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Determination of the Distance Security from Overhead Electric Lines

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Abstract: This study built a computer program in order to carry out accurate calculations of the magnetic field according to time, space and the load of a three-phase line (3 or 6 conductors). The theorem of Ampere and the superposition one were used. We obtained the variations of the magnetic field according to time at a given space point and the magnetic field at a given moment on both sides of the line. These results enabled us to define security distance with respect to critical values used in the literature. The number of parameters did not allow us to calculate standard security distances. For the tested pylons, if reference value is 0.2 μT, the security distance can exceed several hundred meters.

Key words: Magnetic field, biological risk, security distance, overhead transmission line

INTRODUCTION

The progress of technology and the need for increasingly growing electrical energy at low frequencies (50 and 60 Hz) have led to the installation of High Voltage (HV) and Ultra High Voltage (UHV) transmission lines. These lines create electric and magnetic fields which have different properties and different effects on the living cell. The electric field is quickly attenuated by the conducting objects (buildings, human body, trees, etc.). The magnetic field decreases with the distance which separates the observation point from the source and is not attenuated by most materials.

Many epidemiological and experimental studies have been interested by the interactions between the magnetic field and diseases such as breast cancer (Feychting *et al*., 1998; Erren, 2001; Scott *et al*., 2002; London *et al*., 2003; Sorahan and Nichols, 2004; Kliukiene *et al*., 2004) and children leukemia (Skinner *et al*., 2002; Foliart *et al*., 2006; Blaasaas *et al*., 2003). These experimental researches only measure the magnetic field in the surroundings of the populations. Typical values are often 0.1 to 0.2 μT (Heroux, 1987; Qiu, 2004; Havas, 2002).

When the field's source is relatively simple, as in three-phase lines structure, a rigorous calculation of the field's module is possible. In this document, we presented the calculation of the magnetic field produced by air three-phase lines (three or six conductors). To illustrate present calculation, we use the pylons defined by Shaler *et al*. (2003). We define the security distance for the studied pylons. This study can also be used in a pylon optimization procedure.

MATERIALS AND METHODS

Field created by one conductor: Let us consider a conductor placed at the point $P(x_0,y_0)$ and traversed by a current $i = I\sqrt{2}\sin(2\pi ft)$; f being the frequency expressed in Hertz. According to the ampere's theorem, this conductor creates a magnetic field $b = B\sqrt{2}\sin(2\pi ft)$, at a point M(x, y), with module

$$B = \frac{\mu_0 I\sqrt{2}}{2\pi r} \quad \text{with } \vec{r} = \overrightarrow{PM}, \quad r = \sqrt{(x-x_0)^2 - (y-y_0)^2}$$

and $\mu_0 = 4\pi 10^{-7}$ SI

This field is oriented so that $\vec{I}$, $\overrightarrow{PM}$ and $\vec{B}$ constitute a direct trihedron. The line's length is supposed to be infinite. Thus, we can limit the study in the plan perpendicular to the conductor.

The direction of PM is given by an angle β expressed as:

$$\beta = \text{Arctg}\frac{y-y_0}{x-x_0} \quad \text{if } x \neq x_0$$

$$\beta = \text{sign}(y-y_0).\frac{\pi}{2} \quad \text{if } x = x_0$$

The direction of the magnetic field (Fig. 1, 2) is perpendicular to that of PM and its direction depends on the sign of the current. It is defined by an angle α expressed as:

$$\alpha = \beta + \text{sign}(I)\frac{\pi}{2}$$

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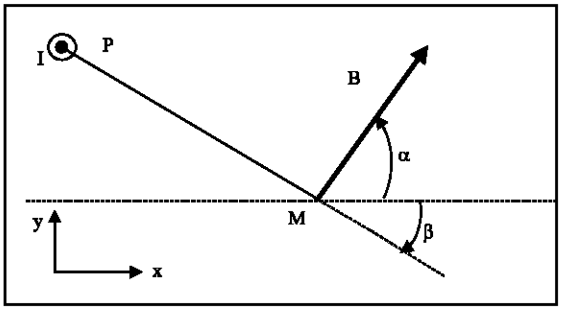

Fig. 1: Orientation of the field for an outgoing current

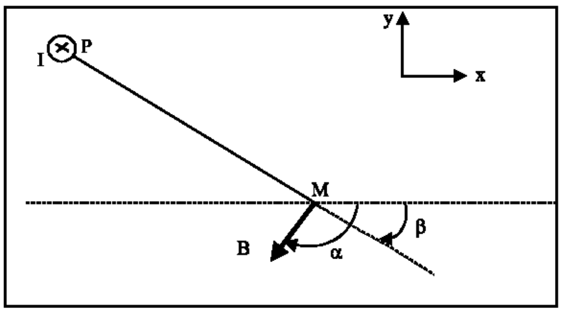

Fig. 2: Orientation of the field for an incoming current

This field is characterized by a horizontal component B_x and a vertical one B_y.

$$B_x = B\cos\alpha \qquad B_y = B\sin\alpha$$

Field created by a three-phase line: Assuming that the currents form a balanced system, the intensity of the instantaneous current in each conductor is given by:

$$i_1 = I\sqrt{2}\sin(2\pi ft)$$
$$i_2 = I\sqrt{2}\sin\left(2\pi ft - \frac{2\pi}{3}\right)$$
$$i_3 = I\sqrt{2}\sin\left(2\pi ft + \frac{2\pi}{3}\right)$$

The magnetic permeability is practically constant in the area under consideration (air) and we can apply the superposition theorem. The resulting field created by a set of conductors is the vectorial sum of the field created by each conductor. Thus, we have:

$$\vec{B} = \sum \overline{B_k} \qquad B_x = \sum B_{xk} \qquad B_y = \sum B_{yk}$$

B_x and B_y depend on distances and thus on the structure of the pylons. Calculation is organized according to the following flowchart (Fig. 3). It makes it possible to determine the field at a point at a given moment.

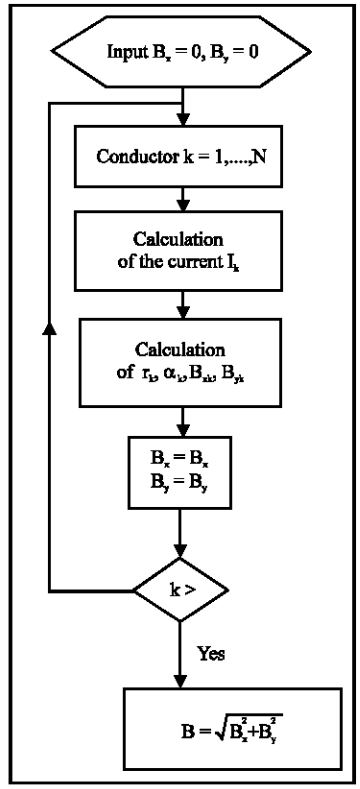

Fig. 3: Flowchart showing the magnetic field calculation procedure. The space point and the moment of calculation are input parameters

Definition of the security distance: The magnetic fields cross all materials used in the dwellings construction. It is then imperative to establish security distances on both sides of the equipment generating these fields. A reference value of the magnetic field being fixed, one seeks the distance from which the field becomes lower than this reference. In the case of three phase lines, several points answer the question. But if one limits the investigation on a plan parallel to the ground, only two points, located on both sides, will be retained. We will use 0.2 μT as the reference value for the calculation.

RESULTS AND DISCUSSION

The security distance depends on the pylon's geometry i.e. the position of the conductors the ones compared to the others and to the ground. We built a computer program which takes as input parameters the geometry of the pylon and the line's load. To illustrate our calculation, we use pylon's structure defined by Shaher *et al.* (2003) recalled here after in Table 1.

Four parameters can describe the system: the magnetic field (module and phase), the time t, the space

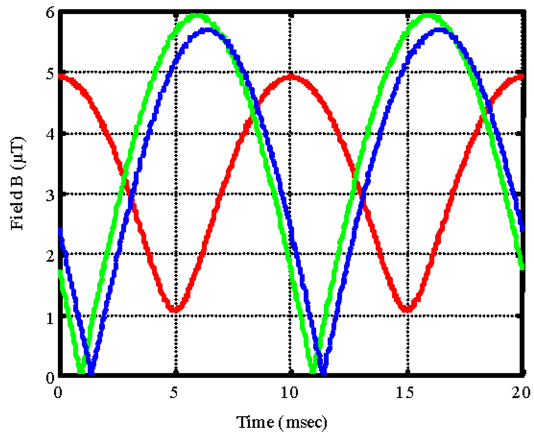

Fig. 4: Field's modulus as a function of time at M(0,0) and I = 1000 A, Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

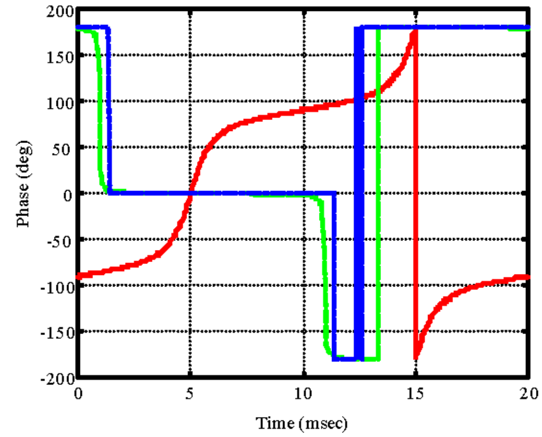

Fig. 5: Field's orientation as a function of time at M(0, 0) and I = 1000 A, Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot : Pylon 3

Table 1: Description of the geometry of conductors on the pylons

Pylon 1 (500 kV, 3 conductors)		Pylon 2 (220 kV, 6 conductors)		Pylon 3 (66 kV, 6 conductors)	
x(m)	y(m)	x(m)	y(m)	x(m)	y(m)
-13.20	22.00	-8.00	15.78	-3.68	11.48
0.00	24.35	-10.60	24.98	3.68	11.48
13.20	22.00	-8.80	35.18	-3.68	14.29
		8.00	15.78	3.68	14.29
		10.60	24.98	-3.68	17.10
		8.80	35.18	3.68	17.10

coordinates (x, y) and the line load I. Thus, the study of the magnetic field amounts studying the functions of type:

$$B = [t, I, M(x, y)]$$

We propose, in the following figures,

- B = f(t): Evolution of the field with time (one period of a 50 Hz sinusoidal wave) at fixed load and fixed point
- B = f(M): Evolution of the field along a straight line parallel to the ground. The line load and the time are fixed
- B = f(I) : Evolution of the field with the load at a given moment and at a fixed point.
- Calculation of the security distance with respect to 0.2 μT as reference value.

Figure 4 and 5 shows the module and the phase of the magnetic field produced by pylons at M(0, 0) according to time. One period of a sinusoidal voltage of 50 Hz was used. The line's load is fixed at I = 1000 A. It can be noted that the field is maximum at t = 6 msec for pylon 1 and 2. For pylon 3, the field is maximum at

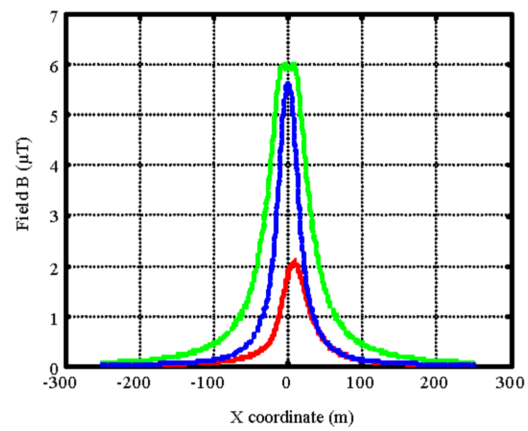

Fig. 6: Field's modulus along a straight line (y = 0; t = 6 msec), Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

t = 10 msec. The disposition of the conductors on the pylons may explain this difference. The variations of the module and the phase might create induced currents in conducting objects (Dawson *et al*., 1999).

Figure 6-9 shows the fast decrease, as 1/r, of the field's module and the orientation of the field along a line. The orientation of the field changes especially in the vicinity of the line.

As the field is a function of time and load, we compute a security distance for t = 6 msec, function of the load (Fig. 10) and a security distance for I = 1000 A, function of time (Fig. 11).

It can be noted that for very weak loads, the maximum field is lower than the reference value. For high loads, the security distance can be approximated by a polynomial of the first degree.

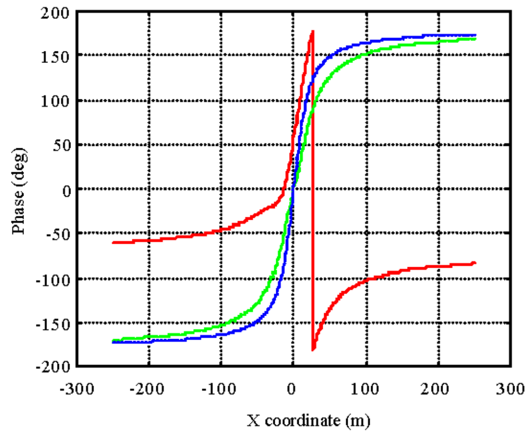

Fig. 7: Field's orientation along a straight line (y = 0; t = 6 msec), Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

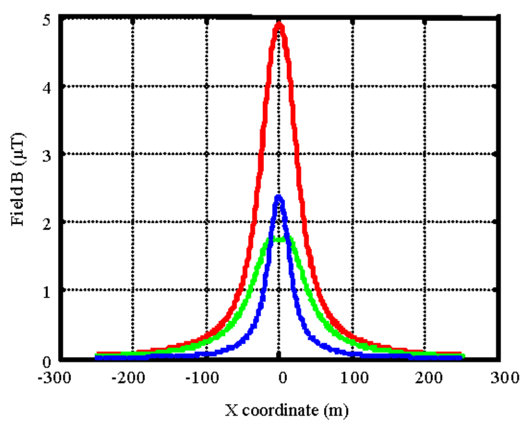

Fig. 8: Field's modulus along a straight line (y = 0; t = 10 msec), Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

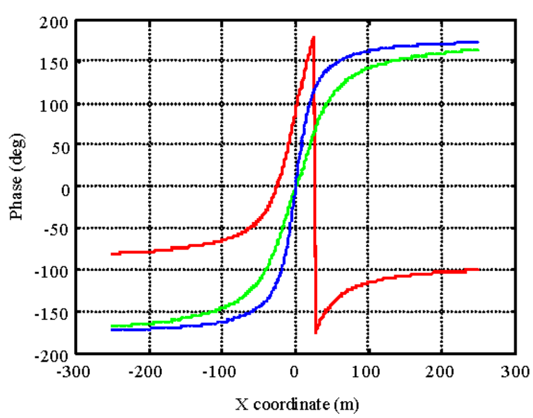

Fig. 9: Field's orientation along a straight line (y = 0; t = 10 msec), Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

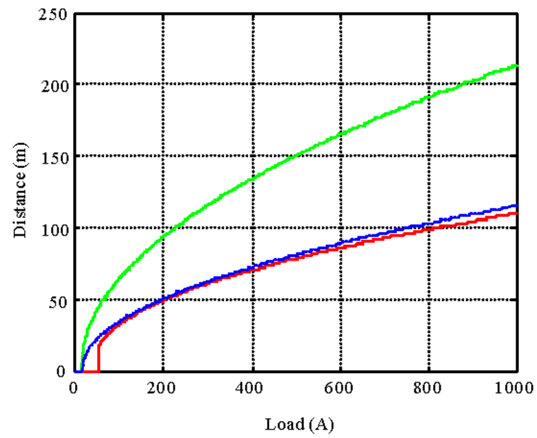

Fig. 10: Evolution of security distance with line's load-t = 6 msec, Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

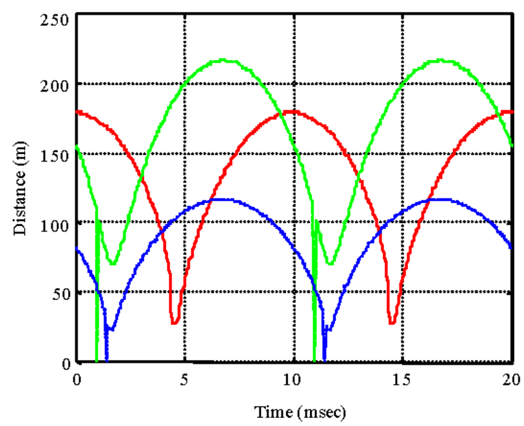

Fig. 11: Evolution of security distance with time −I = 1000 A, Red: Pylon 1; Green dash: Pylon 2; Blue dash-dot: Pylon 3

CONCLUSION

We built a computer program in order to carry out accurate calculations of the magnetic field according to time, space and the load of a three-phase line (3 or 6 conductors). This calculation has enabled us to define the security distance as being the distance beyond which the field is lower than a critical value. This distance depends on the type of the pylon, the time and the line load. The number of parameters did not allow us to calculate standard security distances. For the tested pylons, if reference value is 0.2 µT, the security distance can exceed several hundred meters. This study can also be used in a pylon optimization procedure.

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