XIIIth International Symposium on High Voltage Engineering, Netherlands 2003, Smit (ed.)
© 2003 Millpress, Rotterdam, ISBN 90-77017-79-8

Evaluation of human exposure to magnetic fields under live line maintenance conditions

A.H. Hamza[1], Shaher A. Mahmoud[2] and Samy M. Ghania[1]
[1] Faculty of Engineering at Shoubra, Cairo, Egypt
[2] Egyptian Electricity Holding Company, Cairo, Egypt

Abstract: During live line maintenance, the lineman becomes very close to the power line conductors which would result in the exposure to high levels of magnetic fields associated with high levels of currents induced inside the lineman body. In this paper, the different types of live line maintenance are presented. The magnetic field distribution over the lineman body is evaluated at different positions on the towers of 500 kV and 220 kV lines. The study considers the typical positions occupied by the lineman during his live line working conditions. In addition, the magnetic field is statically tabulated for different sections over the lineman body.

1. Introduction

The expected hazards to the living organisms due to the exposure to the power frequency (50/60 Hz) magnetic fields which resulted from power lines are being discussed and analyzed among the specialized and public communities since the past three decades [1,2].

Due to the exposure to these fields, nowadays live line maintenance is increasingly performed since it secures the continuity of power supply. The magnetic field levels to which the lineman is exposed during his work are expected to be much higher than those levels under the power line.

For the purpose of quantitative assessment of the interaction of these fields with the lineman body during the working period at the different positions on the power line towers, it is necessary to describe the magnetic field distributions over the lineman body. A three dimension technique is used as the base of the magnetic field evaluation [3]. All magnetic field values in the current study are evaluated for a line current of 1 kA.

There are two types of live line maintenance according to the tasks that the linemen have to perform and the tools used. The first type is light maintenance in which the lineman is responsible for cleaning the power line insulators, cleaning substation insulators, switches and the routine maintenance in substations.

The second type is heavy maintenance in which the lineman is responsible for replacing the different types of damaged insulator strings, changing of the hanging clamps and changing of the connection points. This method is done by using heavy and long tools.

2. Types of Live Line Maintenance and Working Conditions

When performing his job, the lineman can use one of two methods [4,5]. The first method is the distance method where the lineman performs his work keeping a specific distance from any live parts (power line conductors and insulators). The lineman climbs the power tower until reaching a specific position then he fixes himself in the tower and starts to use the tools to manage his job (cleaning, substituting power line insulators, etc.). This method is commonly used for light maintenance.

The second method is the potential method at which the lineman wears a conducting suite, which has a clamp to be connected to the line to make the same voltage for both the line and the lineman. Since the lineman and the power conductors have the same voltage, then there is no need to keep specific distance between the lineman and the power line. This method is commonly used in heavy maintenance.

The minimum distances that must be respected in the first method or the minimum distance between the phase conductors and the lineman body; (t), can be calculated as follows:

$$t = 0.005 * U_{kV} \quad \text{(m)} \qquad (1)$$

Where: k_V is the line voltage in kV.

On the other hand, the basic distance between the lineman and the power line insulators (c) can be calculated as follow s :

$$C = 0.0035 * U_{kV} \quad \text{(m)} \qquad (2)$$

To free the lineman from the permanent worry of respecting the basic distance and therefore to allow him to devote all his attention to his work. A guard distance “ g ” is used. For high voltage installations g = 0.5 m. This guard distance should be added to the value of either (t) or (c).

3. Different Positions of the Lineman on the Power Line Tower

The different positions (cross arm positions and potential positions) of the lineman on the single circuit 500 kV and double circuit 220 kV power line towers are shown in Figure 1 and Figure 2, respectively.

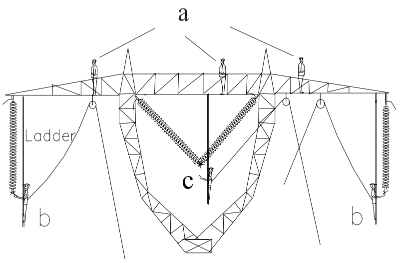

Figure 1: Different positions of the lineman over the 500 kV power line tower.

a) cross arm position b) outer phase potential position c) center phase potential position

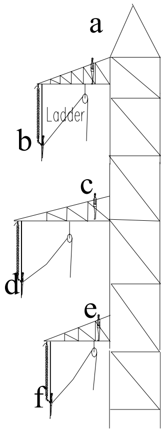

Figure 2: Different positions of the lineman over the 220 kV power line tower.

a) cross arm position phase (A) b) potential position phase (A)
c) cross arm position phase (B) d) potential position phase (B)
e) cross arm position phase (C) f) potential position phase (C)

4. Magnetic Field Distribution Over the Lineman Body

The magnetic field over the lineman body is evaluated at different positions on the power line towers of 500 kV and 220 kV lines. The lineman body is assumed to have 180 cm height, 60 cm width and 20 cm thickness. However, the lineman shape is simulated as parallelepiped for simplicity. Two faces of the simulated body are considered; front face and side face. The front face of the lineman is facing the power line conductors, while the side face is in a side position to the power line conductors.

The magnetic field is depicted across the lineman faces in different tower positions. Also, the magnetic field statistical components are tabulated for different sections across the lineman body at the different organ levels (knee, stomach, heart and brain).

On 500 kV tower

The magnetic field distributions over the lineman faces and sections are depicted for the different positions on the tower of 500 kV line.

Figure 3 shows the magnetic field distribution over the front and side faces of the lineman body for the outer phase potential position for 500 kV power line tower. As shown, the horizontal variation of magnetic field across the side face is clearly greater than that of the front face. This is due to the fact that the side face is in lateral direction to the power line which shows faster variation than that of the front face, which is in longitudinal direction. This can be easily noticed from Table 1 as the difference between the maximum and average values of the magnetic field becomes higher in the side face case than those of the front face.

Table 2 shows the statistical analysis of the magnetic field components at different horizontal cross sectional levels over the lineman body. It is noticed that for the lineman body faces the maximum magnetic field value is reached at the brain section and amount to 410.5 μT/kA, while the minimum value 177.7 μT/kA and occurs at the knee section. The standard deviation (std) of the magnetic field reaches its maximum value of 48.2 μT/kA (14.6% of the average) at the brain section, while it reaches its minimum value of 7.4 μT/kA (3.4% of the average) at the knee section.

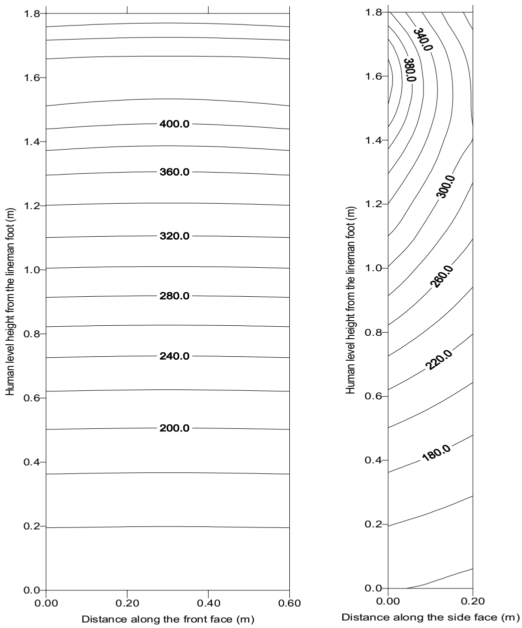

Figure 3: Magnetic field Distribution (μT/kA) over the lineman body faces for 500 kV line outer phase potential position.

Table 1: Max. and Average magnetic field values over the lineman body faces at 500 kV line outer phase potential position.

Human height (m)	Front face		Side face	
	B max (uT/kA)	B avg (uT/kA)	B max (uT/kA)	B avg (uT/kA)
0.0	141.2	141.1	141.2	137.7
0.1	150.3	150.1	150.3	145.9
0.2	160.5	160.3	160.5	155.1
0.3	172.0	171.8	172.0	165.2
0.4	185.0	184.7	185.0	176.5
0.5	199.7	199.3	199.7	188.9
0.6	216.3	215.8	216.3	202.6
0.7	234.8	234.3	234.8	217.5
0.8	255.3	254.6	255.3	233.5
0.9	277.0	276.3	277.0	250.0
1.0	298.9	298.3	298.9	266.6
1.1	319.9	319.3	319.9	282.5
1.2	339.7	339.0	339.8	297.7
1.3	361.1	359.7	361.1	312.5
1.4	388.0	385.6	388.0	327.6
1.5	417.5	414.7	417.5	340.2
1.6	429.8	429.0	429.8	342.7
1.7	410.5	408.9	407.0	329.2
1.8	367.2	365.0	362.4	304.5

Table 2: Tabular representation of magnetic field components over the lineman sections for 500 kV power line tower potential position.

Section name	section level (m)	B max (uT/kA)	B min (uT/kA)	B avg (uT/kA)	B std (uT/kA)
Brain	1.7	410.5	269	330.1	48.2
Heart	1.4	388	274.7	326.4	38.3
Stomach	1.2	339.7	258.7	297.1	27.7
Knee	0.5	199.7	177.7	188.6	7.4

On 220 kV tower

The magnetic field distributions over the lineman faces and sections are depicted for the different positions on the tower of 220 kV line.

Figure 4 shows the magnetic field distribution over the front and side faces of the lineman body for the lower phase (C) potential position for 220 kV power line tower. As shown, some islands appear in upper and lower body sections unlike the case of 500 kV line. This can be attributed to the different line configurations associated with different resultant magnetic field among the line phases.

Table 3 shows the maximum and average magnetic field values over the lineman faces. The horizontal variation over the front face is limited compared to that over the side face.

Table 4 shows the statistical analysis of the magnetic field components at different horizontal cross sectional levels over the lineman body.

It is noticed that, for the lineman body faces, the maximum magnetic field value is reached, at the heart section, 422.5 μT/kA, while the minimum is 150.3 μT/kA at the knee section. The standard deviation (std) of the magnetic field reaches its maximum value of 53.8μT/kA (16.1% of the average) at the heart section, while it reaches its minimum value of 7.1 μT/kA (4.4 % of the average) at the knee section.

5. Conclusion

1- During the live-line maintenance conditions, for 500 kV and 220 kV lines, the magnetic field over the lineman body spans a wide range of 140 – 439 μT/kA for the potential position. This level is well below the International Radiation Protection Association (IRPA) level of occupational exposure, which accounted to 5000 μT for a period of 2 hours.

2- During live line maintenance conditions, the magnetic field levels to which the lineman exposed, may reach 40 times that occurred at ground level (1 m above ground) for the considered cases.

3- For the central phase position (phase A) of 500 kV power line tower, The maximum magnetic field to which the lineman is exposed, ranges from 189.7 μT/kA at the knee section to 409.9.μT/kA at the brain section. While it spans a range from 199.7 μT/kA at the knee section to 410.5 μT/kA at the heart section for the outer phase position (Phases A or C).

4- During the live-line maintenance conditions, the maximum magnetic field value over the lineman body, varies from 74 μT/kA to 439 μT/kA as the lineman changes his position at the 500 kV line tower from cross arm position to potential position.

5- For the upper phase position (phase A) of 220 kV power line towers, the maximum magnetic field value, spans a range from the maximum magnetic field to which the lineman is exposed ranges from 208.551 μT/kA at the knee section to 432.404.μT/kA at the heart section. While it spans a range from 171.4 μT/kA at the knee section to 422.5 μT/kA at the heart section for the lower phase position (Phase C).

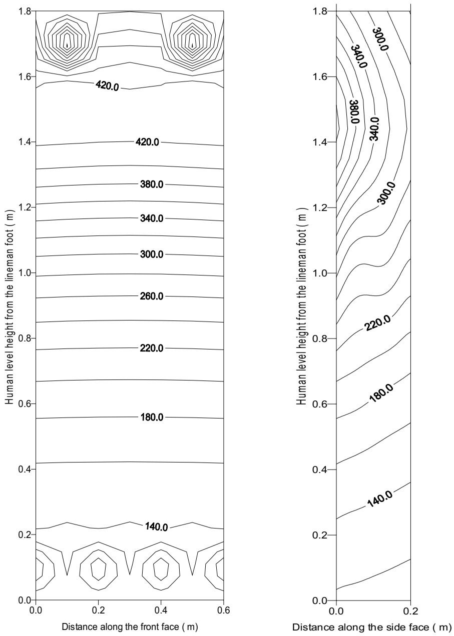

Figure 4: Magnetic field distribution (μT/kA) over the lineman body faces for phase C potential position for 220 kV line.

Table 3: Max. and Average magnetic field values over the lineman body faces at 220 kV line phase (c) potential position

human height (m)	Front face		Side face	
	B max (uT/kA)	B avg (uT/kA)	B max (uT/kA)	B avg (uT/kA)
0.0	116.9	58.4	116.9	112.7
0.1	125.1	62.6	125.2	120.3
0.2	134.6	134.5	134.6	128.8
0.3	145.3	145.1	145.3	138.3
0.4	157.5	157.2	157.5	149.1
0.5	171.4	171.1	171.4	161.1
0.6	187.5	187.1	187.5	174.8
0.7	206.1	205.6	206.2	190.2
0.8	227.9	227.2	227.9	207.7
0.9	253.4	252.5	253.4	227.3
1.0	283.2	282.0	283.2	249.1
1.1	317.7	316.1	317.7	272.8
1.2	356.1	354.0	356.1	297.0
1.3	394.2	392.1	394.2	319.2
1.4	422.5	420.9	422.5	334.5
1.5	428.6	428.5	428.3	337.8
1.6	411.3	410.1	408.7	328.1
1.7	377.3	375.9	374.1	309.4
1.8	339.4	338.1	336.6	287.1

Table 4: Tabular representation of magnetic field components over the lineman sections for 220 kV power line tower phase (C) potential position.

Section name	Section level (m)	B max (uT/kA)	B min (uT/kA)	B ave (uT/kA)	B std (uT/kA)
Brain	1.7	377.3	255.3	310.2	41.6
Heart	1.4	422.5	265.2	333.8	53.8
Stomach	1.2	317.7	231.6	271.7	29.1
knee	0.5	171.4	150.3	160.8	7.1

6. References

[1] P. Baraton, J. Cahouet and B. Hutzler, " Three Dimensional Computation of the Electric Fields Induced In a Human Body by Magnetic Fields". Proceedings 8 th International Symposium on High Voltage Engineering, ISH-93, Yokohama, Japan, paper no. 9002, 1993.

[2] P. S Maruvada, " Characterization of Power Frequency Fields in Different Environments". IEEE Trans. on Power Delivery vol.8, no.2, pp. 598-605, 1993.

[3] H. Anis, M. A. Abd-Allah and Sh. A. Mahmoud, " Computation of Power Line Magnetic Fields - A Three Dimensional Approach". Proceedings 9th International Symposium on High Voltage Engineering (ISH-95), Graz, Austria, paper no. 8333, 1995.

[4] G. Gela, " IEC Method of Calculation of Minimum Approach Distances for Live Working". IEEE Trans. on Power Delivery, vol. 15, no.2, pp. 210-215, 2000.

[5] Egyptian Electricity Holding Company Live Working Committee, "Text Book for Working Conditions of 66, 132, 220 & 500 kV lines". Talkha Training Center of Live-Line Maintenance, 1991.

Author address: A. H. Hamza
Faculty of Engineering at Shoubra
Electrical Engineering Department
108, Shoubra Street, Shoubra, Cairo, Egypt.
Home address (Contact addres):
9 El-hakim- Be- Amr El-aah St. , El-KHALAFAWY, SHOUBRA, cairo, Egpt.
Email: a_hamza55@hotmail.com