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REDUCTION OF MAGNETIC FIELD UNDER THE H.V. TRANSMISSION LINES

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ABSTRACT

When designing line of electric power transport, it is necessary to dimension these installations according to the high magnetic fields.

This present paper gives a method to calculate and represent the magnetic field around a three-phase line; it proposes to bring to the owner of these works the elements to the problems raised by this constraint: determination of the magnetic fields intensities to know their calculation and their measurement.

Certain spirits also worried about a possible physiological action of the magnetic fields; to appreciate such a possibility, it should be retained that the amplitude of the fields produced by the works of transport energy, on the surface of the ground about (1 to 10 µTesla), i.e. of the same order of magnitude as the earth's magnetic field.

We present a calculation programme based on the MATLAB logiciel which makes it possible to better analyze and to represent the transverse profile of the magnetic field under the lines. We also give examples of application of the method and program..

Keywords: *Magnetic filed, transmission lines, transverse profile*

1. INTRODUCTION

The magnetic field at the industrial frequency is a phenomenon which exists around any work of electric power transmission lines and airmails; it is the increasingly high value of the used tensions which results in taking the consequences of this phenomenon in consideration. The solution generally planned to attenuate or eliminate these harmful effects is to design the air lines with conductors in beam in order to increase the apparent ray of the latter and to install magnetic screens.

During the evaluation of the magnetic fields around the installations with VHV, it is often made use of experimental curves or simplified calculation by comparing the beams to equivalent simple conductors, by choosing

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particular geometries and by neglecting the effect of the guard conductors.

2. MAGNETIC FIELD DEFINITION

At the fundamental physics of the quasi-static electric field corresponds that the quasi-static magnetic field. It is indeed the quasi-static property which allows the independent analysis, without interaction, of the magnetic fields and electric. To the electric field E and the electric density flux correspond the magnetic field H and the induction field (or magnetic density flux) B with:

$$B=\mu_0\mu_r\cdot H \quad (1)$$

where: $\mu_0 = 4\pi.10^{-7}$ Henry/m
μ_r relative permeability.
One of the fundamental laws of magneto static is the law of Ampere:

$$\oint \vec{H}\cdot d\vec{l}=i \quad (2)$$

This law can be illustrated by an example which has practise implications; it is the case of the long and rectilinear wire traversed by a given current. Let us consider a circle, in a plan perpendicular to the axis of the conductor, centred to this one. For reasons of symmetry, the magnetic field H is constant throughout circle. If the radius of this one is "r", the magnetic field will be given by:[2,6]

$$H=\frac{i}{2\cdot\pi\cdot r} \ (A/m) \quad (3)$$

and magnetic flux density (or magnetic induction field) by:

$$B=\frac{\mu\cdot i}{2\cdot\pi\cdot r} \ (T) \quad (4)$$

It should be known that the field B is directed tangentially with the circles centred on the conductor and is contained in plans perpendicular to this one.

The magnetic flux crossing a given surface 'S' is determined by:

$$\phi=\int \vec{B}\cdot d\vec{S} \ (W) \quad (5)$$

The integration of the magnetic flux through a closed surface is null. This property leads to the well-known result that the lines of magnetic flux are continuous and that there is not insulated magnetic pole.

The force to which the unit of length of a conductor is subjected is given by the following relation:

$$\vec{F}/l=\vec{i}\wedge\vec{B} \quad (6)$$

where i: is the current traversing the conductor, and B the magnetic induction field, at the point considered of conductor, generated by all the other existing currents in space.

3. MAGNETIC FIELD CALCULATION DUE TO THE TRANSMISSION LINES

A. Introduction

Because of the quasi-static nature of the electromagnetic behaviour at the industrial frequencies, the magnetic field of line is generated only by the current. The intensity of magnetic field around the conductors is thus obtained by application of the Amp's law, then by superposition of the partial results. [2,6,8]

B. Principle of the method

To calculate the magnetic field on the level of the ground in the vicinity of transmission line, one can use the formula (4), this field is generated by the current circulating in the conductor (i) (Fig. 1)

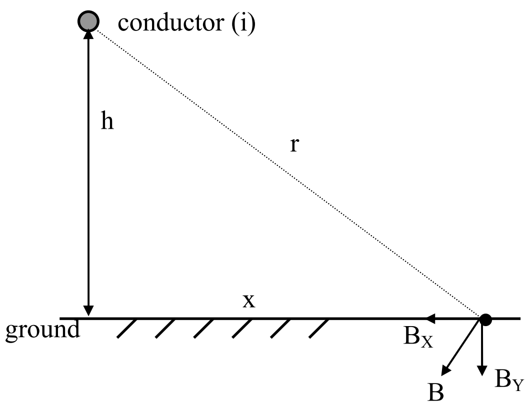

Fig. 1 *Magnetic intensity generated by the current flowing in a conductor (i)*

One can use the theory of the images of the conductors by taking account of the penetration depth; indeed the images are located at a depth, in the ground, much larger than the height of the conductors phases.

At first approximation, the depth "p", is worth:

$$p = 660\sqrt{\frac{\rho}{f}} \quad \text{(m)} \tag{7}$$

Where p : is the resistivity of the ground out in Ω. m and f : the frequency in Hz
To take account of the ground which is imperfectly conductive, the precise calculation of the magnetic field requires the use of the complete terms of Carson. [1]
But, in the majority of the applications, it is enough to consider the conductors phases in open space, without taking account of the images.
For the conductor of Fig. 1, without its image, one can apply the following formula:

$$\vec{B} = \frac{\mu \cdot i}{2 \cdot \pi \cdot r} = \frac{\mu \cdot i}{2 \cdot \pi \cdot \sqrt{h^2 + x^2}} \tag{8}$$

In the case of a three-phase line, the horizontal and vertical components of the field B for the three phases must be treated like vectors of phase and compounds separately, by taking of account dephasing between the currents.

C. Concepts to the measurement of magnetic field

To measure the magnetic fields at frequency industrial generated by the lines of transport to high voltage, one generally uses probes of field consisted of coil under screen, connected to a portable voltmeter. Other types of probes use special resistances whose value is related to B, or the Hall Effect.

The principle of operation of a probe of field with reel is based on the Faraday's law whose differential form is as follows: [2,6,7]

$$rot\vec{E} = -\frac{d\vec{B}}{dt} \tag{9}$$

$$\oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{S} \tag{10}$$

The integral of left is a curvilinear sum, along a curve surrounding a surface S. If the curvilinear way is taken along a conducting closed loop, and if B is the quasi-static uniform field as indicated on the figure (2),

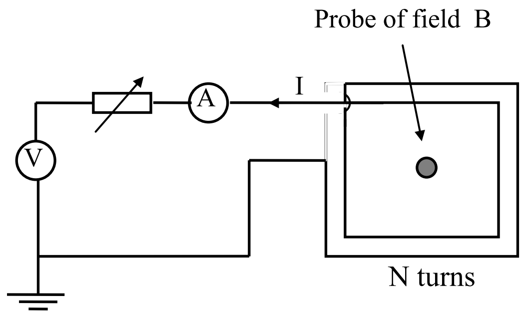

Fig. 2 *Principle of the probe of field B*

The curvilinear integral can be regarded as an electromotive force (e.m.f) developed in the loop and a flowing current I, in consequence of change of magnetic flux (B.S); one will have

$$e.m.f = \oint \vec{E} \cdot d\vec{l} = -\frac{d}{dt}(B \cdot S) \tag{11}$$

and according to the figure (2), one will have:

$$e \cdot m.f = -\omega_0 \cdot B_0 \cdot S \cdot \cos\omega t \tag{12}$$

In the case of a loop to several whorls, the e.m.f will appear in each one of them and the tension V will increase proportionally with the number of whorls. The induced current is supposed sufficiently weak so that the opposite field B which generates can be neglected. It should be noted that the relation between the f.e.m and B_0 supposes that the direction of B_0 is perpendicular to the plan of the whorls of the reel. As only the space component of B perpendicular to the plan of the whorls generates an e.m.f, it is also the orientation of the reel which measures the maximum value of the field B

In addition, the f.e.m being proportional to frequency, it is necessary to consider with attention the harmonic contents of field, i.e. the current which generate this field.

D. Measurement procedure of magnetic field in the vicinity of transmission lines

The position of the probe, proximity of the observer or similar objects, a possible electric leakage along the handle, or a probable non-uniformity of the field has only negligible

effects. However, an electrostatic shielding of the probe can be necessary to avoid the currents of influence due to the ambient electric field.
Effects of temperature on the detector or a light movement around the point of balance remain a source of possible, but weak errors.

The magnetic field under line is generally measured with a height of 1 m above ground-level: when these measurements are taken with other heights, those will have to be explicitly indicated. The probe will be directed so as to obtain the maximum deviation of the reading device. [2,6]

The operator can remain close to the probe. The removable objects containing of magnetic or conducting materials nonmagnetic will be far away from the point of measurement of a distance equal to at least three times their greater dimension, in order to avoid the distortion of the field.

The objects out of nonmagnetic metal are the seat of eddy currents because of the variation according to the time of the magnetic flux. The magnetic fields generated by these eddy currents decrease like the cube of the distance when this one is large compared to dimensions of the conducting object.

4. MAGNETIC FIELD COMPENSATION OF THE TRANSMISSION LINE

A. Effects and shielding of magnetic field

The alternating magnetic fields are likely to induce currents in the wiring of certain sensitive measuring apparatus, in various electronic systems, installations of telecommunication, lines or conduits.

The interference currents are easily calculable only when they are simple loops. It is much more difficult to determine them when the magnetic fields penetrate in conducting volumes with the semiconductors, such as massive metal structures or living organisms. The calculation of the eddy currents generated thus is not possible only in particular simple configurations.

In order to minimize the harmful effects, the disturbing field (here the magnetic field) can be reduced by a suitable choice of the configuration of the phases (see examples), or by the creation of a field of compensation.

With regard to the magnetic fields at industrial frequencies, the shielding by means of envelopes present practise difficulties quite higher than those which one meets in the case of the electric fields.

One uses magnetic screens produced with materials whose susceptance is much larger than that of the air. Not only the permeability but also the thickness and dimensions of such screens are significant, and the direction of field must also be considered. [2,3,6]

B. Study of compensation

To understand the compensation let us take the case of the figure (3), [3,7]
Where 1 and 2 represents the phase's distances from "*d*"
3 and 4 represent the earth wires (or compensation), distant of " *D*"'.

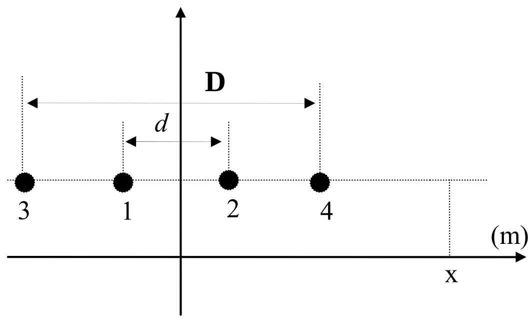

Fig. 3 Biphase line with compensation circuit

The intensity of magnetic field due to the two phases is calculated at the point "x" according to the relation:[3]

$$B_{phase}=0{,}2\cdot I\cdot\frac{d}{x^2-\frac{d^2}{4}} \quad (\mu T) \tag{13}$$

with *I*: the phase current

To have the compensation it is necessary to inject a current in cables 3 and 4, by taking account of geometrical dimensions; this current can be expressed by [3]:

$$I_c=K\cdot I_{phase} \tag{14}$$

The coefficient *K* depends on geometrical dimensions (in meters), it can be expressed by:[3]

$$K = \frac{\log \frac{D+d}{D-d}}{\log \frac{D}{GMR}} \qquad (15)$$

where GMR is the geometrical medium radius for the same conductor.

For example: for a radius conductor r = 0,017 m, D = 20 m, d = 10 m, I_{phase} = 1000 A
by applying the formulas (14) and (15); one finds the current of compensation which is about 150 A.

While referring to the figure (3), and while holding in balancing account the total magnetic field strength is calculated then according to the following approximate formula: [3]

$$B = B_{phase}\left[1 - \frac{I_c}{I_{phase}} \cdot \frac{D}{d}\right] \qquad (16)$$

In the calculation of compensation current, one must take account at the same time of amplitude and dephasing of this last compared to the currents of various phases, which influences directly the value of the magnetic field strength; a thorough study must be made in order to optimise these two parameters to have better compensation.

5. APPLICATIONS

A. 420 kV Horizontal three-phase line [3,11]

Voltage = 420 kV
height of the first phase = 14,6 m
height of the second phase = 14,6 m
height of the third phase = 14,6 m
X-coordinate of the first phase = 0
X-coordinate of the second phase = -9
X-coordinate of the third phase = +9
the current of phase I = 1000 A
After execution of the program one obtains the curve of the figure (4), representing the magnetic field strength of the line considered.

B. 420 kV triangle three-phase line [3,10]

Tension = 420 kV
height of the first phase = 14,6 m
height of the second phase = 20,6 m
height of the third phase = 20,6 m
X-coordinate of the first phase = 0
X-coordinate of the second phase = -3,65
X-coordinate of the third phase = +3,65
the current of phase I = 1000 A

After execution of program, one obtains the curve of figure (5), representing the magnetic field strength of considered line.

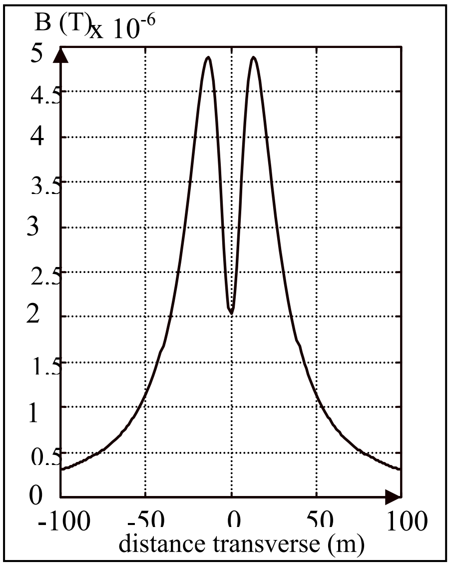

Fig. 4 *Magnetic field for 420 kV horizontal line*

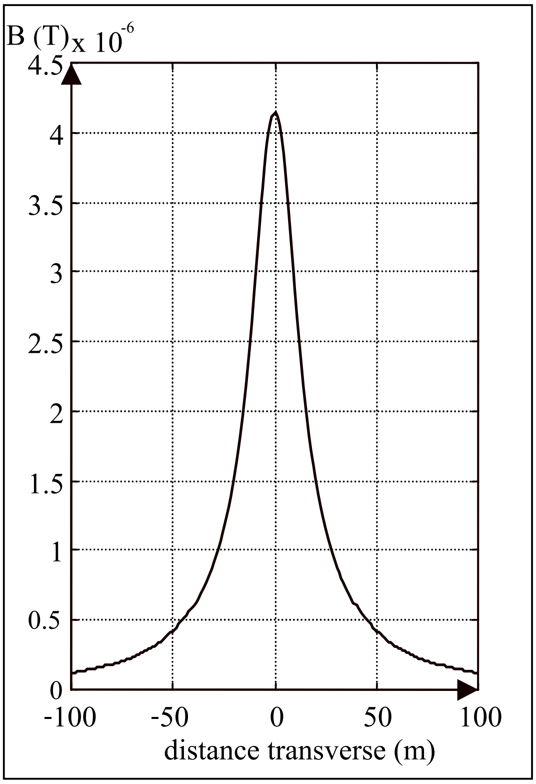

Fig. 5 *Magnetic field for 244 kV triangular line*

C. 225 kV horizontal three-phase line f [1]

Voltage = 225 kV
height of the first phase = 15 m
height of the second phase = 15 m
height of the third phase = 15 m
X-coordinate of the first phase = 8.7
X-coordinate of the second phase = 0
X-coordinate of the third phase = - 8.7
Phase current $I = 200$ A
After execution of program one obtains the curve of the figure (6), representing the magnetic field strength of the line considered.

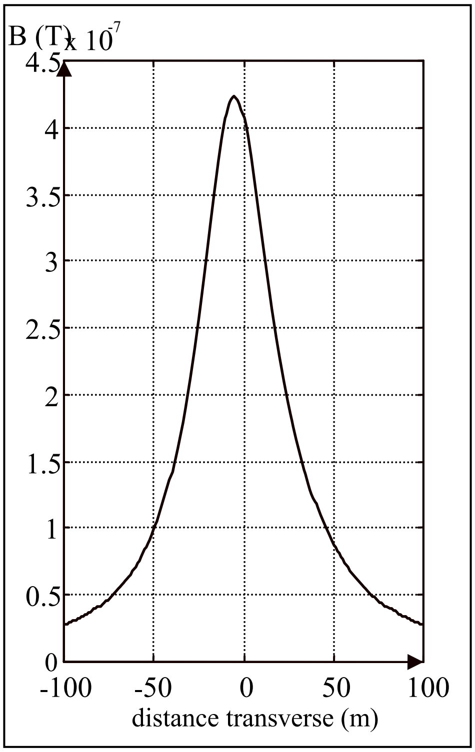

Fig. 6 *Magnetic field for 420 kV triangular line*

D. Comparison between the magnetic field intensity with and without compensation.

In order to compare the magnetic field strength the program first of all calculates the current of compensation and trace the two profiles on the same graph for the following data: [3]
d = 10 m (Fig. 3.)
D = 20 m
I = 1000 A
After execution of the program one obtains the curve of Fig . 7.

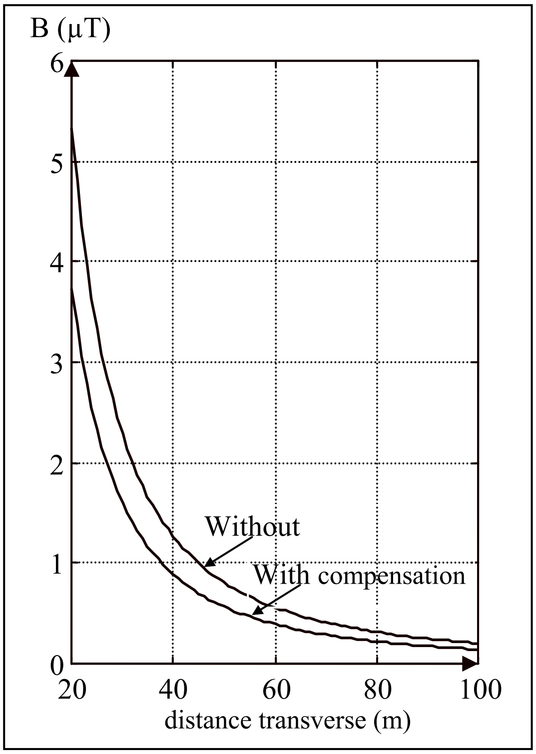

Fig. 7 *Magnetic field with and without compensation*

6. INTERPRETATION OF THE RESULTS

According to the curves obtained one can say that the shape and the intensity of magnetic field depend primarily on dimensions of line: the distance between the conductors and their height above ground-level (it is noticed that one has a value more raised of the field for a less significant height).

By comparing the studied lines, one notices that the magnetic field strength is less significant for the lines whose configurations are in triangles.
Whatever the form of the profile, the curve is symmetrical compared to the central phase.
Lastly, by analysing the figure 7, one notices that one has considerable reduction in the magnetic field strength by adopting the circuit with compensation.

7. CONCLUSION

The calculation program that we carried out, appears very useful to us to calculate and trace the transverse profile of magnetic field under the lines and to quickly simulate a very great number of cases, which makes it possible to see the influence of each parameter on the intensity of this field in order to make the provisions necessary to minimize the intensity of these fields.

A study must be made concerning the calculation of the compensating network traversed by an adjustable current in amplitude and phase and consequently the need for optimising them.

REFERENCES

[1] Claude Gary and Marcel Moreau, *the effect corona in alternating voltage* , Eyrols 1976

[2] Working group 36.01 CIGRE "Electric and magnetic fields generated by the grid systems". 1980

[3] U.Jonsson; A.Larsson; OJ. Sjodin, "*Optimized reduction of the magnetic field near swedish 400 Kv lines*". *IEEE - SM 429-1 PWRD* (1993)

[4] P.A.Chamorel Bull ,"*Calculation and representation of the electric fields around a line with three-phase H.T*" *ASE/UCS67* 1976

[5] Marcel Moreau, " *Predetermination of the disturbing level of the lines of transport of General energy* "
(R.G.E); Divide into volumes 80 N°9 - 1971

[6] *IEEE standard procedures for measurement of power frequency electric and magnetic fields from AC power lines*, IEEE Std 644-1994, USA, 1995

[7] M.Carrescia, F.Profumo and M.Tartaglia
"*Prediction of magnetic fields in multiconductor systems with significant harmonic currents*"
Transactin IEEE, 1999

[8] V.Allegranza, A.Canova and M.Tartaglia
"*Reduction of magnetic fields in power lines: cables and GIL*"
Workshop on 'Protection in complex and distributed systems inckuding railways';
Hungary june 2002

[9] A. Bendaoud, M.Rahli, M.Brahami & H. Sayah, " *Reduction of the intensity of the electric field under the HV transmission lines*"
SICEL'2001 Bogota, Colombie du 28 au 30 novembre 2001

[10] A.Bendaoud, M.Rahli, M.Brahami & J.L.Lilien, "*Couplage électromagnétique des lignes de transport d'énergie avec les circuits métalliques proches et calcul du courant d'induit*", TELECOM'2001& 2èmeJFMMA – Maroc, 17-19 octobre 2001.

[10] A. Bendaoud, M.Rahli, M. Brahami, H. Sayah & K. Medles, " *Calculation and reduction of the magnetic field under the H.V. transmission lines*". CNEA'2004 (Université de Sidi Bel Abbès), Algeria ; 24 -25 Mai 2004

[11] M. Brahami, M.Ghezaili, A. Bendaoud, M. Miloudi, H. Sayah, "*Lignes de transport d'énergie et champs électromagnétiques*", 6ème conférence régionale des comités CIGRE des pays arabes, Caire-Egypt 21-23 Novembre 2005

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