV transmission lines, the same strategy is used as the last adopted for the calculation of electric field.

From Fig. 6 *a* and Fig. 7 *a*, the peak value reach 0.0018 T at the line center level exactly at the phase *B* in case without including human body. And it reach the value of 0.0019 T for all conductor phases in the second case where the human body model is presented under the line, this point of measure is taking in to account for analysis the effect of magnetic fields on the human body and some leaving being.



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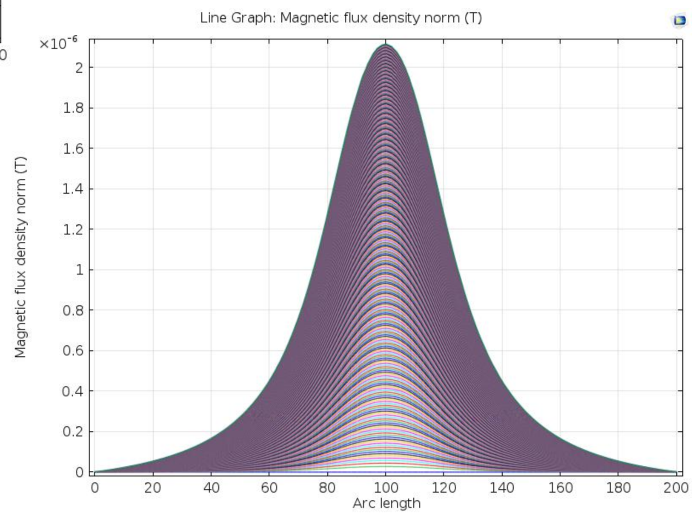

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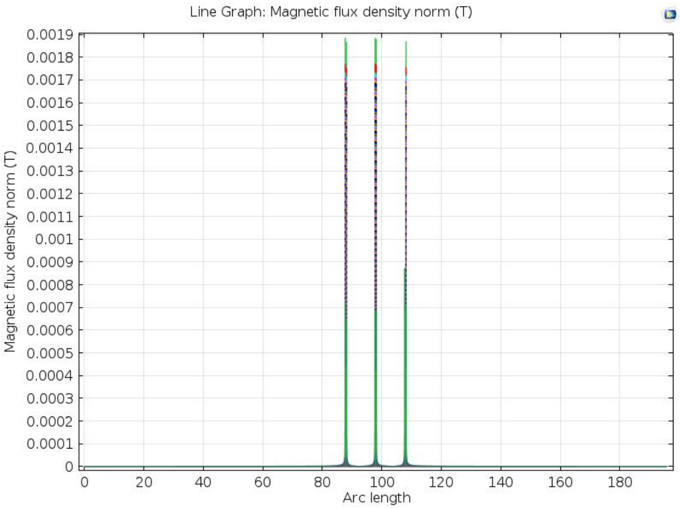
Fig. 6. Magnetic field distribution without including of human body.



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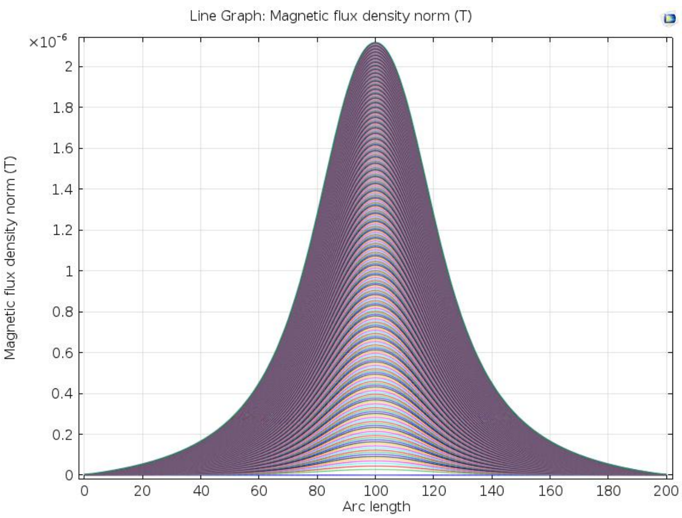

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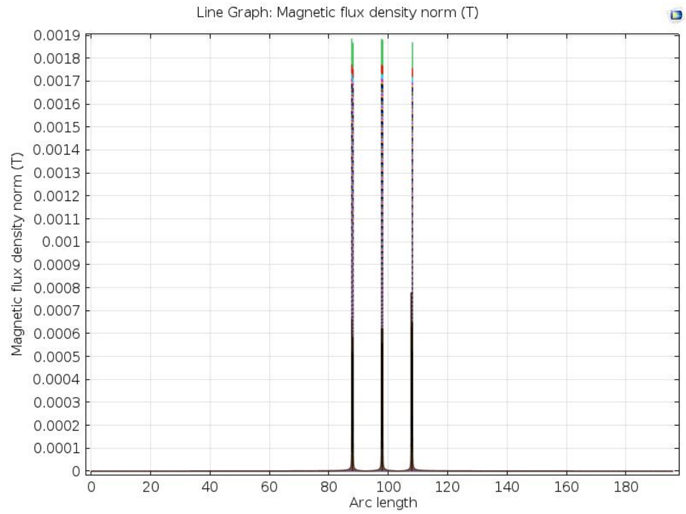
Fig. 7. Magnetic field distribution with including of human body.



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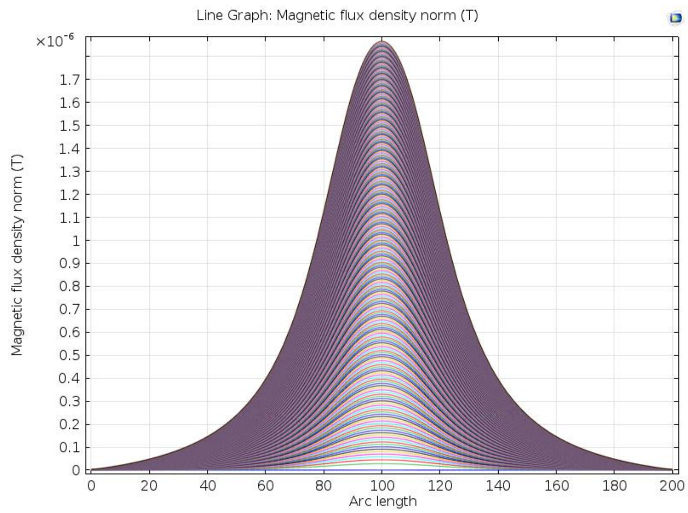

b-

Fig. 8. Magnetic field distribution with including of human body at 6m.

Fig. 8 shows the magnetic field profiles at the conductor's level and at the human head above ground (at 1.9 m) and shows the lateral magnetic field variation at the conductor's level and at the human head.

For verification purposes, the position of the human body model is changed at 6m near the tower system. The simulation results are shown in Fig. 8. At all configurations the magnetic field under the HVAC system has a higher amplitude compared to the results of Fig. 6.

VII. CONCLUSION

In this paper the COMSOL Multiphysics software is used in the computation of the electromagnetic fields by using of the Electrostatic and Magnetic Modules.

The analysis of the electric and magnetic fields generated by the 220kV HV power transmission lines operating at a frequency of 50 Hz, is done at many levels with and without presence of human body. This software is based on the finite element method.

This work could be extended to analyze the effects of electric and magnetic fields due to the HV transmission line on the interior organs of human body and leaving being and to treat it for the long times.

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