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Magnetic Field Exposure Assessment During Live Line Maintenance in Saudi Arabia

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Abstract- Live working maintenance of the power transmission lines is a practice adapted by the national grid. This procedure exposes the lineman to a considerable amount of magnetic field. This may lead to a possible effect on health in the long term. A model for the interaction between a lineman and the extremely low frequency magnetic field (ELF) generated by Jeddah-Rabiegh EHV line, between two cities in the west of Saudi Arabia, is proposed in this paper. The induced current densities in a lineman's body were calculated and analyzed at different positions on the tower, near the lower and middle phase conductors of the line. The specific absorption rate (SAR) for a lineman is calculated and investigated.
Keywords- Extremely Low Frequency magnetic field (ELF), Lineman, Specific Absorption Rate (SAR), Induced current density.

I. INTRODUCTION

Recently, attention has been given to studing the possible effects of extremely low frequency magnetic field (ELF) on humans. The management of occupational exposure to electromagnetic fields (EMF) has become one of the main issues of occupational health and safety practices [1]. Many reports became available to the public, relating the exposure to a magnetic field to some severe illnesses, which raised awareness of the potential hazard that may affect humans' health [2-5].

Researchers were thus motivated to suggest methods for magnetic field mitigation to reduceexpected effects on health [6]. Great efforts were done to accurately calculate and measure the magnetic field emanating from power lines [7,8]. Though it could be a tedious task to measure and calculate the magnetic field precisely, especially with the complexity of the grid, where different loads are supplied with different conductor sizes.

The interaction between the humans and the magnetic field was documented in several studies, and guidelines were issued to raise awareness about the possibility of the effects of field exposure on health. Some studies related particular illnesses to electric fields and currents induced in the human body [9]. The magnitude of the induced current is related to the damage that it may cause to the human body organs. This inspired researchers to model the lineman to study the induced currents in his body and relate it to the high magnetic field emanating from the high voltage powerlines.

In order to get the specific absorption rate (SAR) for parts of the human body, it is essential to estimate the induced currents. The knowledge of the induced current magnitude is important in determining the hazards on the different organs of the human bodies, which help in compliance with the maximum recommended specific absorption rate. Many governmental institutions and regulating bodies recommended maximum SAR exposure for humans. The Federal Communication Commission (FCC) and ANSI limited the maximum exposure of the public to cellular phones to 1.6 watts per kilogram (1.6 W/kg) [10]. The Institute of Electrical and Electronics Engineers (IEEE) issued a standard for the measures recommended to be taken to prevent the harm that may affect human beings who are exposed to the ELF magnetic field (0-3kHz) [11].

In this paper, a model for the interaction between the ELF magnetic field, emanating from Jeddah-Rabiegh EHV, and the lineman is proposed. The current densities induced in a lineman due to the 50 Hz magnetic fields at different positions on the tower, the lower and middle phase conductors, are investigated and the specific absorption rate (SAR), is evaluated.

II. MAGNETIC FIELD OF POWER LINES

A proposed prolate spheroid model was adapted to model the body of a lineman body, Figure 4. This model was placed near the conductors of the 380 kV double-circuit power lines. The transmission lines are bundled. The size of each bundle is 4x500 mm2 with an inner spacing of 40cm. The clearance between the lines and the ground is not less than 10 m. The full load current is considered to be 1600 A per phase. Two positions were selected to simulate the lineman positions, close to the lowest phase conductor and to the middle phase conductor.

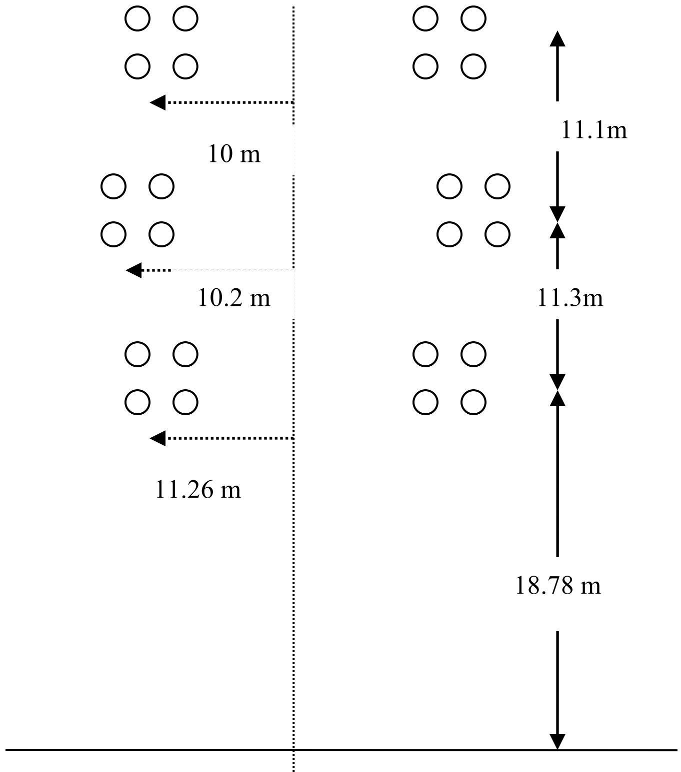

Figure 1 configuration of 380 kV Rabeigh-Jeddah line.

The magnetic field was computed in the proximity of the phase conductors, 0.5 m away from the phase conductor, at which the linemen are found. The magnetic field at the lineman model circumferential nearest to the phase conductor of the lower and middle phase conductors are shown in Figs.2 and 3, respectively. A prolate spheroid model was adapted to model the lineman body, Figure 4.

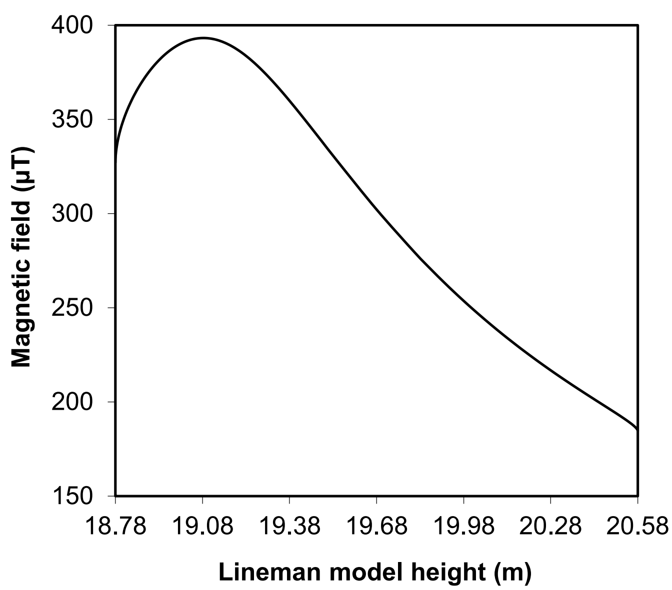

Figure 2 The magnetic field on the lineman model circumferential nearest to lower phase conductor.

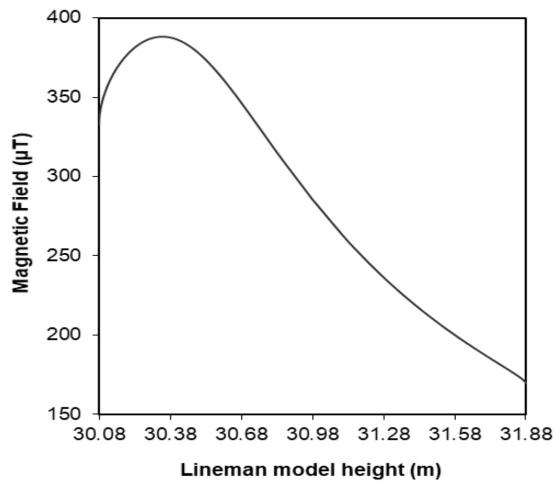

Figure 3 The magnetic field on the lineman model circumferential nearest to middle phase conductor.

The lineman height exposure to the magnetic field, represented in the above figures, shows that the field is strong along the feet and then the decreases along the body of the lineman. The large values of the magnetic field at the lower part of the model are due to its nearness to the conductor, which is about 390 µT for both positions.

III. HUMAN MODEL EXPOSURE ASSESSMENT

A prolate spheroid model was adapted to model the lineman body, Figure 4. The internal tissues were considered to homogeneous and the outer medium is air. The height 2a is assumed 1.8 m and the width 2b is 0.5 m. The three-dimensional magnet flux Bx, By and Bz are evaluated by placing the lineman model near the lower and middle phase conductors.

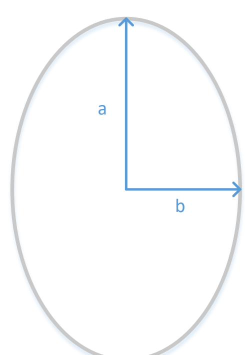

Figure 4 Prolate spheroidal model [1].

The relative permeability of the human body is considered equal to that of the free space µo, since the human body is nonmagnetic. The lineman body size is smaller than the power frequency wavelength, which makes it possible to deal with analysis as a quasi-static problem. The problem can be simplified more, by neglecting the secondary magnetic field produced in the lineman tissues, due to the induced current that resulted from the external magnetic field for the frequencies that satisfy the following inequality (1) [12]:

$$f \mu o \sigma L2 << 1 \quad (1)$$

Where, σ is the conductivity, L is the maximum size of the body and f is the power frequency. The following inequality (2) is satisfied as well when the frequency is 50 Hz.

$$\sigma >> 2 \pi f \varepsilon' \quad (2)$$

The following three-dimensional expressions (3) represent the vectors of the internal electric fields in the 3 directions of the alternating magnetic fields.

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$$\vec{E}_{Bx} = \frac{\omega}{a^2+b^2}(b^2 z\hat{y} - a^2 y\hat{z})\left|\dot{B}_x\right| e^{j(-\pi/2+\varphi_{Bx})} \tag{3}$$

$$\vec{E}_{By} = \frac{\omega}{a^2+b^2}(a^2 x\hat{z} - b^2 z\hat{x})\left|\dot{B}_y\right| e^{j(-\pi/2+\varphi_{By})} \tag{4}$$

$$\vec{E}_{Bz} = \frac{\omega}{2}(y\hat{x} - x\hat{y})\left|\dot{B}_z\right| e^{j(-\pi/2+\varphi_{Bz})} \tag{5}$$

Where, EBx , EBy and EBz are the electric field induced by magnetic flux densities Bx, By and Bz respectively. The angular frequency ($\omega=2\pi f$) is evaluated at frequency f=50 Hz, where φ is the magnetic flux density phase angles of Bx, By and Bz.

Expression (6) gives the total electric field that is induced in the model of the lineman:

$$\overline{E} = \overline{E}_{Bx} + \overline{E}_{By} + \overline{E}_{Bz} \tag{6}$$

Expression (7) gives the current density that is induced by magnetic fields.

$$\overline{J} = \sigma\overline{E} \tag{7}$$

A base conductivity for the lineman tissues was selected to be 0.1 S/m. The circulating currents induced in the tissues were evaluated for comparison purposes. The true values for the current density can be evaluated by multiplying the normalized density by the base.

IV. INDUCED CURRENT DENSITY –

Figures 5 and 6 demonstrate the induced current density variation along the lineman height, where the model was placed in the proximity of the lower and middle phase conductors. The maximum induced current density in the lineman model, near the lower phase conductor, is at the head, which is about 850 µA/m2, while it is minimum at the feet. A similar trend is shown near the middle phase conductor, where the maximum current density is about 780 µA/m2 at the head of the model.

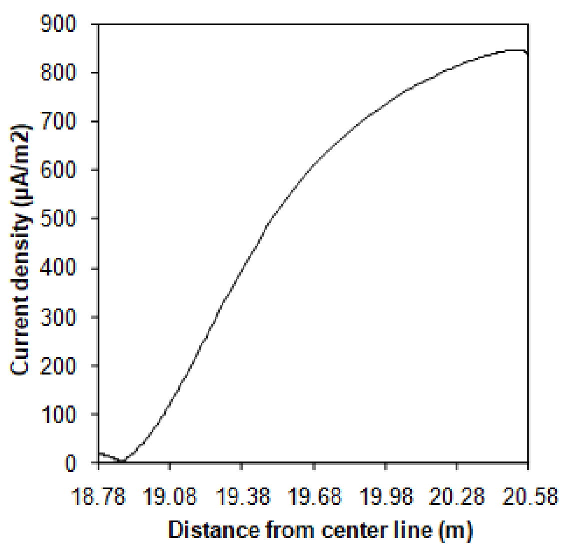

Figure 5 Current density induced in the lineman model near the lower phase conductor.

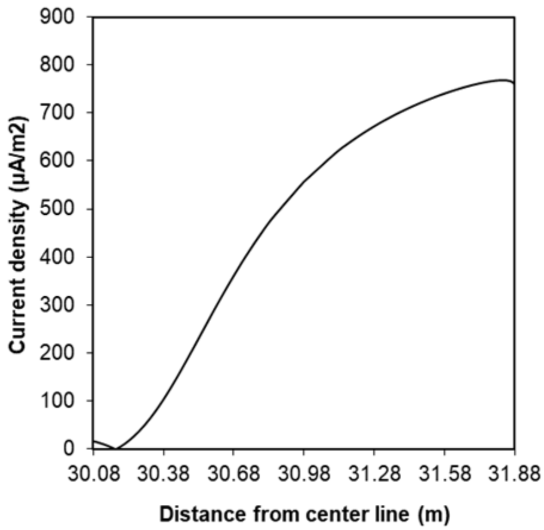

Figure 6 Current density induced in the lineman model near the middle phase conductor.

V. SPECIFIC ABSORPTION RATE (SAR)

The specific absorption rate (SAR) is "the time derivative of the incremental energy absorbed by (dissipated in) an incremental mass contained in a volume element of a given density. SAR is expressed in watts per kilogram (W/kg) " [10].

$$SAR = \frac{\sigma |E|^2}{\rho_m} \tag{8}$$

Where ρm is the density of specific tissues.

To evaluate the energy absorbance by the lineman tissues, a quantitative evaluation needs to be adapted, to assess the impact of the magnetic field on the human tissues and organs.

The mass density ρm for the lineman in this investigation was considered to be 103 kg/m3 and the body conductivity is uniform, σ=0.1 S/m. The true value of the specific absorption rate (SAR) is obtained by multiplying the normalized value by the base.

Figures 7 and 8 show the specific absorption rate (SAR) on the lineman tissues near the lower and the middle phase conductors respectively.

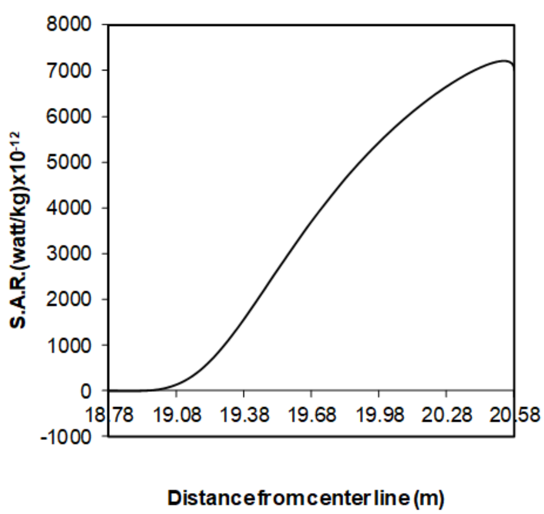

Figure 7 SAR for lineman model at lower phase conductor.

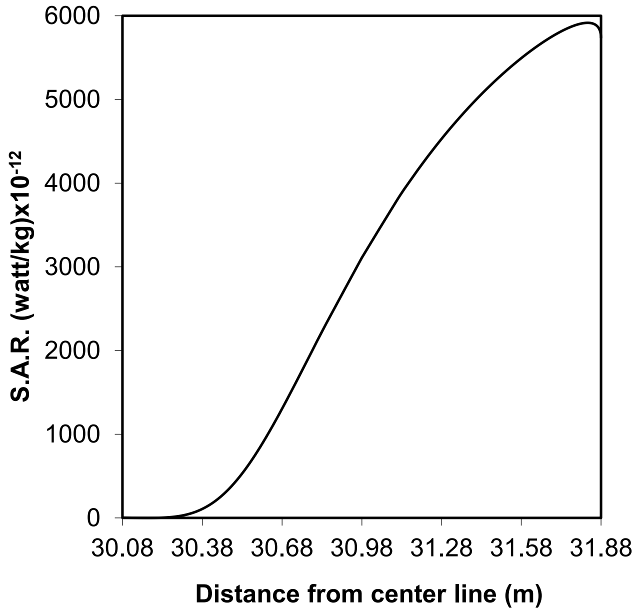

Figure 8 SAR for lineman model at middle phase conductor.

VI. CONCLUSION

The live line maintenance workers are exposed to a considerable magnetic field values.The magnetic field values at the leg of the lineman model are larger than that at the head, when the model is placed nearest to the lower and middle phase conductor. The current density varies rapidly along the human model. The largest values are at the model head, which can reach as high as 850 μA/m2, while the smallest values are at the leg section.The specific absorption rate is very high at the head section, which can reach to about 8000 (watt/kg)x10-12. These values are below the recommended maximum specific absorption rate (SAR) that are specified by the international regulations and standards. Further investigations and real measurements will be conducted to explore the harm that the induced current in the human body organs may cause due to the ELF magnetic field and the temperature rise.

VII. REFERENCE

[1] G.A. Gourzoulidisa,c, P. Tsaprounib, N. Skamnakisb, C. Tzoumanikab, E. Kalampalikib, E. Karastergiosb, A. Gialofasb, A. Achtipisa, C. Kappasc, E. Karabetsos, “Occupational exposure to electromagnetic fields. The situation in Greece”, Physica Medica, Volume 49, May 2018, Pages 83-89

[2] M. A. Abd-Allah, Shaher A. Mahmoud and H. Anis, "Interaction of ELF Electromagnetic Fields With Living Bodies", Electric Machines and Power Systems, 28:301-312, June 2000.

[3] M.A. Abd-Allah. "Magnetic field-induced currents in human body in the proximity of power lines", 2003 IEEE Power Engineering Society General Meeting (IEEE Cat No 03CH37491) PES-03, 2003

[4] T. Matsumoto, N. Hayashi and K. Isaka, "Quantification of Interaction Between 2-Dimensional Low Frequency Magnetic Fields and Spherical Model of Biological Object", 10th ISH, Montreal, Canada, 1997.

[5] T. W. Dawson and M. A. Stuchly, "High Resolution Organ Dosimetry for Human Exposure to Low-Frequency Magnetic Fields", IEEE Trans. Mag., Vol. 34, No. 3, pp. 708-718, 1998.

[6] M. A. Abdullah, A.S. Alghamdi, “Magnetic Field Mitigation Using Line Compaction. THE 8 th INTERNATIONAL MIDDLE-EAST POWER SYSTEMS CONFERENCE MEPCON 2001, University of Helwan, Cairo, Egypt, DECEMBER 29-31, 2001.

[7] H. Anis, M. A. Abd-Allah and Sh. A. Mahmoud, "Computation of Power Line Magnetic Fields- A Three Dimensional Approach", 9th IS, ISH'95, Paper 8333, Graz, Austeria, 1995.

[8] P. S. Wong, et al., "Long Term Magnetic Field Monitoring Near Power Lines", IEEE Trans. On Power Delivery, Vol.12, No.2, pp. 922-927, 1997.

[9] R. Luben, "Effects of Low Frequency Electromagnetic Fields (Pulsed and DC) on Membrane Signal Transduction Processes in Biological Systems", Health Physics Vol. 61, pp. 12-28, 1991.

[10] Specific Absorption Rate (SAR) for Cellular Telephones, Federal Communication Commission, https://www.fcc.gov/general/specific-absorption-rate-sar-cellular-telephones

[11] IEEE Std C95.6™-2002, “IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz”, The Institute of Electrical and Electronics Engineers, Inc., October 2002.

[12] C. Polk, "Electric Fields and Surface Charges Due to ELF Magnetic Fields", Bioelectromagnetics, Vol. 11, pp. 189-201, 1990.